

# **LightDB Enterprise Postgres 13.8-23.4 Documentation**

**Hundsun Technologies Inc**

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Hundsun Technologies Inc

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# Preface

This book is the official documentation of LightDB. It has been written by the LightDB developers and other volunteers in parallel to the development of the LightDB software. It describes all the functionality that the current version of LightDB officially supports.

To make the large amount of information about LightDB manageable, this book has been organized in several parts. Each part is targeted at a different class of users, or at users in different stages of their LightDB experience:

- Part I is an informal introduction for new users.
- Part II documents the SQL query language environment, including data types and functions, as well as user-level performance tuning. Every LightDB user should read this.
- Part III describes the installation and administration of the server. Everyone who runs a LightDB server, be it for private use or for others, should read this part.
- Part IV describes the programming interfaces for LightDB client programs.
- Part V contains information for advanced users about the extensibility capabilities of the server. Topics include user-defined data types and functions.
- Part VI contains reference information about SQL commands, client and server programs. This part supports the other parts with structured information sorted by command or program.
- Part VII contains assorted information that might be of use to LightDB developers.

## 1. What Is LightDB?

LightDB is an object-relational database management system (ORDBMS) based on POSTGRES, Version 4.2<sup>1</sup>, developed at the University of California at Berkeley Computer Science Department. POSTGRES pioneered many concepts that only became available in some commercial database systems much later.

LightDB is an open-source descendant of this original Berkeley code. It supports a large part of the SQL standard and offers many modern features:

- complex queries
- foreign keys
- triggers
- updatable views
- transactional integrity
- multiversion concurrency control

Also, LightDB can be extended by the user in many ways, for example by adding new

- data types
- functions
- operators
- aggregate functions
- index methods
- procedural languages

And because of the liberal license, LightDB can be used, modified, and distributed by anyone free of charge for any purpose, be it private, commercial, or academic.

---

<sup>1</sup> <https://dsf.berkeley.edu/postgres.html>

## 2. Conventions

The following conventions are used in the synopsis of a command: brackets ( [ and ] ) indicate optional parts. Braces ( { and } ) and vertical lines ( | ) indicate that you must choose one alternative. Dots ( . . . ) mean that the preceding element can be repeated. All other symbols, including parentheses, should be taken literally.

Where it enhances the clarity, SQL commands are preceded by the prompt =>, and shell commands are preceded by the prompt \$. Normally, prompts are not shown, though.

An *administrator* is generally a person who is in charge of installing and running the server. A *user* could be anyone who is using, or wants to use, any part of the LightDB system. These terms should not be interpreted too narrowly; this book does not have fixed presumptions about system administration procedures.

## 3. Further Information

Besides the documentation, that is, this book, there are other resources about LightDB:

### Wiki

The LightDB wiki<sup>2</sup> contains the project's FAQ<sup>3</sup> (Frequently Asked Questions) list, TODO<sup>4</sup> list, and detailed information about many more topics.

### Web Site

The LightDB web site<sup>5</sup> carries details on the latest release and other information to make your work or play with LightDB more productive.

### Mailing Lists

The mailing lists are a good place to have your questions answered, to share experiences with other users, and to contact the developers. Consult the LightDB web site for details.

### Yourself!

LightDB is an open-source project. As such, it depends on the user community for ongoing support. As you begin to use LightDB, you will rely on others for help, either through the documentation or through the mailing lists. Consider contributing your knowledge back. Read the mailing lists and answer questions. If you learn something which is not in the documentation, write it up and contribute it. If you add features to the code, contribute them.

---

<sup>2</sup> <https://www.light-pg.com/documents.html>

<sup>3</sup> <https://github.com/hslightdb/LightDB-FAQ>

<sup>4</sup> <https://wiki.postgresql.org/wiki/ToDo>

<sup>5</sup> [www.hs.net/lightdb](http://www.hs.net/lightdb)



---

# Part I. Tutorial

Welcome to the LightDB Tutorial. The following few chapters are intended to give a simple introduction to LightDB, relational database concepts, and the SQL language to those who are new to any one of these aspects. We only assume some general knowledge about how to use computers. No particular Unix or programming experience is required. This part is mainly intended to give you some hands-on experience with important aspects of the LightDB system. It makes no attempt to be a complete or thorough treatment of the topics it covers.

After you have worked through this tutorial you might want to move on to reading Part II to gain a more formal knowledge of the SQL language, or Part IV for information about developing applications for LightDB. Those who set up and manage their own server should also read Part III.

---

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# Chapter 1. Getting Started

## 1.1. Installation

Before you can use LightDB you need to install it, of course. It is possible that LightDB is already installed at your site, either because it was included in your operating system distribution or because the system administrator already installed it. If that is the case, you should obtain information from the operating system documentation or your system administrator about how to access LightDB.

If you are not sure whether LightDB is already available or whether you can use it for your experimentation then you can install it yourself. Doing so is not hard and it can be a good exercise. LightDB can be installed by any unprivileged user; no superuser (root) access is required.

If your site administrator has not set things up in the default way, you might have some more work to do. For example, if the database server machine is a remote machine, you will need to set the `LTHOST` environment variable to the name of the database server machine. The environment variable `LTPORT` might also have to be set. The bottom line is this: if you try to start an application program and it complains that it cannot connect to the database, you should consult your site administrator or, if that is you, the documentation to make sure that your environment is properly set up. If you did not understand the preceding paragraph then read the next section.

## 1.2. Architectural Fundamentals

Before we proceed, you should understand the basic LightDB system architecture. Understanding how the parts of LightDB interact will make this chapter somewhat clearer.

In database jargon, LightDB uses a client/server model. A LightDB session consists of the following cooperating processes (programs):

- A server process, which manages the database files, accepts connections to the database from client applications, and performs database actions on behalf of the clients. The database server program is called `lightdb`.
- The user's client (frontend) application that wants to perform database operations. Client applications can be very diverse in nature: a client could be a text-oriented tool, a graphical application, a web server that accesses the database to display web pages, or a specialized database maintenance tool. Some client applications are supplied with the LightDB distribution; most are developed by users.

As is typical of client/server applications, the client and the server can be on different hosts. In that case they communicate over a TCP/IP network connection. You should keep this in mind, because the files that can be accessed on a client machine might not be accessible (or might only be accessible using a different file name) on the database server machine.

The LightDB server can handle multiple concurrent connections from clients. To achieve this it starts (“forks”) a new process for each connection. From that point on, the client and the new server process communicate without intervention by the original `lightdb` process. Thus, the master server process is always running, waiting for client connections, whereas client and associated server processes come and go. (All of this is of course invisible to the user. We only mention it here for completeness.)

## 1.3. Creating a Database

The first test to see whether you can access the database server is to try to create a database. A running LightDB server can manage many databases. Typically, a separate database is used for each project or for each user.

Possibly, your site administrator has already created a database for your use. In that case you can omit this step and skip ahead to the next section.

To create a new database, in this example named `mydb`, you use the following command:

```
$ createdb mydb
```

If this produces no response then this step was successful and you can skip over the remainder of this section.

If you see a message similar to:

```
createdb: command not found
```

then LightDB was not installed properly. Either it was not installed at all or your shell's search path was not set to include it. Try calling the command with an absolute path instead:

```
$ /usr/local/lightdb-x/bin/createdb mydb
```

The path at your site might be different. Contact your site administrator or check the installation instructions to correct the situation.

Another response could be this:

```
createdb: could not connect to database postgres: could not connect
to server: No such file or directory
        Is the server running locally and accepting
connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

This means that the server was not started, or it was not started where `createdb` expected it. Again, check the installation instructions or consult the administrator.

Another response could be this:

```
createdb: could not connect to database postgres: FATAL:  role
"joe" does not exist
```

where your own login name is mentioned. This will happen if the administrator has not created a LightDB user account for you. (LightDB user accounts are distinct from operating system user accounts.) If you are the administrator, see Chapter 19 for help creating accounts. You will need to become the operating system user under which LightDB was installed (usually `lightdb`) to create the first user account. It could also be that you were assigned a LightDB user name that is different from your operating system user name; in that case you need to use the `-U` switch or set the `LTUSER` environment variable to specify your LightDB user name.

If you have a user account but it does not have the privileges required to create a database, you will see the following:

```
createdb: database creation failed: ERROR:  permission denied to
create database
```

Not every user has authorization to create new databases. If LightDB refuses to create databases for you then the site administrator needs to grant you permission to create databases. Consult your site

administrator if this occurs. If you installed LightDB yourself then you should log in for the purposes of this tutorial under the user account that you started the server as.<sup>1</sup>

You can also create databases with other names. LightDB allows you to create any number of databases at a given site. Database names must have an alphabetic first character and are limited to 63 bytes in length. A convenient choice is to create a database with the same name as your current user name. Many tools assume that database name as the default, so it can save you some typing. To create that database, simply type:

```
$ createdb
```

If you want to create a distributed database named `mydb`, you can use the `lt_createdb` command to create it:

```
$  
lt_createdb mydb
```

For this command, you must execute it on a `cn` node. If executed on a `non-cn` node, a regular database will be created.

If you do not want to use your database anymore you can remove it. For example, if you are the owner (creator) of the database `mydb`, you can destroy it using the following command:

```
$ dropdb mydb
```

(For this command, the database name does not default to the user account name. You always need to specify it.) This action physically removes all files associated with the database and cannot be undone, so this should only be done with a great deal of forethought.

More about `createdb` and `dropdb` can be found in `createdb` and `dropdb` respectively.

## 1.4. Accessing a Database

Once you have created a database, you can access it by:

- Running the LightDB interactive terminal program, called *ltsql*, which allows you to interactively enter, edit, and execute SQL commands.
- Using an existing graphical frontend tool like pgAdmin or an office suite with ODBC or JDBC support to create and manipulate a database. These possibilities are not covered in this tutorial.
- Writing a custom application, using one of the several available language bindings. These possibilities are discussed further in Part IV.

You probably want to start up `ltsql` to try the examples in this tutorial. It can be activated for the `mydb` database by typing the command:

```
$ ltsql mydb
```

If you do not supply the database name then it will default to your user account name. You already discovered this scheme in the previous section using `createdb`.

---

<sup>1</sup> As an explanation for why this works: LightDB user names are separate from operating system user accounts. When you connect to a database, you can choose what LightDB user name to connect as; if you don't, it will default to the same name as your current operating system account. As it happens, there will always be a LightDB user account that has the same name as the operating system user that started the server, and it also happens that that user always has permission to create databases. Instead of logging in as that user you can also specify the `-U` option everywhere to select a LightDB user name to connect as.

In `ltsql`, you will be greeted with the following message:

```
ltsql (13.8-23.4)
compatible type: postgresql
Type "help" for help.
```

```
mydb=>
```

The last line could also be:

```
mydb=#
```

That would mean you are a database superuser, which is most likely the case if you installed the LightDB instance yourself. Being a superuser means that you are not subject to access controls. For the purposes of this tutorial that is not important.

If you encounter problems starting `ltsql` then go back to the previous section. The diagnostics of `createdb` and `ltsql` are similar, and if the former worked the latter should work as well.

The last line printed out by `ltsql` is the prompt, and it indicates that `ltsql` is listening to you and that you can type SQL queries into a work space maintained by `ltsql`. Try out these commands:

```
mydb=> SELECT version();
                                     version
-----
LightDB 13.8-23.4 on x86_64-pc-linux-gnu, compiled by gcc (Debian
4.9.2-10) 4.9.2, 64-bit
(1 row)

mydb=> SELECT current_date;
      date
-----
2016-01-07
(1 row)

mydb=> SELECT 2 + 2;
?column?
-----
      4
(1 row)
```

The `ltsql` program has a number of internal commands that are not SQL commands. They begin with the backslash character, “\”. For example, you can get help on the syntax of various LightDB SQL commands by typing:

```
mydb=> \h
```

To get out of `ltsql`, type:

```
mydb=> \q
```

and `ltsql` will quit and return you to your command shell. (For more internal commands, type `\?` at the `ltsql` prompt.) The full capabilities of `ltsql` are documented in `ltsql`. In this tutorial we will not use these features explicitly, but you can use them yourself when it is helpful.

---

# Chapter 2. The SQL Language

## 2.1. Introduction

This chapter provides an overview of how to use SQL to perform simple operations. This tutorial is only intended to give you an introduction and is in no way a complete tutorial on SQL. Numerous books have been written on SQL, including [melt93] and [date97]. You should be aware that some LightDB language features are extensions to the standard.

In the examples that follow, we assume that you have created a database named `mydb`, as described in the previous chapter, and have been able to start `ltsql`.

Examples in this manual can also be found in the LightDB source distribution in the directory `src/tutorial/`. (Binary distributions of LightDB might not provide those files.) To use those files, first change to that directory and run `make`:

```
$ cd ../src/tutorial
$ make
```

This creates the scripts and compiles the C files containing user-defined functions and types. Then, to start the tutorial, do the following:

```
$ ltsql -s mydb
```

```
...
```

```
mydb=> \i basics.sql
```

The `\i` command reads in commands from the specified file. `ltsql`'s `-s` option puts you in single step mode which pauses before sending each statement to the server. The commands used in this section are in the file `basics.sql`.

## 2.2. Concepts

LightDB is a *relational database management system* (RDBMS). That means it is a system for managing data stored in *relations*. Relation is essentially a mathematical term for *table*. The notion of storing data in tables is so commonplace today that it might seem inherently obvious, but there are a number of other ways of organizing databases. Files and directories on Unix-like operating systems form an example of a hierarchical database. A more modern development is the object-oriented database.

Each table is a named collection of *rows*. Each row of a given table has the same set of named *columns*, and each column is of a specific data type. Whereas columns have a fixed order in each row, it is important to remember that SQL does not guarantee the order of the rows within the table in any way (although they can be explicitly sorted for display).

Tables are grouped into databases, and a collection of databases managed by a single LightDB server instance constitutes a database *cluster*.

## 2.3. Creating a New Table

You can create a new table by specifying the table name, along with all column names and their types:

```
CREATE TABLE weather (  
    city          varchar(80),  
    temp_lo      int,          -- low temperature  
    temp_hi      int,          -- high temperature  
    prcp         real,        -- precipitation  
    date         date  
);
```

You can enter this into `ltsql` with the line breaks. `ltsql` will recognize that the command is not terminated until the semicolon.

White space (i.e., spaces, tabs, and newlines) can be used freely in SQL commands. That means you can type the command aligned differently than above, or even all on one line. Two dashes (“--”) introduce comments. Whatever follows them is ignored up to the end of the line. SQL is case insensitive about key words and identifiers, except when identifiers are double-quoted to preserve the case (not done above).

`varchar(80)` specifies a data type that can store arbitrary character strings up to 80 characters in length. `int` is the normal integer type. `real` is a type for storing single precision floating-point numbers. `date` should be self-explanatory. (Yes, the column of type `date` is also named `date`. This might be convenient or confusing — you choose.)

LightDB supports the standard SQL types `int`, `smallint`, `real`, `double precision`, `char(N)`, `varchar(N)`, `date`, `time`, `timestamp`, and `interval`, as well as other types of general utility and a rich set of geometric types. LightDB can be customized with an arbitrary number of user-defined data types. Consequently, type names are not key words in the syntax, except where required to support special cases in the SQL standard.

The second example will store cities and their associated geographical location:

```
CREATE TABLE cities (  
    name          varchar(80),  
    location      point  
);
```

The `point` type is an example of a LightDB-specific data type.

Finally, it should be mentioned that if you don't need a table any longer or want to recreate it differently you can remove it using the following command:

```
DROP TABLE tablename;
```

## 2.4. Populating a Table With Rows

The `INSERT` statement is used to populate a table with rows:

```
INSERT INTO weather VALUES ('San Francisco', 46, 50, 0.25,  
    '1994-11-27');
```

Note that all data types use rather obvious input formats. Constants that are not simple numeric values usually must be surrounded by single quotes (`'`), as in the example. The `date` type is actually quite flexible in what it accepts, but for this tutorial we will stick to the unambiguous format shown here.

The `point` type requires a coordinate pair as input, as shown here:



```
INSERT INTO cities VALUES ('San Francisco', '(-194.0, 53.0)');
```

The syntax used so far requires you to remember the order of the columns. An alternative syntax allows you to list the columns explicitly:

```
INSERT INTO weather (city, temp_lo, temp_hi, prcp, date)
VALUES ('San Francisco', 43, 57, 0.0, '1994-11-29');
```

You can list the columns in a different order if you wish or even omit some columns, e.g., if the precipitation is unknown:

```
INSERT INTO weather (date, city, temp_hi, temp_lo)
VALUES ('1994-11-29', 'Hayward', 54, 37);
```

Many developers consider explicitly listing the columns better style than relying on the order implicitly.

Please enter all the commands shown above so you have some data to work with in the following sections.

You could also have used `COPY` to load large amounts of data from flat-text files. This is usually faster because the `COPY` command is optimized for this application while allowing less flexibility than `INSERT`. An example would be:

```
COPY weather FROM '/home/user/weather.txt';
```

where the file name for the source file must be available on the machine running the backend process, not the client, since the backend process reads the file directly. You can read more about the `COPY` command in `COPY`.

## 2.5. Querying a Table

To retrieve data from a table, the table is *queried*. An SQL `SELECT` statement is used to do this. The statement is divided into a select list (the part that lists the columns to be returned), a table list (the part that lists the tables from which to retrieve the data), and an optional qualification (the part that specifies any restrictions). For example, to retrieve all the rows of table `weather`, type:

```
SELECT * FROM weather;
```

Here `*` is a shorthand for “all columns”.<sup>1</sup> So the same result would be had with:

```
SELECT city, temp_lo, temp_hi, prcp, date FROM weather;
```

The output should be:

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	43	57	0	1994-11-29
Hayward	37	54		1994-11-29

(3 rows)

---

<sup>1</sup> While `SELECT *` is useful for off-the-cuff queries, it is widely considered bad style in production code, since adding a column to the table would change the results.

You can write expressions, not just simple column references, in the select list. For example, you can do:

```
SELECT city, (temp_hi+temp_lo)/2 AS temp_avg, date FROM weather;
```

This should give:

city	temp_avg	date
San Francisco	48	1994-11-27
San Francisco	50	1994-11-29
Hayward	45	1994-11-29

(3 rows)

Notice how the AS clause is used to relabel the output column. (The AS clause is optional.)

A query can be “qualified” by adding a WHERE clause that specifies which rows are wanted. The WHERE clause contains a Boolean (truth value) expression, and only rows for which the Boolean expression is true are returned. The usual Boolean operators (AND, OR, and NOT) are allowed in the qualification. For example, the following retrieves the weather of San Francisco on rainy days:

```
SELECT * FROM weather
WHERE city = 'San Francisco' AND prcp > 0.0;
```

Result:

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27

(1 row)

You can request that the results of a query be returned in sorted order:

```
SELECT * FROM weather
ORDER BY city;
```

city	temp_lo	temp_hi	prcp	date
Hayward	37	54		1994-11-29
San Francisco	43	57	0	1994-11-29
San Francisco	46	50	0.25	1994-11-27

In this example, the sort order isn't fully specified, and so you might get the San Francisco rows in either order. But you'd always get the results shown above if you do:

```
SELECT * FROM weather
ORDER BY city, temp_lo;
```

You can request that duplicate rows be removed from the result of a query:

```
SELECT DISTINCT city
FROM weather;
```

```

      city
-----
 Hayward
 San Francisco
(2 rows)

```

Here again, the result row ordering might vary. You can ensure consistent results by using `DISTINCT` and `ORDER BY` together:<sup>2</sup>

```

SELECT DISTINCT city
   FROM weather
  ORDER BY city;

```

## 2.6. Joins Between Tables

Thus far, our queries have only accessed one table at a time. Queries can access multiple tables at once, or access the same table in such a way that multiple rows of the table are being processed at the same time. A query that accesses multiple rows of the same or different tables at one time is called a *join* query. As an example, say you wish to list all the weather records together with the location of the associated city. To do that, we need to compare the `city` column of each row of the `weather` table with the `name` column of all rows in the `cities` table, and select the pairs of rows where these values match.

### Note

This is only a conceptual model. The join is usually performed in a more efficient manner than actually comparing each possible pair of rows, but this is invisible to the user.

This would be accomplished by the following query:

```

SELECT *
   FROM weather, cities
  WHERE city = name;

```

```

      city      | temp_lo | temp_hi | prcp | date       | name
-----+-----+-----+-----+-----+-----
 | location
-----+-----+-----+-----+-----+-----
 San Francisco |      46 |      50 | 0.25 | 1994-11-27 | San
 Francisco | (-194,53)
 San Francisco |      43 |      57 | 0    | 1994-11-29 | San
 Francisco | (-194,53)
(2 rows)

```

Observe two things about the result set:

- There is no result row for the city of Hayward. This is because there is no matching entry in the `cities` table for Hayward, so the join ignores the unmatched rows in the `weather` table. We will see shortly how this can be fixed.

<sup>2</sup> In some database systems, including older versions of LightDB, the implementation of `DISTINCT` automatically orders the rows and so `ORDER BY` is unnecessary. But this is not required by the SQL standard, and current LightDB does not guarantee that `DISTINCT` causes the rows to be ordered.

- There are two columns containing the city name. This is correct because the lists of columns from the `weather` and `cities` tables are concatenated. In practice this is undesirable, though, so you will probably want to list the output columns explicitly rather than using `*`:

```
SELECT city, temp_lo, temp_hi, prcp, date, location
       FROM weather, cities
       WHERE city = name;
```

**Exercise:** Attempt to determine the semantics of this query when the `WHERE` clause is omitted.

Since the columns all had different names, the parser automatically found which table they belong to. If there were duplicate column names in the two tables you'd need to *qualify* the column names to show which one you meant, as in:

```
SELECT weather.city, weather.temp_lo, weather.temp_hi,
       weather.prcp, weather.date, cities.location
       FROM weather, cities
       WHERE cities.name = weather.city;
```

It is widely considered good style to qualify all column names in a join query, so that the query won't fail if a duplicate column name is later added to one of the tables.

Join queries of the kind seen thus far can also be written in this alternative form:

```
SELECT *
       FROM weather INNER JOIN cities ON (weather.city = cities.name);
```

This syntax is not as commonly used as the one above, but we show it here to help you understand the following topics.

Now we will figure out how we can get the Hayward records back in. What we want the query to do is to scan the `weather` table and for each row to find the matching `cities` row(s). If no matching row is found we want some “empty values” to be substituted for the `cities` table's columns. This kind of query is called an *outer join*. (The joins we have seen so far are inner joins.) The command looks like this:

```
SELECT *
       FROM weather LEFT OUTER JOIN cities ON (weather.city =
       cities.name);
```

city   location	temp_lo	temp_hi	prcp	date	name
Hayward	37	54		1994-11-29	
San Francisco   (-194,53)	46	50	0.25	1994-11-27	San
San Francisco   (-194,53)	43	57	0	1994-11-29	San

(3 rows)

This query is called a *left outer join* because the table mentioned on the left of the join operator will have each of its rows in the output at least once, whereas the table on the right will only have those rows output that match some row of the left table. When outputting a left-table row for which there is no right-table match, empty (null) values are substituted for the right-table columns.

**Exercise:** There are also right outer joins and full outer joins. Try to find out what those do.

We can also join a table against itself. This is called a *self join*. As an example, suppose we wish to find all the weather records that are in the temperature range of other weather records. So we need to compare the `temp_lo` and `temp_hi` columns of each weather row to the `temp_lo` and `temp_hi` columns of all other weather rows. We can do this with the following query:

```
SELECT W1.city, W1.temp_lo AS low, W1.temp_hi AS high,
       W2.city, W2.temp_lo AS low, W2.temp_hi AS high
FROM weather W1, weather W2
WHERE W1.temp_lo < W2.temp_lo
AND W1.temp_hi > W2.temp_hi;
```

city	low	high	city	low	high
San Francisco	43	57	San Francisco	46	50
Hayward	37	54	San Francisco	46	50

(2 rows)

Here we have relabeled the weather table as W1 and W2 to be able to distinguish the left and right side of the join. You can also use these kinds of aliases in other queries to save some typing, e.g.:

```
SELECT *
FROM weather w, cities c
WHERE w.city = c.name;
```

You will encounter this style of abbreviating quite frequently.

## 2.7. Aggregate Functions

Like most other relational database products, LightDB supports *aggregate functions*. An aggregate function computes a single result from multiple input rows. For example, there are aggregates to compute the `count`, `sum`, `avg` (average), `max` (maximum) and `min` (minimum) over a set of rows.

As an example, we can find the highest low-temperature reading anywhere with:

```
SELECT max(temp_lo) FROM weather;
```

```
max
----
 46
(1 row)
```

If we wanted to know what city (or cities) that reading occurred in, we might try:

```
SELECT city FROM weather WHERE temp_lo = max(temp_lo);      WRONG
```

but this will not work since the aggregate `max` cannot be used in the `WHERE` clause. (This restriction exists because the `WHERE` clause determines which rows will be included in the aggregate calculation; so obviously it has to be evaluated before aggregate functions are computed.) However, as is often the case the query can be restated to accomplish the desired result, here by using a *subquery*:

```
SELECT city FROM weather
```

```
WHERE temp_lo = (SELECT max(temp_lo) FROM weather);
```

```

      city
-----
San Francisco
(1 row)

```

This is OK because the subquery is an independent computation that computes its own aggregate separately from what is happening in the outer query.

Aggregates are also very useful in combination with `GROUP BY` clauses. For example, we can get the maximum low temperature observed in each city with:

```
SELECT city, max(temp_lo)
FROM weather
GROUP BY city;
```

```

      city      | max
-----+-----
Hayward        |   37
San Francisco  |   46
(2 rows)

```

which gives us one output row per city. Each aggregate result is computed over the table rows matching that city. We can filter these grouped rows using `HAVING`:

```
SELECT city, max(temp_lo)
FROM weather
GROUP BY city
HAVING max(temp_lo) < 40;
```

```

      city      | max
-----+-----
Hayward        |   37
(1 row)

```

which gives us the same results for only the cities that have all `temp_lo` values below 40. Finally, if we only care about cities whose names begin with “S”, we might do:

```
SELECT city, max(temp_lo)
FROM weather
WHERE city LIKE 'S%'           -- I
GROUP BY city
HAVING max(temp_lo) < 40;
```

**I** The `LIKE` operator does pattern matching and is explained in Section 9.7.

It is important to understand the interaction between aggregates and SQL's `WHERE` and `HAVING` clauses. The fundamental difference between `WHERE` and `HAVING` is this: `WHERE` selects input rows before groups and aggregates are computed (thus, it controls which rows go into the aggregate computation), whereas `HAVING` selects group rows after groups and aggregates are computed. Thus, the `WHERE` clause must not contain aggregate functions; it makes no sense to try to use an aggregate to determine which rows will be inputs to the aggregates. On the other hand, the `HAVING` clause always contains aggregate functions. (Strictly speaking, you are allowed to write a `HAVING` clause

that doesn't use aggregates, but it's seldom useful. The same condition could be used more efficiently at the WHERE stage.)

In the previous example, we can apply the city name restriction in WHERE, since it needs no aggregate. This is more efficient than adding the restriction to HAVING, because we avoid doing the grouping and aggregate calculations for all rows that fail the WHERE check.

## 2.8. Updates

You can update existing rows using the UPDATE command. Suppose you discover the temperature readings are all off by 2 degrees after November 28. You can correct the data as follows:

```
UPDATE weather
  SET temp_hi = temp_hi - 2, temp_lo = temp_lo - 2
  WHERE date > '1994-11-28';
```

Look at the new state of the data:

```
SELECT * FROM weather;
```

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	41	55	0	1994-11-29
Hayward	35	52		1994-11-29

(3 rows)

## 2.9. Deletions

Rows can be removed from a table using the DELETE command. Suppose you are no longer interested in the weather of Hayward. Then you can do the following to delete those rows from the table:

```
DELETE FROM weather WHERE city = 'Hayward';
```

All weather records belonging to Hayward are removed.

```
SELECT * FROM weather;
```

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	41	55	0	1994-11-29

(2 rows)

One should be wary of statements of the form

```
DELETE FROM tablename;
```

Without a qualification, DELETE will remove *all* rows from the given table, leaving it empty. The system will not request confirmation before doing this!

---

# Chapter 3. Advanced Features

## 3.1. Introduction

In the previous chapter we have covered the basics of using SQL to store and access your data in LightDB. We will now discuss some more advanced features of SQL that simplify management and prevent loss or corruption of your data. Finally, we will look at some LightDB extensions.

This chapter will on occasion refer to examples found in Chapter 2 to change or improve them, so it will be useful to have read that chapter. Some examples from this chapter can also be found in `advanced.sql` in the tutorial directory. This file also contains some sample data to load, which is not repeated here. (Refer to Section 2.1 for how to use the file.)

## 3.2. Views

Refer back to the queries in Section 2.6. Suppose the combined listing of weather records and city location is of particular interest to your application, but you do not want to type the query each time you need it. You can create a *view* over the query, which gives a name to the query that you can refer to like an ordinary table:

```
CREATE VIEW myview AS
  SELECT name, temp_lo, temp_hi, prcp, date, location
     FROM weather, cities
     WHERE city = name;
```

```
SELECT * FROM myview;
```

Making liberal use of views is a key aspect of good SQL database design. Views allow you to encapsulate the details of the structure of your tables, which might change as your application evolves, behind consistent interfaces.

Views can be used in almost any place a real table can be used. Building views upon other views is not uncommon.

## 3.3. Foreign Keys

Recall the `weather` and `cities` tables from Chapter 2. Consider the following problem: You want to make sure that no one can insert rows in the `weather` table that do not have a matching entry in the `cities` table. This is called maintaining the *referential integrity* of your data. In simplistic database systems this would be implemented (if at all) by first looking at the `cities` table to check if a matching record exists, and then inserting or rejecting the new `weather` records. This approach has a number of problems and is very inconvenient, so LightDB can do this for you.

The new declaration of the tables would look like this:

```
CREATE TABLE cities (
  name      varchar(80) primary key,
  location  point
);

CREATE TABLE weather (
  city      varchar(80) references cities(name),
  temp_lo  int,
```



```
        temp_hi    int,  
        prcp      real,  
        date      date  
    );
```

Now try inserting an invalid record:

```
INSERT INTO weather VALUES ('Berkeley', 45, 53, 0.0, '1994-11-28');
```

```
ERROR: insert or update on table "weather" violates foreign key  
constraint "weather_city_fkey"  
DETAIL: Key (city)=(Berkeley) is not present in table "cities".
```

The behavior of foreign keys can be finely tuned to your application. We will not go beyond this simple example in this tutorial, but just refer you to Chapter 5 for more information. Making correct use of foreign keys will definitely improve the quality of your database applications, so you are strongly encouraged to learn about them.

## 3.4. Transactions

*Transactions* are a fundamental concept of all database systems. The essential point of a transaction is that it bundles multiple steps into a single, all-or-nothing operation. The intermediate states between the steps are not visible to other concurrent transactions, and if some failure occurs that prevents the transaction from completing, then none of the steps affect the database at all.

For example, consider a bank database that contains balances for various customer accounts, as well as total deposit balances for branches. Suppose that we want to record a payment of \$100.00 from Alice's account to Bob's account. Simplifying outrageously, the SQL commands for this might look like:

```
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
UPDATE branches SET balance = balance - 100.00  
    WHERE name = (SELECT branch_name FROM accounts WHERE name =  
    'Alice');  
UPDATE accounts SET balance = balance + 100.00  
    WHERE name = 'Bob';  
UPDATE branches SET balance = balance + 100.00  
    WHERE name = (SELECT branch_name FROM accounts WHERE name =  
    'Bob');
```

The details of these commands are not important here; the important point is that there are several separate updates involved to accomplish this rather simple operation. Our bank's officers will want to be assured that either all these updates happen, or none of them happen. It would certainly not do for a system failure to result in Bob receiving \$100.00 that was not debited from Alice. Nor would Alice long remain a happy customer if she was debited without Bob being credited. We need a guarantee that if something goes wrong partway through the operation, none of the steps executed so far will take effect. Grouping the updates into a *transaction* gives us this guarantee. A transaction is said to be *atomic*: from the point of view of other transactions, it either happens completely or not at all.

We also want a guarantee that once a transaction is completed and acknowledged by the database system, it has indeed been permanently recorded and won't be lost even if a crash ensues shortly thereafter. For example, if we are recording a cash withdrawal by Bob, we do not want any chance that the debit to his account will disappear in a crash just after he walks out the bank door. A transactional database guarantees that all the updates made by a transaction are logged in permanent storage (i.e., on disk) before the transaction is reported complete.

Another important property of transactional databases is closely related to the notion of atomic updates: when multiple transactions are running concurrently, each one should not be able to see the incomplete changes made by others. For example, if one transaction is busy totalling all the branch balances, it would not do for it to include the debit from Alice's branch but not the credit to Bob's branch, nor vice versa. So transactions must be all-or-nothing not only in terms of their permanent effect on the database, but also in terms of their visibility as they happen. The updates made so far by an open transaction are invisible to other transactions until the transaction completes, whereupon all the updates become visible simultaneously.

In LightDB, a transaction is set up by surrounding the SQL commands of the transaction with `BEGIN` and `COMMIT` commands. So our banking transaction would actually look like:

```
BEGIN;  
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
-- etc etc  
COMMIT;
```

If, partway through the transaction, we decide we do not want to commit (perhaps we just noticed that Alice's balance went negative), we can issue the command `ROLLBACK` instead of `COMMIT`, and all our updates so far will be canceled.

LightDB actually treats every SQL statement as being executed within a transaction. If you do not issue a `BEGIN` command, then each individual statement has an implicit `BEGIN` and (if successful) `COMMIT` wrapped around it. A group of statements surrounded by `BEGIN` and `COMMIT` is sometimes called a *transaction block*.

### Note

Some client libraries issue `BEGIN` and `COMMIT` commands automatically, so that you might get the effect of transaction blocks without asking. Check the documentation for the interface you are using.

It's possible to control the statements in a transaction in a more granular fashion through the use of *savepoints*. Savepoints allow you to selectively discard parts of the transaction, while committing the rest. After defining a savepoint with `SAVEPOINT`, you can if needed roll back to the savepoint with `ROLLBACK TO`. All the transaction's database changes between defining the savepoint and rolling back to it are discarded, but changes earlier than the savepoint are kept.

After rolling back to a savepoint, it continues to be defined, so you can roll back to it several times. Conversely, if you are sure you won't need to roll back to a particular savepoint again, it can be released, so the system can free some resources. Keep in mind that either releasing or rolling back to a savepoint will automatically release all savepoints that were defined after it.

All this is happening within the transaction block, so none of it is visible to other database sessions. When and if you commit the transaction block, the committed actions become visible as a unit to other sessions, while the rolled-back actions never become visible at all.

Remembering the bank database, suppose we debit \$100.00 from Alice's account, and credit Bob's account, only to find later that we should have credited Wally's account. We could do it using savepoints like this:

```
BEGIN;  
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
SAVEPOINT my_savepoint;
```

```

UPDATE accounts SET balance = balance + 100.00
  WHERE name = 'Bob';
-- oops ... forget that and use Wally's account
ROLLBACK TO my_savepoint;
UPDATE accounts SET balance = balance + 100.00
  WHERE name = 'Wally';
COMMIT;

```

This example is, of course, oversimplified, but there's a lot of control possible in a transaction block through the use of savepoints. Moreover, `ROLLBACK TO` is the only way to regain control of a transaction block that was put in aborted state by the system due to an error, short of rolling it back completely and starting again.

## 3.5. Window Functions

A *window function* performs a calculation across a set of table rows that are somehow related to the current row. This is comparable to the type of calculation that can be done with an aggregate function. However, window functions do not cause rows to become grouped into a single output row like non-window aggregate calls would. Instead, the rows retain their separate identities. Behind the scenes, the window function is able to access more than just the current row of the query result.

Here is an example that shows how to compare each employee's salary with the average salary in his or her department:

```

SELECT depname, empno, salary, avg(salary) OVER (PARTITION BY
  depname) FROM empsalary;

```

depname	empno	salary	avg
develop	11	5200	5020.000000000000000000
develop	7	4200	5020.000000000000000000
develop	9	4500	5020.000000000000000000
develop	8	6000	5020.000000000000000000
develop	10	5200	5020.000000000000000000
personnel	5	3500	3700.000000000000000000
personnel	2	3900	3700.000000000000000000
sales	3	4800	4866.666666666666666667
sales	1	5000	4866.666666666666666667
sales	4	4800	4866.666666666666666667

(10 rows)

The first three output columns come directly from the table `empsalary`, and there is one output row for each row in the table. The fourth column represents an average taken across all the table rows that have the same `depname` value as the current row. (This actually is the same function as the non-window `avg` aggregate, but the `OVER` clause causes it to be treated as a window function and computed across the window frame.)

A window function call always contains an `OVER` clause directly following the window function's name and argument(s). This is what syntactically distinguishes it from a normal function or non-window aggregate. The `OVER` clause determines exactly how the rows of the query are split up for processing by the window function. The `PARTITION BY` clause within `OVER` divides the rows into groups, or partitions, that share the same values of the `PARTITION BY` expression(s). For each row, the window function is computed across the rows that fall into the same partition as the current row.

You can also control the order in which rows are processed by window functions using `ORDER BY` within `OVER`. (The window `ORDER BY` does not even have to match the order in which the rows are output.) Here is an example:

```
SELECT depname, empno, salary,
       rank() OVER (PARTITION BY depname ORDER BY salary DESC)
FROM empsalary;
```

depname	empno	salary	rank
develop	8	6000	1
develop	10	5200	2
develop	11	5200	2
develop	9	4500	4
develop	7	4200	5
personnel	2	3900	1
personnel	5	3500	2
sales	1	5000	1
sales	4	4800	2
sales	3	4800	2

(10 rows)

As shown here, the `rank` function produces a numerical rank for each distinct `ORDER BY` value in the current row's partition, using the order defined by the `ORDER BY` clause. `rank` needs no explicit parameter, because its behavior is entirely determined by the `OVER` clause.

The rows considered by a window function are those of the “virtual table” produced by the query's `FROM` clause as filtered by its `WHERE`, `GROUP BY`, and `HAVING` clauses if any. For example, a row removed because it does not meet the `WHERE` condition is not seen by any window function. A query can contain multiple window functions that slice up the data in different ways using different `OVER` clauses, but they all act on the same collection of rows defined by this virtual table.

We already saw that `ORDER BY` can be omitted if the ordering of rows is not important. It is also possible to omit `PARTITION BY`, in which case there is a single partition containing all rows.

There is another important concept associated with window functions: for each row, there is a set of rows within its partition called its *window frame*. Some window functions act only on the rows of the window frame, rather than of the whole partition. By default, if `ORDER BY` is supplied then the frame consists of all rows from the start of the partition up through the current row, plus any following rows that are equal to the current row according to the `ORDER BY` clause. When `ORDER BY` is omitted the default frame consists of all rows in the partition.<sup>1</sup> Here is an example using `sum`:

```
SELECT salary, sum(salary) OVER () FROM empsalary;
```

salary	sum
5200	47100
5000	47100
3500	47100
4800	47100
3900	47100
4200	47100
4500	47100
4800	47100
6000	47100
5200	47100

(10 rows)

<sup>1</sup> There are options to define the window frame in other ways, but this tutorial does not cover them. See Section 4.2.8 for details.

Above, since there is no `ORDER BY` in the `OVER` clause, the window frame is the same as the partition, which for lack of `PARTITION BY` is the whole table; in other words each sum is taken over the whole table and so we get the same result for each output row. But if we add an `ORDER BY` clause, we get very different results:

```
SELECT salary, sum(salary) OVER (ORDER BY salary) FROM empsalary;
```

salary	sum
3500	3500
3900	7400
4200	11600
4500	16100
4800	25700
4800	25700
5000	30700
5200	41100
5200	41100
6000	47100

(10 rows)

Here the sum is taken from the first (lowest) salary up through the current one, including any duplicates of the current one (notice the results for the duplicated salaries).

Window functions are permitted only in the `SELECT` list and the `ORDER BY` clause of the query. They are forbidden elsewhere, such as in `GROUP BY`, `HAVING` and `WHERE` clauses. This is because they logically execute after the processing of those clauses. Also, window functions execute after non-window aggregate functions. This means it is valid to include an aggregate function call in the arguments of a window function, but not vice versa.

If there is a need to filter or group rows after the window calculations are performed, you can use a sub-select. For example:

```
SELECT depname, empno, salary, enroll_date
FROM
  (SELECT depname, empno, salary, enroll_date,
         rank() OVER (PARTITION BY depname ORDER BY salary DESC,
                    empno) AS pos
   FROM empsalary
  ) AS ss
WHERE pos < 3;
```

The above query only shows the rows from the inner query having rank less than 3.

When a query involves multiple window functions, it is possible to write out each one with a separate `OVER` clause, but this is duplicative and error-prone if the same windowing behavior is wanted for several functions. Instead, each windowing behavior can be named in a `WINDOW` clause and then referenced in `OVER`. For example:

```
SELECT sum(salary) OVER w, avg(salary) OVER w
FROM empsalary
WINDOW w AS (PARTITION BY depname ORDER BY salary DESC);
```

More details about window functions can be found in Section 4.2.8, Section 9.22, Section 7.2.5, and the `SELECT` reference page.

## 3.6. Inheritance

Inheritance is a concept from object-oriented databases. It opens up interesting new possibilities of database design.

Let's create two tables: A table `cities` and a table `capitals`. Naturally, capitals are also cities, so you want some way to show the capitals implicitly when you list all cities. If you're really clever you might invent some scheme like this:

```
CREATE TABLE capitals (  
  name      text,  
  population real,  
  elevation int,    -- (in ft)  
  state     char(2)  
);  
  
CREATE TABLE non_capitals (  
  name      text,  
  population real,  
  elevation int    -- (in ft)  
);  
  
CREATE VIEW cities AS  
  SELECT name, population, elevation FROM capitals  
  UNION  
  SELECT name, population, elevation FROM non_capitals;
```

This works OK as far as querying goes, but it gets ugly when you need to update several rows, for one thing.

A better solution is this:

```
CREATE TABLE cities (  
  name      text,  
  population real,  
  elevation int    -- (in ft)  
);  
  
CREATE TABLE capitals (  
  state     char(2) UNIQUE NOT NULL  
) INHERITS (cities);
```

In this case, a row of `capitals` *inherits* all columns (name, population, and elevation) from its *parent*, `cities`. The type of the column name is `text`, a native LightDB type for variable length character strings. The `capitals` table has an additional column, `state`, which shows its state abbreviation. In LightDB, a table can inherit from zero or more other tables.

For example, the following query finds the names of all cities, including state capitals, that are located at an elevation over 500 feet:

```
SELECT name, elevation  
  FROM cities  
  WHERE elevation > 500;
```

which returns:

name	elevation
Las Vegas	2174
Mariposa	1953
Madison	845

(3 rows)

On the other hand, the following query finds all the cities that are not state capitals and are situated at an elevation over 500 feet:

```
SELECT name, elevation
   FROM ONLY cities
  WHERE elevation > 500;
```

name	elevation
Las Vegas	2174
Mariposa	1953

(2 rows)

Here the `ONLY` before `cities` indicates that the query should be run over only the `cities` table, and not tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE`, and `DELETE` — support this `ONLY` notation.

### Note

Although inheritance is frequently useful, it has not been integrated with unique constraints or foreign keys, which limits its usefulness. See Section 5.10 for more detail.

## 3.7. Conclusion

LightDB has many features not touched upon in this tutorial introduction, which has been oriented toward newer users of SQL. These features are discussed in more detail in the remainder of this book.

If you feel you need more introductory material, please visit the LightDB web site<sup>2</sup> for links to more resources.

<sup>2</sup> <https://www.hs.net/lightdb>

---

# Part II. The SQL Language

This part describes the use of the SQL language in LightDB. We start with describing the general syntax of SQL, then explain how to create the structures to hold data, how to populate the database, and how to query it. The middle part lists the available data types and functions for use in SQL commands. The rest treats several aspects that are important for tuning a database for optimal performance.

The information in this part is arranged so that a novice user can follow it start to end to gain a full understanding of the topics without having to refer forward too many times. The chapters are intended to be self-contained, so that advanced users can read the chapters individually as they choose. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

Readers of this part should know how to connect to a LightDB database and issue SQL commands. Readers that are unfamiliar with these issues are encouraged to read Part I first. SQL commands are typically entered using the LightDB interactive terminal `ltsql`, but other programs that have similar functionality can be used as well.

---



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# Chapter 4. SQL Syntax

This chapter describes the syntax of SQL. It forms the foundation for understanding the following chapters which will go into detail about how SQL commands are applied to define and modify data.

We also advise users who are already familiar with SQL to read this chapter carefully because it contains several rules and concepts that are implemented inconsistently among SQL databases or that are specific to LightDB.

## 4.1. Lexical Structure

SQL input consists of a sequence of *commands*. A command is composed of a sequence of *tokens*, terminated by a semicolon (“;”). The end of the input stream also terminates a command. Which tokens are valid depends on the syntax of the particular command.

A token can be a *key word*, an *identifier*, a *quoted identifier*, a *literal* (or constant), or a special character symbol. Tokens are normally separated by whitespace (space, tab, newline), but need not be if there is no ambiguity (which is generally only the case if a special character is adjacent to some other token type).

For example, the following is (syntactically) valid SQL input:

```
SELECT * FROM MY_TABLE;
UPDATE MY_TABLE SET A = 5;
INSERT INTO MY_TABLE VALUES (3, 'hi there');
```

This is a sequence of three commands, one per line (although this is not required; more than one command can be on a line, and commands can usefully be split across lines).

Additionally, *comments* can occur in SQL input. They are not tokens, they are effectively equivalent to whitespace.

The SQL syntax is not very consistent regarding what tokens identify commands and which are operands or parameters. The first few tokens are generally the command name, so in the above example we would usually speak of a “SELECT”, an “UPDATE”, and an “INSERT” command. But for instance the UPDATE command always requires a SET token to appear in a certain position, and this particular variation of INSERT also requires a VALUES in order to be complete. The precise syntax rules for each command are described in Part VI.

To be compatible with Oracle databases, LightDB allows you to combine double quotation marks with uppercase column names to manipulate lowercase column names. This feature is only available in Oracle compatibility mode.

```
create table t1(id int);
insert into t1("ID") values(10),(20),(30);
select "ID" from t1;
update t1 set "ID"=25 where id = 20;
delete from t1 where "ID" = 25;
```

### 4.1.1. Identifiers and Key Words

Tokens such as SELECT, UPDATE, or VALUES in the example above are examples of *key words*, that is, words that have a fixed meaning in the SQL language. The tokens MY\_TABLE and A are examples of *identifiers*. They identify names of tables, columns, or other database objects, depending on the command they are used in. Therefore they are sometimes simply called “names”. Key words and identifiers have the same lexical structure, meaning that one cannot know whether a token is an



identifier or a key word without knowing the language. A complete list of key words can be found in Appendix C.

SQL identifiers and key words must begin with a letter (a-z, but also letters with diacritical marks and non-Latin letters) or an underscore (`_`). Subsequent characters in an identifier or key word can be letters, underscores, digits (0-9), or dollar signs (`$`). Note that dollar signs are not allowed in identifiers according to the letter of the SQL standard, so their use might render applications less portable. The SQL standard will not define a key word that contains digits or starts or ends with an underscore, so identifiers of this form are safe against possible conflict with future extensions of the standard.

The system uses no more than `NAMEDATALEN-1` bytes of an identifier; longer names can be written in commands, but they will be truncated. By default, `NAMEDATALEN` is 64 so the maximum identifier length is 63 bytes. If this limit is problematic, it can be raised by changing the `NAMEDATALEN` constant in `src/include/pg_config_manual.h`.

Key words and unquoted identifiers are case insensitive. Therefore:

```
UPDATE MY_TABLE SET A = 5;
```

can equivalently be written as:

```
uPDaTE my_TabLE SeT a = 5;
```

A convention often used is to write key words in upper case and names in lower case, e.g.:

```
UPDATE my_table SET a = 5;
```

There is a second kind of identifier: the *delimited identifier* or *quoted identifier*. It is formed by enclosing an arbitrary sequence of characters in double-quotes (`"`). A delimited identifier is always an identifier, never a key word. So `"select"` could be used to refer to a column or table named `select`, whereas an unquoted `select` would be taken as a key word and would therefore provoke a parse error when used where a table or column name is expected. The example can be written with quoted identifiers like this:

```
UPDATE "my_table" SET "a" = 5;
```

Quoted identifiers can contain any character, except the character with code zero. (To include a double quote, write two double quotes.) This allows constructing table or column names that would otherwise not be possible, such as ones containing spaces or ampersands. The length limitation still applies.

Quoting an identifier also makes it case-sensitive, whereas unquoted names are always folded to lower case. For example, the identifiers `FOO`, `fOO`, and `"fOO"` are considered the same by LightDB, but `"FOO"` and `"FOO"` are different from these three and each other. (The folding of unquoted names to lower case in LightDB is incompatible with the SQL standard, which says that unquoted names should be folded to upper case. Thus, `fOO` should be equivalent to `"FOO"` not `"fOO"` according to the standard. If you want to write portable applications you are advised to always quote a particular name or never quote it.)

A variant of quoted identifiers allows including escaped Unicode characters identified by their code points. This variant starts with `U&` (upper or lower case `U` followed by ampersand) immediately before the opening double quote, without any spaces in between, for example `U&"fOO"`. (Note that this creates an ambiguity with the operator `&`. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the identifier `"data"` could be written as

```
U&"d\0061t\+000061"
```

The following less trivial example writes the Russian word “slon” (elephant) in Cyrillic letters:

```
U&"\0441\043B\043E\043D"
```

If a different escape character than backslash is desired, it can be specified using the `UESCAPE` clause after the string, for example:

```
U&"d!0061t!+000061" UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character. Note that the escape character is written in single quotes, not double quotes, after `UESCAPE`.

To include the escape character in the identifier literally, write it twice.

Either the 4-digit or the 6-digit escape form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than `U+FFFF`, although the availability of the 6-digit form technically makes this unnecessary. (Surrogate pairs are not stored directly, but are combined into a single code point.)

If the server encoding is not UTF-8, the Unicode code point identified by one of these escape sequences is converted to the actual server encoding; an error is reported if that's not possible.

## 4.1.2. Constants

There are three kinds of *implicitly-typed constants* in LightDB: strings, bit strings, and numbers. Constants can also be specified with explicit types, which can enable more accurate representation and more efficient handling by the system. These alternatives are discussed in the following subsections.

### 4.1.2.1. String Constants

A string constant in SQL is an arbitrary sequence of characters bounded by single quotes (`'`), for example `'This is a string'`. To include a single-quote character within a string constant, write two adjacent single quotes, e.g., `'Dianne' 's horse'`. Note that this is *not* the same as a double-quote character (`"`).

Two string constants that are only separated by whitespace *with at least one newline* are concatenated and effectively treated as if the string had been written as one constant. For example:

```
SELECT 'foo'  
'bar';
```

is equivalent to:

```
SELECT 'foobar';
```

but:

```
SELECT 'foo'      'bar';
```

is not valid syntax. (This slightly bizarre behavior is specified by SQL; LightDB is following the standard.)

### 4.1.2.2. String Constants with C-Style Escapes

LightDB also accepts “escape” string constants, which are an extension to the SQL standard. An escape string constant is specified by writing the letter E (upper or lower case) just before the opening single quote, e.g., E'foo'. (When continuing an escape string constant across lines, write E only before the first opening quote.) Within an escape string, a backslash character (\) begins a C-like *backslash escape* sequence, in which the combination of backslash and following character(s) represent a special byte value, as shown in Table 4.1.

**Table 4.1. Backslash Escape Sequences**

Backslash Escape Sequence	Interpretation
\b	backspace
\f	form feed
\n	newline
\r	carriage return
\t	tab
\o, \ooo, \oooo (o = 0–7)	octal byte value
\xh, \xhh (h = 0–9, A–F)	hexadecimal byte value
\uxxxxx, \Uxxxxxxxx (x = 0–9, A–F)	16 or 32-bit hexadecimal Unicode character value

Any other character following a backslash is taken literally. Thus, to include a backslash character, write two backslashes (\). Also, a single quote can be included in an escape string by writing \', in addition to the normal way of ' '.

It is your responsibility that the byte sequences you create, especially when using the octal or hexadecimal escapes, compose valid characters in the server character set encoding. A useful alternative is to use Unicode escapes or the alternative Unicode escape syntax, explained in Section 4.1.2.3; then the server will check that the character conversion is possible.

### Caution

If the configuration parameter `standard_conforming_strings` is `off`, then LightDB recognizes backslash escapes in both regular and escape string constants. However, as of LightDB 9.1, the default is `on`, meaning that backslash escapes are recognized only in escape string constants. This behavior is more standards-compliant, but might break applications which rely on the historical behavior, where backslash escapes were always recognized. As a workaround, you can set this parameter to `off`, but it is better to migrate away from using backslash escapes. If you need to use a backslash escape to represent a special character, write the string constant with an E.

In addition to `standard_conforming_strings`, the configuration parameters `escape_string_warning` and `backslash_quote` govern treatment of backslashes in string constants.

The character with the code zero cannot be in a string constant.

Lightdb 23.3 introduced a new database level GUC parameter `lightdb_ascii_zero_store_value`. If the database compatible type is set to Oracle or Mysql, and `lightdb_ascii_zero_store_value` is set to non-zero ASCII value, E'\0' would result in the ASCII value equal to `lightdb_ascii_zero_store_value`.

For more information about GUC `lightdb_ascii_zero_store_value`, See `lightdb_ascii_zero_store_value`

### 4.1.2.3. String Constants with Unicode Escapes

LightDB also supports another type of escape syntax for strings that allows specifying arbitrary Unicode characters by code point. A Unicode escape string constant starts with `U&` (upper or lower case letter `U` followed by ampersand) immediately before the opening quote, without any spaces in between, for example `U&'foo'`. (Note that this creates an ambiguity with the operator `&`. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the string `'data'` could be written as

```
U&'d\0061t\+000061'
```

The following less trivial example writes the Russian word “slon” (elephant) in Cyrillic letters:

```
U&'\'0441\043B\043E\043D'
```

If a different escape character than backslash is desired, it can be specified using the `UESCAPE` clause after the string, for example:

```
U&'d!0061t!+000061' UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character.

To include the escape character in the string literally, write it twice.

Either the 4-digit or the 6-digit escape form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than `U+FFFF`, although the availability of the 6-digit form technically makes this unnecessary. (Surrogate pairs are not stored directly, but are combined into a single code point.)

If the server encoding is not UTF-8, the Unicode code point identified by one of these escape sequences is converted to the actual server encoding; an error is reported if that's not possible.

Also, the Unicode escape syntax for string constants only works when the configuration parameter `standard_conforming_strings` is turned on. This is because otherwise this syntax could confuse clients that parse the SQL statements to the point that it could lead to SQL injections and similar security issues. If the parameter is set to off, this syntax will be rejected with an error message.

### 4.1.2.4. Dollar-Quoted String Constants

While the standard syntax for specifying string constants is usually convenient, it can be difficult to understand when the desired string contains many single quotes or backslashes, since each of those must be doubled. To allow more readable queries in such situations, LightDB provides another way, called “dollar quoting”, to write string constants. A dollar-quoted string constant consists of a dollar sign (`$`), an optional “tag” of zero or more characters, another dollar sign, an arbitrary sequence of characters that makes up the string content, a dollar sign, the same tag that began this dollar quote, and a dollar sign. For example, here are two different ways to specify the string “Dianne’s horse” using dollar quoting:

```
$$Dianne's horse$$
$SomeTag$Dianne's horse$SomeTag$
```

Notice that inside the dollar-quoted string, single quotes can be used without needing to be escaped. Indeed, no characters inside a dollar-quoted string are ever escaped: the string content is always written

literally. Backslashes are not special, and neither are dollar signs, unless they are part of a sequence matching the opening tag.

It is possible to nest dollar-quoted string constants by choosing different tags at each nesting level. This is most commonly used in writing function definitions. For example:

```
$function$
BEGIN
    RETURN ($1 ~ $q$[\t\r\n\v\\]$q$);
END;
$function$
```

Here, the sequence `$q$[\t\r\n\v\\]$q$` represents a dollar-quoted literal string `[\t\r\n\v\\]`, which will be recognized when the function body is executed by LightDB. But since the sequence does not match the outer dollar quoting delimiter `$function$`, it is just some more characters within the constant so far as the outer string is concerned.

The tag, if any, of a dollar-quoted string follows the same rules as an unquoted identifier, except that it cannot contain a dollar sign. Tags are case sensitive, so `$tag$string content$tag$` is correct, but `$TAG$string content$tag$` is not.

A dollar-quoted string that follows a keyword or identifier must be separated from it by whitespace; otherwise the dollar quoting delimiter would be taken as part of the preceding identifier.

Dollar quoting is not part of the SQL standard, but it is often a more convenient way to write complicated string literals than the standard-compliant single quote syntax. It is particularly useful when representing string constants inside other constants, as is often needed in procedural function definitions. With single-quote syntax, each backslash in the above example would have to be written as four backslashes, which would be reduced to two backslashes in parsing the original string constant, and then to one when the inner string constant is re-parsed during function execution.

#### 4.1.2.5. Q-Quoted String Constants

Use the text literal notation to specify values whenever string appears in the syntax of expressions, conditions, SQL functions, and SQL statements in other parts of this reference. This reference uses the terms text literal, character literal, and string interchangeably. Text, character, and string literals are always surrounded by single quotation marks. If the syntax uses the term `char`, then you can specify either a text literal or another expression that resolves to character data. When `char` appears in the syntax, the single quotation marks are not used. using q quoting:

```
q'!name LIKE '%DBMS_%%!'
q'<'So,' she said, 'It's finished.'>'
q'{SELECT * FROM employees WHERE last_name = 'Smith';}'
nq'i Ÿ1234 i'
q"name like '['"
```

Lightdb Database offers the ability, in both SQL and PL/pgSQL, to specify our own user-defined delimiters for string literals. Here's how it works: you prefix your literal with the letter "q". Then you type a single quote, followed by your starting delimiter for the literal. Then you type your literal string without having to double up on your single quote characters. When you have typed in your full literal, terminate it with your ending delimiter, followed by a single quote. In other words, you will follow this general format: `q[your string here]` where `"["` represents (and certainly could be used for) the starting delimiter, and `"]"` represents the ending delimiter. Lightdb automatically recognizes "paired" delimiters, such as `[], {}, (), and <>`. If you want to use some other character as your start delimiter and it doesn't have a "natural" partner for termination, you must use the same character for start and end delimiters. Finally, if you choose a character for a delimiter and it appears in your string immediately before a single quotation mark, Lightdb will be unhappy and raise an error.

### 4.1.2.6. Bit-String Constants

Bit-string constants look like regular string constants with a `B` (upper or lower case) immediately before the opening quote (no intervening whitespace), e.g., `B '1001'`. The only characters allowed within bit-string constants are 0 and 1.

Alternatively, bit-string constants can be specified in hexadecimal notation, using a leading `X` (upper or lower case), e.g., `X '1FF'`. This notation is equivalent to a bit-string constant with four binary digits for each hexadecimal digit.

Both forms of bit-string constant can be continued across lines in the same way as regular string constants. Dollar quoting cannot be used in a bit-string constant.

### 4.1.2.7. Numeric Constants

Numeric constants are accepted in these general forms:

```
digits
digits.[digits][e[+-]digits]
[digits].digits[e[+-]digits]
digite[+-]digits
```

where *digits* is one or more decimal digits (0 through 9). At least one digit must be before or after the decimal point, if one is used. At least one digit must follow the exponent marker (*e*), if one is present. There cannot be any spaces or other characters embedded in the constant. Note that any leading plus or minus sign is not actually considered part of the constant; it is an operator applied to the constant.

These are some examples of valid numeric constants:

```
42
3.5
4.
.001
5e2
1.925e-3
```

A numeric constant that contains neither a decimal point nor an exponent is initially presumed to be type `integer` if its value fits in type `integer` (32 bits); otherwise it is presumed to be type `bigint` if its value fits in type `bigint` (64 bits); otherwise it is taken to be type `numeric`. Constants that contain decimal points and/or exponents are always initially presumed to be type `numeric`.

The initially assigned data type of a numeric constant is just a starting point for the type resolution algorithms. In most cases the constant will be automatically coerced to the most appropriate type depending on context. When necessary, you can force a numeric value to be interpreted as a specific data type by casting it. For example, you can force a numeric value to be treated as type `real` (`float4`) by writing:

```
REAL '1.23' -- string style
1.23::REAL -- LightDB (historical) style
```

These are actually just special cases of the general casting notations discussed next.

### 4.1.2.8. Constants of Other Types

A constant of an *arbitrary* type can be entered using any one of the following notations:

```
type 'string'  
'string'::type  
CAST ( 'string' AS type )
```

The string constant's text is passed to the input conversion routine for the type called *type*. The result is a constant of the indicated type. The explicit type cast can be omitted if there is no ambiguity as to the type the constant must be (for example, when it is assigned directly to a table column), in which case it is automatically coerced.

The string constant can be written using either regular SQL notation or dollar-quoting.

It is also possible to specify a type coercion using a function-like syntax:

```
typename ( 'string' )
```

but not all type names can be used in this way; see Section 4.2.9 for details.

The `::`, `CAST()`, and function-call syntaxes can also be used to specify run-time type conversions of arbitrary expressions, as discussed in Section 4.2.9. To avoid syntactic ambiguity, the *type* `'string'` syntax can only be used to specify the type of a simple literal constant. Another restriction on the *type* `'string'` syntax is that it does not work for array types; use `::` or `CAST()` to specify the type of an array constant.

The `CAST()` syntax conforms to SQL. The *type* `'string'` syntax is a generalization of the standard: SQL specifies this syntax only for a few data types, but LightDB allows it for all types. The syntax with `::` is historical LightDB usage, as is the function-call syntax.

### 4.1.3. Operators

An operator name is a sequence of up to NAMEDATALEN-1 (63 by default) characters from the following list:

```
+ - * / < > = ~ ! @ # % ^ & | ` ?
```

There are a few restrictions on operator names, however:

- `--` and `/*` cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multiple-character operator name cannot end in `+` or `-`, unless the name also contains at least one of these characters:

```
~ ! @ # % ^ & | ` ?
```

For example, `@-` is an allowed operator name, but `*-` is not. This restriction allows LightDB to parse SQL-compliant queries without requiring spaces between tokens.

When working with non-SQL-standard operator names, you will usually need to separate adjacent operators with spaces to avoid ambiguity. For example, if you have defined a left unary operator named `@`, you cannot write `X*@Y`; you must write `X* @Y` to ensure that LightDB reads it as two operator names not one.

### 4.1.4. Special Characters

Some characters that are not alphanumeric have a special meaning that is different from being an operator. Details on the usage can be found at the location where the respective syntax element

is described. This section only exists to advise the existence and summarize the purposes of these characters.

- A dollar sign (\$) followed by digits is used to represent a positional parameter in the body of a function definition or a prepared statement. In other contexts the dollar sign can be part of an identifier or a dollar-quoted string constant.
- Parentheses ( ( ) ) have their usual meaning to group expressions and enforce precedence. In some cases parentheses are required as part of the fixed syntax of a particular SQL command.
- Brackets ( [ ] ) are used to select the elements of an array. See Section 8.15 for more information on arrays.
- Commas ( , ) are used in some syntactical constructs to separate the elements of a list.
- The semicolon ( ; ) terminates an SQL command. It cannot appear anywhere within a command, except within a string constant or quoted identifier.
- The colon ( : ) is used to select “slices” from arrays. (See Section 8.15.) In certain SQL dialects (such as Embedded SQL), the colon is used to prefix variable names.
- The asterisk ( \* ) is used in some contexts to denote all the fields of a table row or composite value. It also has a special meaning when used as the argument of an aggregate function, namely that the aggregate does not require any explicit parameter.
- The period ( . ) is used in numeric constants, and to separate schema, table, and column names.

## 4.1.5. Comments

A comment is a sequence of characters beginning with double dashes and extending to the end of the line, e.g.:

```
-- This is a standard SQL comment
```

Alternatively, C-style block comments can be used:

```
/* multiline comment
 * with nesting: /* nested block comment */
 */
```

where the comment begins with /\* and extends to the matching occurrence of \*/. These block comments nest, as specified in the SQL standard but unlike C, so that one can comment out larger blocks of code that might contain existing block comments.

A comment is removed from the input stream before further syntax analysis and is effectively replaced by whitespace.

## 4.1.6. Operator Precedence

Table 4.2 shows the precedence and associativity of the operators in LightDB. Most operators have the same precedence and are left-associative. The precedence and associativity of the operators is hard-wired into the parser. Add parentheses if you want an expression with multiple operators to be parsed in some other way than what the precedence rules imply.

**Table 4.2. Operator Precedence (highest to lowest)**

Operator/Element	Associativity	Description
.	left	table/column name separator



Operator/Element	Associativity	Description
::	left	LightDB-style typecast
[ ]	left	array element selection
+ -	right	unary plus, unary minus
^	left	exponentiation
* / %	left	multiplication, division, modulo
+ -	left	addition, subtraction
(any other operator)	left	all other native and user-defined operators
BETWEEN IN LIKE ILIKE SIMILAR		range containment, set membership, string matching
< > = <= >= <>		comparison operators
IS ISNULL NOTNULL		IS TRUE, IS FALSE, IS NULL, IS DISTINCT FROM, etc
NOT	right	logical negation
AND	left	logical conjunction
OR	left	logical disjunction

Note that the operator precedence rules also apply to user-defined operators that have the same names as the built-in operators mentioned above. For example, if you define a “+” operator for some custom data type it will have the same precedence as the built-in “+” operator, no matter what yours does.

When a schema-qualified operator name is used in the OPERATOR syntax, as for example in:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

the OPERATOR construct is taken to have the default precedence shown in Table 4.2 for “any other operator”. This is true no matter which specific operator appears inside OPERATOR ( ).

### Note

LightDB versions before 9.5 used slightly different operator precedence rules. In particular, <= >= and <> used to be treated as generic operators; IS tests used to have higher priority; and NOT BETWEEN and related constructs acted inconsistently, being taken in some cases as having the precedence of NOT rather than BETWEEN. These rules were changed for better compliance with the SQL standard and to reduce confusion from inconsistent treatment of logically equivalent constructs. In most cases, these changes will result in no behavioral change, or perhaps in “no such operator” failures which can be resolved by adding parentheses. However there are corner cases in which a query might change behavior without any parsing error being reported. If you are concerned about whether these changes have silently broken something, you can test your application with the configuration parameter operator\_precedence\_warning turned on to see if any warnings are logged.

## 4.2. Value Expressions

Value expressions are used in a variety of contexts, such as in the target list of the SELECT command, as new column values in INSERT or UPDATE, or in search conditions in a number of commands. The result of a value expression is sometimes called a *scalar*, to distinguish it from the result of a table expression (which is a table). Value expressions are therefore also called *scalar expressions* (or even

simply *expressions*). The expression syntax allows the calculation of values from primitive parts using arithmetic, logical, set, and other operations.

A value expression is one of the following:

- A constant or literal value
- A column reference
- A positional parameter reference, in the body of a function definition or prepared statement
- A subscripted expression
- A field selection expression
- An operator invocation
- A function call
- An aggregate expression
- A window function call
- A type cast
- A collation expression
- A scalar subquery
- An array constructor
- A row constructor
- Another value expression in parentheses (used to group subexpressions and override precedence)

In addition to this list, there are a number of constructs that can be classified as an expression but do not follow any general syntax rules. These generally have the semantics of a function or operator and are explained in the appropriate location in Chapter 9. An example is the `IS NULL` clause.

We have already discussed constants in Section 4.1.2. The following sections discuss the remaining options.

## 4.2.1. Column References

A column can be referenced in the form:

*correlation.columnname*

*correlation* is the name of a table (possibly qualified with a schema name), or an alias for a table defined by means of a `FROM` clause. The correlation name and separating dot can be omitted if the column name is unique across all the tables being used in the current query. (See also Chapter 7.)

## 4.2.2. Positional Parameters

A positional parameter reference is used to indicate a value that is supplied externally to an SQL statement. Parameters are used in SQL function definitions and in prepared queries. Some client libraries also support specifying data values separately from the SQL command string, in which case parameters are used to refer to the out-of-line data values. The form of a parameter reference is:

*\$number*

For example, consider the definition of a function, `dept`, as:

```
CREATE FUNCTION dept(text) RETURNS dept
  AS $$ SELECT * FROM dept WHERE name = $1 $$
LANGUAGE SQL;
```

Here the `$1` references the value of the first function argument whenever the function is invoked.

### 4.2.3. Subscripts

If an expression yields a value of an array type, then a specific element of the array value can be extracted by writing

```
expression[subscript]
```

or multiple adjacent elements (an “array slice”) can be extracted by writing

```
expression[lower_subscript:upper_subscript]
```

(Here, the brackets [ ] are meant to appear literally.) Each *subscript* is itself an expression, which will be rounded to the nearest integer value.

In general the array *expression* must be parenthesized, but the parentheses can be omitted when the expression to be subscripted is just a column reference or positional parameter. Also, multiple subscripts can be concatenated when the original array is multidimensional. For example:

```
mytable.arraycolumn[4]
mytable.two_d_column[17][34]
$1[10:42]
(arrayfunction(a,b))[42]
```

The parentheses in the last example are required. See Section 8.15 for more about arrays.

### 4.2.4. Field Selection

If an expression yields a value of a composite type (row type), then a specific field of the row can be extracted by writing

```
expression.fieldname
```

In general the row *expression* must be parenthesized, but the parentheses can be omitted when the expression to be selected from is just a table reference or positional parameter. For example:

```
mytable.mycolumn
$1.somecolumn
(rowfunction(a,b)).col3
```

(Thus, a qualified column reference is actually just a special case of the field selection syntax.) An important special case is extracting a field from a table column that is of a composite type:

```
(compositecol).somefield
```

```
(mytable.compositecol).somefield
```

The parentheses are required here to show that `compositecol` is a column name not a table name, or that `mytable` is a table name not a schema name in the second case.

You can ask for all fields of a composite value by writing `.*`:

```
(compositecol).*
```

This notation behaves differently depending on context; see Section 8.16.5 for details.

## 4.2.5. Operator Invocations

There are three possible syntaxes for an operator invocation:

```
expression operator expression (binary infix operator)  
operator expression (unary prefix operator)  
expression operator (unary postfix operator)
```

where the *operator* token follows the syntax rules of Section 4.1.3, or is one of the key words `AND`, `OR`, and `NOT`, or is a qualified operator name in the form:

```
OPERATOR(schema.operatorname)
```

Which particular operators exist and whether they are unary or binary depends on what operators have been defined by the system or the user. Chapter 9 describes the built-in operators.

## 4.2.6. Function Calls

The syntax for a function call is the name of a function (possibly qualified with a schema name), followed by its argument list enclosed in parentheses:

```
function_name ([expression [, expression ... ]])
```

For example, the following computes the square root of 2:

```
sqrt(2)
```

The list of built-in functions is in Chapter 9. Other functions can be added by the user.

When issuing queries in a database where some users mistrust other users, observe security precautions from Section 10.3 when writing function calls.

The arguments can optionally have names attached. See Section 4.3 for details.

### Note

A function that takes a single argument of composite type can optionally be called using field-selection syntax, and conversely field selection can be written in functional style. That is, the notations `col(table)` and `table.col` are interchangeable. This behavior is not SQL-standard but is provided in LightDB because it allows use of functions to emulate “computed fields”. For more information see Section 8.16.5.

## 4.2.7. Aggregate Expressions

An *aggregate expression* represents the application of an aggregate function across the rows selected by a query. An aggregate function reduces multiple inputs to a single output value, such as the sum or average of the inputs. The syntax of an aggregate expression is one of the following:

```
aggregate_name (expression [ , ... ] [ order_by_clause ] ) [ FILTER
  ( WHERE filter_clause ) ]
aggregate_name (ALL expression [ , ... ] [ order_by_clause ] )
  [ FILTER ( WHERE filter_clause ) ]
aggregate_name (DISTINCT expression [ , ... ] [ order_by_clause ] )
  [ FILTER ( WHERE filter_clause ) ]
aggregate_name ( * ) [ FILTER ( WHERE filter_clause ) ]
aggregate_name ( [ expression [ , ... ] ] ) WITHIN GROUP
  ( order_by_clause ) [ FILTER ( WHERE filter_clause ) ]
```

where *aggregate\_name* is a previously defined aggregate (possibly qualified with a schema name) and *expression* is any value expression that does not itself contain an aggregate expression or a window function call. The optional *order\_by\_clause* and *filter\_clause* are described below.

The first form of aggregate expression invokes the aggregate once for each input row. The second form is the same as the first, since ALL is the default. The third form invokes the aggregate once for each distinct value of the expression (or distinct set of values, for multiple expressions) found in the input rows. The fourth form invokes the aggregate once for each input row; since no particular input value is specified, it is generally only useful for the `count ( * )` aggregate function. The last form is used with *ordered-set* aggregate functions, which are described below.

Most aggregate functions ignore null inputs, so that rows in which one or more of the expression(s) yield null are discarded. This can be assumed to be true, unless otherwise specified, for all built-in aggregates.

For example, `count ( * )` yields the total number of input rows; `count ( f1 )` yields the number of input rows in which `f1` is non-null, since `count` ignores nulls; and `count ( distinct f1 )` yields the number of distinct non-null values of `f1`.

Ordinarily, the input rows are fed to the aggregate function in an unspecified order. In many cases this does not matter; for example, `min` produces the same result no matter what order it receives the inputs in. However, some aggregate functions (such as `array_agg` and `string_agg`) produce results that depend on the ordering of the input rows. When using such an aggregate, the optional *order\_by\_clause* can be used to specify the desired ordering. The *order\_by\_clause* has the same syntax as for a query-level ORDER BY clause, as described in Section 7.5, except that its expressions are always just expressions and cannot be output-column names or numbers. For example:

```
SELECT array_agg(a ORDER BY b DESC) FROM table;
```

When dealing with multiple-argument aggregate functions, note that the ORDER BY clause goes after all the aggregate arguments. For example, write this:

```
SELECT string_agg(a, ',' ORDER BY a) FROM table;
```

not this:

```
SELECT string_agg(a ORDER BY a, ',') FROM table; -- incorrect
```

The latter is syntactically valid, but it represents a call of a single-argument aggregate function with two ORDER BY keys (the second one being rather useless since it's a constant).

If `DISTINCT` is specified in addition to an *order\_by\_clause*, then all the `ORDER BY` expressions must match regular arguments of the aggregate; that is, you cannot sort on an expression that is not included in the `DISTINCT` list.

### Note

The ability to specify both `DISTINCT` and `ORDER BY` in an aggregate function is a LightDB extension.

Placing `ORDER BY` within the aggregate's regular argument list, as described so far, is used when ordering the input rows for general-purpose and statistical aggregates, for which ordering is optional. There is a subclass of aggregate functions called *ordered-set aggregates* for which an *order\_by\_clause* is *required*, usually because the aggregate's computation is only sensible in terms of a specific ordering of its input rows. Typical examples of ordered-set aggregates include rank and percentile calculations. For an ordered-set aggregate, the *order\_by\_clause* is written inside `WITHIN GROUP (...)`, as shown in the final syntax alternative above. The expressions in the *order\_by\_clause* are evaluated once per input row just like regular aggregate arguments, sorted as per the *order\_by\_clause*'s requirements, and fed to the aggregate function as input arguments. (This is unlike the case for a non-`WITHIN GROUP` *order\_by\_clause*, which is not treated as argument(s) to the aggregate function.) The argument expressions preceding `WITHIN GROUP`, if any, are called *direct arguments* to distinguish them from the *aggregated arguments* listed in the *order\_by\_clause*. Unlike regular aggregate arguments, direct arguments are evaluated only once per aggregate call, not once per input row. This means that they can contain variables only if those variables are grouped by `GROUP BY`; this restriction is the same as if the direct arguments were not inside an aggregate expression at all. Direct arguments are typically used for things like percentile fractions, which only make sense as a single value per aggregation calculation. The direct argument list can be empty; in this case, write just `()` not `(*)`. (LightDB will actually accept either spelling, but only the first way conforms to the SQL standard.)

An example of an ordered-set aggregate call is:

```
SELECT percentile_cont(0.5) WITHIN GROUP (ORDER BY income) FROM
households;
percentile_cont
-----
                50489
```

which obtains the 50th percentile, or median, value of the `income` column from table `households`. Here, `0.5` is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

If `FILTER` is specified, then only the input rows for which the *filter\_clause* evaluates to true are fed to the aggregate function; other rows are discarded. For example:

```
SELECT
  count(*) AS unfiltered,
  count(*) FILTER (WHERE i < 5) AS filtered
FROM generate_series(1,10) AS s(i);
unfiltered | filtered
-----+-----
                10 |          4
(1 row)
```

The predefined aggregate functions are described in Section 9.21. Other aggregate functions can be added by the user.

An aggregate expression can only appear in the result list or `HAVING` clause of a `SELECT` command. It is forbidden in other clauses, such as `WHERE`, because those clauses are logically evaluated before the results of aggregates are formed.

When an aggregate expression appears in a subquery (see Section 4.2.11 and Section 9.23), the aggregate is normally evaluated over the rows of the subquery. But an exception occurs if the aggregate's arguments (and *filter\_clause* if any) contain only outer-level variables: the aggregate then belongs to the nearest such outer level, and is evaluated over the rows of that query. The aggregate expression as a whole is then an outer reference for the subquery it appears in, and acts as a constant over any one evaluation of that subquery. The restriction about appearing only in the result list or `HAVING` clause applies with respect to the query level that the aggregate belongs to.

## 4.2.8. Window Function Calls

A *window function call* represents the application of an aggregate-like function over some portion of the rows selected by a query. Unlike non-window aggregate calls, this is not tied to grouping of the selected rows into a single output row — each row remains separate in the query output. However the window function has access to all the rows that would be part of the current row's group according to the grouping specification (`PARTITION BY` list) of the window function call. The syntax of a window function call is one of the following:

```
function_name ([expression [, expression ... ]]) [ FILTER
  ( WHERE filter_clause ) ] OVER window_name
function_name ([expression [, expression ... ]]) [ FILTER
  ( WHERE filter_clause ) ] OVER ( window_definition )
function_name ( * ) [ FILTER ( WHERE filter_clause ) ]
  OVER window_name
function_name ( * ) [ FILTER ( WHERE filter_clause ) ] OVER
  ( window_definition )
```

where *window\_definition* has the syntax

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
  { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

The optional *frame\_clause* can be one of

```
{ RANGE | ROWS | GROUPS } frame_start [ frame_exclusion ]
{ RANGE | ROWS | GROUPS } BETWEEN frame_start AND frame_end
[ frame_exclusion ]
```

where *frame\_start* and *frame\_end* can be one of

```
UNBOUNDED PRECEDING
offset PRECEDING
CURRENT ROW
offset FOLLOWING
UNBOUNDED FOLLOWING
```

and *frame\_exclusion* can be one of

```
EXCLUDE CURRENT ROW
EXCLUDE GROUP
EXCLUDE TIES
EXCLUDE NO OTHERS
```

Here, *expression* represents any value expression that does not itself contain window function calls.

*window\_name* is a reference to a named window specification defined in the query's WINDOW clause. Alternatively, a full *window\_definition* can be given within parentheses, using the same syntax as for defining a named window in the WINDOW clause; see the SELECT reference page for details. It's worth pointing out that `OVER wname` is not exactly equivalent to `OVER (wname ...)`; the latter implies copying and modifying the window definition, and will be rejected if the referenced window specification includes a frame clause.

The `PARTITION BY` clause groups the rows of the query into *partitions*, which are processed separately by the window function. `PARTITION BY` works similarly to a query-level `GROUP BY` clause, except that its expressions are always just expressions and cannot be output-column names or numbers. Without `PARTITION BY`, all rows produced by the query are treated as a single partition. The `ORDER BY` clause determines the order in which the rows of a partition are processed by the window function. It works similarly to a query-level `ORDER BY` clause, but likewise cannot use output-column names or numbers. Without `ORDER BY`, rows are processed in an unspecified order.

The *frame\_clause* specifies the set of rows constituting the *window frame*, which is a subset of the current partition, for those window functions that act on the frame instead of the whole partition. The set of rows in the frame can vary depending on which row is the current row. The frame can be specified in RANGE, ROWS or GROUPS mode; in each case, it runs from the *frame\_start* to the *frame\_end*. If *frame\_end* is omitted, the end defaults to `CURRENT ROW`.

A *frame\_start* of `UNBOUNDED PRECEDING` means that the frame starts with the first row of the partition, and similarly a *frame\_end* of `UNBOUNDED FOLLOWING` means that the frame ends with the last row of the partition.

In RANGE or GROUPS mode, a *frame\_start* of `CURRENT ROW` means the frame starts with the current row's first *peer* row (a row that the window's `ORDER BY` clause sorts as equivalent to the current row), while a *frame\_end* of `CURRENT ROW` means the frame ends with the current row's last peer row. In ROWS mode, `CURRENT ROW` simply means the current row.

In the *offset* `PRECEDING` and *offset* `FOLLOWING` frame options, the *offset* must be an expression not containing any variables, aggregate functions, or window functions. The meaning of the *offset* depends on the frame mode:

- In ROWS mode, the *offset* must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of rows before or after the current row.
- In GROUPS mode, the *offset* again must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of *peer groups* before or after the current row's peer group, where a peer group is a set of rows that are equivalent in the `ORDER BY` ordering. (There must be an `ORDER BY` clause in the window definition to use GROUPS mode.)
- In RANGE mode, these options require that the `ORDER BY` clause specify exactly one column. The *offset* specifies the maximum difference between the value of that column in the current row and its value in preceding or following rows of the frame. The data type of the *offset* expression varies depending on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an *interval*. For example, if the ordering column is of type `date` or `timestamp`, one could write `RANGE BETWEEN '1 day' PRECEDING AND '10 days' FOLLOWING`. The *offset* is still required to be non-null and non-negative, though the meaning of “non-negative” depends on its data type.



In any case, the distance to the end of the frame is limited by the distance to the end of the partition, so that for rows near the partition ends the frame might contain fewer rows than elsewhere.

Notice that in both ROWS and GROUPS mode, 0 PRECEDING and 0 FOLLOWING are equivalent to CURRENT ROW. This normally holds in RANGE mode as well, for an appropriate data-type-specific meaning of “zero”.

The *frame\_exclusion* option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. EXCLUDE CURRENT ROW excludes the current row from the frame. EXCLUDE GROUP excludes the current row and its ordering peers from the frame. EXCLUDE TIES excludes any peers of the current row from the frame, but not the current row itself. EXCLUDE NO OTHERS simply specifies explicitly the default behavior of not excluding the current row or its peers.

The default framing option is RANGE UNBOUNDED PRECEDING, which is the same as RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW. With ORDER BY, this sets the frame to be all rows from the partition start up through the current row's last ORDER BY peer. Without ORDER BY, this means all rows of the partition are included in the window frame, since all rows become peers of the current row.

Restrictions are that *frame\_start* cannot be UNBOUNDED FOLLOWING, *frame\_end* cannot be UNBOUNDED PRECEDING, and the *frame\_end* choice cannot appear earlier in the above list of *frame\_start* and *frame\_end* options than the *frame\_start* choice does — for example RANGE BETWEEN CURRENT ROW AND *offset* PRECEDING is not allowed. But, for example, ROWS BETWEEN 7 PRECEDING AND 8 PRECEDING is allowed, even though it would never select any rows.

If FILTER is specified, then only the input rows for which the *filter\_clause* evaluates to true are fed to the window function; other rows are discarded. Only window functions that are aggregates accept a FILTER clause.

The built-in window functions are described in Table 9.61. Other window functions can be added by the user. Also, any built-in or user-defined general-purpose or statistical aggregate can be used as a window function. (Ordered-set and hypothetical-set aggregates cannot presently be used as window functions.)

The syntaxes using \* are used for calling parameter-less aggregate functions as window functions, for example count(\*) OVER (PARTITION BY x ORDER BY y). The asterisk (\*) is customarily not used for window-specific functions. Window-specific functions do not allow DISTINCT or ORDER BY to be used within the function argument list.

Window function calls are permitted only in the SELECT list and the ORDER BY clause of the query.

More information about window functions can be found in Section 3.5, Section 9.22, and Section 7.2.5.

## 4.2.9. Type Casts

A type cast specifies a conversion from one data type to another. LightDB accepts two equivalent syntaxes for type casts:

```
CAST ( expression AS type )
expression::type
```

The CAST syntax conforms to SQL; the syntax with :: is historical LightDB usage.

To be compatible with MySQL, on mysql mode(See `lightdb_dblevel_syntax_compatible_type`), `cast(expr as char[(n)])` is equivalent to `cast(expr as varchar[(n)])`.

When a cast is applied to a value expression of a known type, it represents a run-time type conversion. The cast will succeed only if a suitable type conversion operation has been defined. Notice that this

is subtly different from the use of casts with constants, as shown in Section 4.1.2.8. A cast applied to an unadorned string literal represents the initial assignment of a type to a literal constant value, and so it will succeed for any type (if the contents of the string literal are acceptable input syntax for the data type).

An explicit type cast can usually be omitted if there is no ambiguity as to the type that a value expression must produce (for example, when it is assigned to a table column); the system will automatically apply a type cast in such cases. However, automatic casting is only done for casts that are marked “OK to apply implicitly” in the system catalogs. Other casts must be invoked with explicit casting syntax. This restriction is intended to prevent surprising conversions from being applied silently.

It is also possible to specify a type cast using a function-like syntax:

```
typename ( expression )
```

However, this only works for types whose names are also valid as function names. For example, `double precision` cannot be used this way, but the equivalent `float8` can. Also, the names `interval`, `time`, and `timestamp` can only be used in this fashion if they are double-quoted, because of syntactic conflicts. Therefore, the use of the function-like cast syntax leads to inconsistencies and should probably be avoided.

### Note

The function-like syntax is in fact just a function call. When one of the two standard cast syntaxes is used to do a run-time conversion, it will internally invoke a registered function to perform the conversion. By convention, these conversion functions have the same name as their output type, and thus the “function-like syntax” is nothing more than a direct invocation of the underlying conversion function. Obviously, this is not something that a portable application should rely on. For further details see `CREATE CAST`.

## 4.2.10. Collation Expressions

The `COLLATE` clause overrides the collation of an expression. It is appended to the expression it applies to:

```
expr COLLATE collation
```

where *collation* is a possibly schema-qualified identifier. The `COLLATE` clause binds tighter than operators; parentheses can be used when necessary.

If no collation is explicitly specified, the database system either derives a collation from the columns involved in the expression, or it defaults to the default collation of the database if no column is involved in the expression.

The two common uses of the `COLLATE` clause are overriding the sort order in an `ORDER BY` clause, for example:

```
SELECT a, b, c FROM tbl WHERE ... ORDER BY a COLLATE "C";
```

and overriding the collation of a function or operator call that has locale-sensitive results, for example:

```
SELECT * FROM tbl WHERE a > 'foo' COLLATE "C";
```

Note that in the latter case the `COLLATE` clause is attached to an input argument of the operator we wish to affect. It doesn't matter which argument of the operator or function call the `COLLATE` clause is attached to, because the collation that is applied by the operator or function is derived by considering all arguments, and an explicit `COLLATE` clause will override the collations of all other arguments. (Attaching non-matching `COLLATE` clauses to more than one argument, however, is an error. For more details see Section 21.2.) Thus, this gives the same result as the previous example:

```
SELECT * FROM tbl WHERE a COLLATE "C" > 'foo';
```

But this is an error:

```
SELECT * FROM tbl WHERE (a > 'foo') COLLATE "C";
```

because it attempts to apply a collation to the result of the `>` operator, which is of the non-collatable data type `boolean`.

## 4.2.11. Scalar Subqueries

A scalar subquery is an ordinary `SELECT` query in parentheses that returns exactly one row with one column. (See Chapter 7 for information about writing queries.) The `SELECT` query is executed and the single returned value is used in the surrounding value expression. It is an error to use a query that returns more than one row or more than one column as a scalar subquery. (But if, during a particular execution, the subquery returns no rows, there is no error; the scalar result is taken to be null.) The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery. See also Section 9.23 for other expressions involving subqueries.

For example, the following finds the largest city population in each state:

```
SELECT name, (SELECT max(pop) FROM cities WHERE cities.state =
             states.name)
           FROM states;
```

## 4.2.12. Array Constructors

An array constructor is an expression that builds an array value using values for its member elements. A simple array constructor consists of the key word `ARRAY`, a left square bracket `[`, a list of expressions (separated by commas) for the array element values, and finally a right square bracket `]`. For example:

```
SELECT ARRAY[1,2,3+4];
       array
-----
      {1,2,7}
(1 row)
```

By default, the array element type is the common type of the member expressions, determined using the same rules as for `UNION` or `CASE` constructs (see Section 10.5). You can override this by explicitly casting the array constructor to the desired type, for example:

```
SELECT ARRAY[1,2,22.7]::integer[];
       array
-----
      {1,2,23}
(1 row)
```

This has the same effect as casting each expression to the array element type individually. For more on casting, see Section 4.2.9.

Multidimensional array values can be built by nesting array constructors. In the inner constructors, the key word ARRAY can be omitted. For example, these produce the same result:

```
SELECT ARRAY[ARRAY[1,2], ARRAY[3,4]];
      array
-----
 {{1,2},{3,4}}
(1 row)
```

```
SELECT ARRAY[[1,2],[3,4]];
      array
-----
 {{1,2},{3,4}}
(1 row)
```

Since multidimensional arrays must be rectangular, inner constructors at the same level must produce sub-arrays of identical dimensions. Any cast applied to the outer ARRAY constructor propagates automatically to all the inner constructors.

Multidimensional array constructor elements can be anything yielding an array of the proper kind, not only a sub-ARRAY construct. For example:

```
CREATE TABLE arr(f1 int[], f2 int[]);

INSERT INTO arr VALUES (ARRAY[[1,2],[3,4]], ARRAY[[5,6],[7,8]]);

SELECT ARRAY[f1, f2, '{{9,10},{11,12}}'::int[]] FROM arr;
      array
-----
 {{{1,2},{3,4}},{5,6},{7,8}},{9,10},{11,12}}
(1 row)
```

You can construct an empty array, but since it's impossible to have an array with no type, you must explicitly cast your empty array to the desired type. For example:

```
SELECT ARRAY[]::integer[];
      array
-----
 {}
(1 row)
```

It is also possible to construct an array from the results of a subquery. In this form, the array constructor is written with the key word ARRAY followed by a parenthesized (not bracketed) subquery. For example:

```
SELECT ARRAY(SELECT oid FROM pg_proc WHERE proname LIKE 'bytea%');
      array
-----
 {2011,1954,1948,1952,1951,1244,1950,2005,1949,1953,2006,31,2412}
(1 row)

SELECT ARRAY(SELECT ARRAY[i, i*2] FROM generate_series(1,5) AS
a(i));
```

array

```
-----
{{1,2},{2,4},{3,6},{4,8},{5,10}}
(1 row)
```

The subquery must return a single column. If the subquery's output column is of a non-array type, the resulting one-dimensional array will have an element for each row in the subquery result, with an element type matching that of the subquery's output column. If the subquery's output column is of an array type, the result will be an array of the same type but one higher dimension; in this case all the subquery rows must yield arrays of identical dimensionality, else the result would not be rectangular.

The subscripts of an array value built with ARRAY always begin with one. For more information about arrays, see Section 8.15.

## 4.2.13. Row Constructors

A row constructor is an expression that builds a row value (also called a composite value) using values for its member fields. A row constructor consists of the key word ROW, a left parenthesis, zero or more expressions (separated by commas) for the row field values, and finally a right parenthesis. For example:

```
SELECT ROW(1,2.5,'this is a test');
```

The key word ROW is optional when there is more than one expression in the list.

A row constructor can include the syntax *rowvalue.\**, which will be expanded to a list of the elements of the row value, just as occurs when the *.\** syntax is used at the top level of a SELECT list (see Section 8.16.5). For example, if table *t* has columns *f1* and *f2*, these are the same:

```
SELECT ROW(t.*, 42) FROM t;
SELECT ROW(t.f1, t.f2, 42) FROM t;
```

### Note

Before LightDB 8.2, the *.\** syntax was not expanded in row constructors, so that writing `ROW(t.*, 42)` created a two-field row whose first field was another row value. The new behavior is usually more useful. If you need the old behavior of nested row values, write the inner row value without *.\**, for instance `ROW(t, 42)`.

By default, the value created by a ROW expression is of an anonymous record type. If necessary, it can be cast to a named composite type — either the row type of a table, or a composite type created with CREATE TYPE AS. An explicit cast might be needed to avoid ambiguity. For example:

```
CREATE TABLE mytable(f1 int, f2 float, f3 text);

CREATE FUNCTION getf1(mytable) RETURNS int AS 'SELECT $1.f1'
LANGUAGE SQL;

-- No cast needed since only one getf1() exists
SELECT getf1(ROW(1,2.5,'this is a test'));
getf1
-----
      1
(1 row)
```

```

CREATE TYPE myrowtype AS (f1 int, f2 text, f3 numeric);

CREATE FUNCTION getf1(myrowtype) RETURNS int AS 'SELECT $1.f1'
LANGUAGE SQL;

-- Now we need a cast to indicate which function to call:
SELECT getf1(ROW(1,2.5,'this is a test'));
ERROR:  function getf1(record) is not unique

SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
 getf1
-----
      1
(1 row)

SELECT getf1(CAST(ROW(11,'this is a test',2.5) AS myrowtype));
 getf1
-----
     11
(1 row)

```

Row constructors can be used to build composite values to be stored in a composite-type table column, or to be passed to a function that accepts a composite parameter. Also, it is possible to compare two row values or test a row with `IS NULL` or `IS NOT NULL`, for example:

```

SELECT ROW(1,2.5,'this is a test') = ROW(1, 3, 'not the same');

SELECT ROW(table.*) IS NULL FROM table;  -- detect all-null rows

```

For more detail see Section 9.24. Row constructors can also be used in connection with subqueries, as discussed in Section 9.23.

## 4.2.14. User Variable

On `mysql` mode (See `lightdb_dblevel_syntax_compatible_type`), you can store a value in a user-defined variable in one statement and refer to it later in another statement. This enables you to pass values from one statement to another.

User variables are written as `@var_name`, where the variable name `var_name` must be an Identifiers or an Key Words. If you quote it identifier#`var_name` will be treated as a column name (for example, `@"my-var"`). `@var_name` and `@ var_name` are different. `@var_name` is a user variable expression, `@ var_name` is the absolute value of the column `var_name`.

```

lightdb@test=# select @c1 := 5;
@c1
-----
      5
(1 row)

lightdb@test=# SELECT c1, @c1, @ c1 FROM t;
 c1 | @c1 | ?column?
-----+-----+-----
  0 |   5 |         0
  1 |   5 |         1
(2 rows)

```

```

lightdb@testmysql01=# SET @col = 'c1';
@col
-----
c1
(1 row)

lightdb@testmysql01=# SELECT @col from dual;
@col
-----
c1
(1 row)

lightdb@testmysql01=# select 'c2' into @col;
@col
-----
c2
(1 row)

lightdb@testmysql01=# SELECT @col from dual;
@col
-----
c2
(1 row)

```

User-defined variables are session specific. A user variable defined by one client cannot be seen or used by other clients.

User variable names are not case-sensitive. Names have a maximum length of 64 characters.

User variables can be assigned a value from a limited set of data types: integer, decimal, floating-point, text, or NULL value. Assignment of decimal and real values does not preserve the precision or scale of the value. A value of a type other than one of the permissible types is converted to a permissible type. For example, A value having the JSON data type is converted to a string.

If the value of a user variable is selected in a result set, it is returned to the client as a string.

If you refer to a variable that has not been initialized, it has a value of NULL and a type of string.

When making an assignment in this way, the assignment operator must be := and not = because the latter is treated as the comparison operator = in statements:

```

lightdb@test=# select @t1:=1, @t2:=2, @t3:=4;
@t1 | @t2 | @t3
-----+-----+-----
  1 |   2 |   4
(1 row)

lightdb@test=# SELECT @t1, @t2, @t3, @t4 := @t1 + @t2 + @t3;
@t1 | @t2 | @t3 | @t4
-----+-----+-----+-----
  1 |   2 |   4 |   7
(1 row)

```

For all statements, you might get the results you expect, but this is not guaranteed. In the following statement, you might think that LightDB evaluates @a first and then does an assignment second:

```
SELECT @a, @a:=@a+1, ...;
```

However, the order of evaluation for expressions involving user variables is undefined.

Another issue with assigning a value to a variable and reading the value within the same statement is that the default result type of a variable is based on its type at the start of the statement. The following example illustrates this:

```
lightdb@test=# select @a:='test';
lightdb@test=# SELECT @a, (@a:=20) FROM tbl_name;
```

For this SELECT statement, LightDB reports to the client that column one is a string and converts all accesses of @a to strings, even though @a is set to a number for the second row. After the SELECT statement executes, @a is regarded as a number for the next statement.

To avoid problems with this behavior, either do not assign a value to and read the value of the same variable within a single statement to define its type before you use it.

## 4.2.15. Expression Evaluation Rules

The order of evaluation of subexpressions is not defined. In particular, the inputs of an operator or function are not necessarily evaluated left-to-right or in any other fixed order.

Furthermore, if the result of an expression can be determined by evaluating only some parts of it, then other subexpressions might not be evaluated at all. For instance, if one wrote:

```
SELECT true OR somefunc();
```

then `somefunc()` would (probably) not be called at all. The same would be the case if one wrote:

```
SELECT somefunc() OR true;
```

Note that this is not the same as the left-to-right “short-circuiting” of Boolean operators that is found in some programming languages.

As a consequence, it is unwise to use functions with side effects as part of complex expressions. It is particularly dangerous to rely on side effects or evaluation order in WHERE and HAVING clauses, since those clauses are extensively reprocessed as part of developing an execution plan. Boolean expressions (AND/OR/NOT combinations) in those clauses can be reorganized in any manner allowed by the laws of Boolean algebra.

When it is essential to force evaluation order, a CASE construct (see Section 9.18) can be used. For example, this is an untrustworthy way of trying to avoid division by zero in a WHERE clause:

```
SELECT ... WHERE x > 0 AND y/x > 1.5;
```

But this is safe:

```
SELECT ... WHERE CASE WHEN x > 0 THEN y/x > 1.5 ELSE false END;
```

A CASE construct used in this fashion will defeat optimization attempts, so it should only be done when necessary. (In this particular example, it would be better to sidestep the problem by writing `y > 1.5*x` instead.)

CASE is not a cure-all for such issues, however. One limitation of the technique illustrated above is that it does not prevent early evaluation of constant subexpressions. As described in Section 36.7,



functions and operators marked `IMMUTABLE` can be evaluated when the query is planned rather than when it is executed. Thus for example

```
SELECT CASE WHEN x > 0 THEN x ELSE 1/0 END FROM tab;
```

is likely to result in a division-by-zero failure due to the planner trying to simplify the constant subexpression, even if every row in the table has `x > 0` so that the `ELSE` arm would never be entered at run time.

While that particular example might seem silly, related cases that don't obviously involve constants can occur in queries executed within functions, since the values of function arguments and local variables can be inserted into queries as constants for planning purposes. Within PL/pgSQL functions, for example, using an `IF-THEN-ELSE` statement to protect a risky computation is much safer than just nesting it in a `CASE` expression.

Another limitation of the same kind is that a `CASE` cannot prevent evaluation of an aggregate expression contained within it, because aggregate expressions are computed before other expressions in a `SELECT` list or `HAVING` clause are considered. For example, the following query can cause a division-by-zero error despite seemingly having protected against it:

```
SELECT CASE WHEN min(employees) > 0
           THEN avg(expenses / employees)
           END
FROM departments;
```

The `min()` and `avg()` aggregates are computed concurrently over all the input rows, so if any row has `employees` equal to zero, the division-by-zero error will occur before there is any opportunity to test the result of `min()`. Instead, use a `WHERE` or `FILTER` clause to prevent problematic input rows from reaching an aggregate function in the first place.

## 4.3. Calling Functions

LightDB allows functions that have named parameters to be called using either *positional* or *named* notation. Named notation is especially useful for functions that have a large number of parameters, since it makes the associations between parameters and actual arguments more explicit and reliable. In positional notation, a function call is written with its argument values in the same order as they are defined in the function declaration. In named notation, the arguments are matched to the function parameters by name and can be written in any order. For each notation, also consider the effect of function argument types, documented in Section 10.3.

In either notation, parameters that have default values given in the function declaration need not be written in the call at all. But this is particularly useful in named notation, since any combination of parameters can be omitted; while in positional notation parameters can only be omitted from right to left.

LightDB also supports *mixed* notation, which combines positional and named notation. In this case, positional parameters are written first and named parameters appear after them.

The following examples will illustrate the usage of all three notations, using the following function definition:

```
CREATE FUNCTION concat_lower_or_upper(a text, b text, uppercase
  boolean DEFAULT false)
RETURNS text
AS
$$
```

```
SELECT CASE
    WHEN $3 THEN UPPER($1 || ' ' || $2)
    ELSE LOWER($1 || ' ' || $2)
END;
$$
LANGUAGE SQL IMMUTABLE STRICT;
```

Function `concat_lower_or_upper` has two mandatory parameters, `a` and `b`. Additionally there is one optional parameter `uppercase` which defaults to `false`. The `a` and `b` inputs will be concatenated, and forced to either upper or lower case depending on the `uppercase` parameter. The remaining details of this function definition are not important here (see Chapter 36 for more information).

### 4.3.1. Using Positional Notation

Positional notation is the traditional mechanism for passing arguments to functions in LightDB. An example is:

```
SELECT concat_lower_or_upper('Hello', 'World', true);
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

All arguments are specified in order. The result is upper case since `uppercase` is specified as `true`. Another example is:

```
SELECT concat_lower_or_upper('Hello', 'World');
concat_lower_or_upper
-----
hello world
(1 row)
```

Here, the `uppercase` parameter is omitted, so it receives its default value of `false`, resulting in lower case output. In positional notation, arguments can be omitted from right to left so long as they have defaults.

### 4.3.2. Using Named Notation

In named notation, each argument's name is specified using `=>` to separate it from the argument expression. For example:

```
SELECT concat_lower_or_upper(a => 'Hello', b => 'World');
concat_lower_or_upper
-----
hello world
(1 row)
```

Again, the argument `uppercase` was omitted so it is set to `false` implicitly. One advantage of using named notation is that the arguments may be specified in any order, for example:

```
SELECT concat_lower_or_upper(a => 'Hello', b => 'World', uppercase
=> true);
concat_lower_or_upper
-----
```

```
HELLO WORLD
(1 row)
```

```
SELECT concat_lower_or_upper(a => 'Hello', uppercase => true, b =>
'World');
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

An older syntax based on "!=" is supported for backward compatibility:

```
SELECT concat_lower_or_upper(a != 'Hello', uppercase != true, b !=
'World');
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

### 4.3.3. Using Mixed Notation

The mixed notation combines positional and named notation. However, as already mentioned, named arguments cannot precede positional arguments. For example:

```
SELECT concat_lower_or_upper('Hello', 'World', uppercase => true);
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

In the above query, the arguments `a` and `b` are specified positionally, while `uppercase` is specified by name. In this example, that adds little except documentation. With a more complex function having numerous parameters that have default values, named or mixed notation can save a great deal of writing and reduce chances for error.

#### Note

Named and mixed call notations currently cannot be used when calling an aggregate function (but they do work when an aggregate function is used as a window function).

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# Chapter 5. Data Definition

This chapter covers how one creates the database structures that will hold one's data. In a relational database, the raw data is stored in tables, so the majority of this chapter is devoted to explaining how tables are created and modified and what features are available to control what data is stored in the tables. Subsequently, we discuss how tables can be organized into schemas, and how privileges can be assigned to tables. Finally, we will briefly look at other features that affect the data storage, such as inheritance, table partitioning, views, functions, and triggers.

## 5.1. Table Basics

A table in a relational database is much like a table on paper: It consists of rows and columns. The number and order of the columns is fixed, and each column has a name. The number of rows is variable — it reflects how much data is stored at a given moment. SQL does not make any guarantees about the order of the rows in a table. When a table is read, the rows will appear in an unspecified order, unless sorting is explicitly requested. This is covered in Chapter 7. Furthermore, SQL does not assign unique identifiers to rows, so it is possible to have several completely identical rows in a table. This is a consequence of the mathematical model that underlies SQL but is usually not desirable. Later in this chapter we will see how to deal with this issue.

Each column has a data type. The data type constrains the set of possible values that can be assigned to a column and assigns semantics to the data stored in the column so that it can be used for computations. For instance, a column declared to be of a numerical type will not accept arbitrary text strings, and the data stored in such a column can be used for mathematical computations. By contrast, a column declared to be of a character string type will accept almost any kind of data but it does not lend itself to mathematical calculations, although other operations such as string concatenation are available.

LightDB includes a sizable set of built-in data types that fit many applications. Users can also define their own data types. Most built-in data types have obvious names and semantics, so we defer a detailed explanation to Chapter 8. Some of the frequently used data types are `integer` for whole numbers, `numeric` for possibly fractional numbers, `text` for character strings, `date` for dates, `time` for time-of-day values, and `timestamp` for values containing both date and time.

To create a table, you use the aptly named `CREATE TABLE` command. In this command you specify at least a name for the new table, the names of the columns and the data type of each column. For example:

```
CREATE TABLE my_first_table (  
    first_column text,  
    second_column integer  
);
```

This creates a table named `my_first_table` with two columns. The first column is named `first_column` and has a data type of `text`; the second column has the name `second_column` and the type `integer`. The table and column names follow the identifier syntax explained in Section 4.1.1. The type names are usually also identifiers, but there are some exceptions. Note that the column list is comma-separated and surrounded by parentheses.

Of course, the previous example was heavily contrived. Normally, you would give names to your tables and columns that convey what kind of data they store. So let's look at a more realistic example:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric
```

```
);
```

(The `numeric` type can store fractional components, as would be typical of monetary amounts.)

### Tip

When you create many interrelated tables it is wise to choose a consistent naming pattern for the tables and columns. For instance, there is a choice of using singular or plural nouns for table names, both of which are favored by some theorist or other.

There is a limit on how many columns a table can contain. Depending on the column types, it is between 250 and 1600. However, defining a table with anywhere near this many columns is highly unusual and often a questionable design.

If you no longer need a table, you can remove it using the `DROP TABLE` command. For example:

```
DROP TABLE my_first_table;
DROP TABLE products;
```

Attempting to drop a table that does not exist is an error. Nevertheless, it is common in SQL script files to unconditionally try to drop each table before creating it, ignoring any error messages, so that the script works whether or not the table exists. (If you like, you can use the `DROP TABLE IF EXISTS` variant to avoid the error messages, but this is not standard SQL.)

If you need to modify a table that already exists, see Section 5.6 later in this chapter.

With the tools discussed so far you can create fully functional tables. The remainder of this chapter is concerned with adding features to the table definition to ensure data integrity, security, or convenience. If you are eager to fill your tables with data now you can skip ahead to Chapter 6 and read the rest of this chapter later.

## 5.2. Default Values

A column can be assigned a default value. When a new row is created and no values are specified for some of the columns, those columns will be filled with their respective default values. A data manipulation command can also request explicitly that a column be set to its default value, without having to know what that value is. (Details about data manipulation commands are in Chapter 6.)

If no default value is declared explicitly, the default value is the null value. This usually makes sense because a null value can be considered to represent unknown data.

In a table definition, default values are listed after the column data type. For example:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric DEFAULT 9.99
);
```

The default value can be an expression, which will be evaluated whenever the default value is inserted (*not* when the table is created). A common example is for a `timestamp` column to have a default of `CURRENT_TIMESTAMP`, so that it gets set to the time of row insertion. Another common example is generating a “serial number” for each row. In LightDB this is typically done by something like:

```
CREATE TABLE products (
```

```

        product_no integer DEFAULT nextval('products_product_no_seq'),
        ...
    );

```

where the `nextval()` function supplies successive values from a *sequence object* (see Section 9.17). This arrangement is sufficiently common that there's a special shorthand for it:

```

CREATE TABLE products (
    product_no SERIAL,
    ...
);

```

The `SERIAL` shorthand is discussed further in Section 8.1.4.

In particular, the expression used for the default value can be an expression that references other columns. Several restrictions apply to the expression that references other columns:

- The column referenced by the expression used for the default value must be defined before the current column.
- A expression used for the default value cannot reference a system column.

For example:

```

CREATE TABLE test (
    a integer,
    b integer default a*5,
);

```

## 5.3. Generated Columns

A generated column is a special column that is always computed from other columns. Thus, it is for columns what a view is for tables. There are two kinds of generated columns: stored and virtual. A stored generated column is computed when it is written (inserted or updated) and occupies storage as if it were a normal column. A virtual generated column occupies no storage and is computed when it is read. Thus, a virtual generated column is similar to a view and a stored generated column is similar to a materialized view (except that it is always updated automatically). LightDB currently implements only stored generated columns.

To create a generated column, use the `GENERATED ALWAYS AS` clause in `CREATE TABLE`, for example:

```

CREATE TABLE people (
    ...,
    height_cm numeric,
    height_in numeric GENERATED ALWAYS AS (height_cm / 2.54) STORED
);

```

The keyword `STORED` must be specified to choose the stored kind of generated column. See `CREATE TABLE` for more details.

A generated column cannot be written to directly. In `INSERT` or `UPDATE` commands, a value cannot be specified for a generated column, but the keyword `DEFAULT` may be specified.

Consider the differences between a column with a default and a generated column. The column default is evaluated once when the row is first inserted if no other value was provided; a generated column is updated whenever the row changes and cannot be overridden. A column default may not refer to other

columns of the table; a generation expression would normally do so. A column default can use volatile functions, for example `random()` or functions referring to the current time; this is not allowed for generated columns.

Several restrictions apply to the definition of generated columns and tables involving generated columns:

- The generation expression can only use immutable functions and cannot use subqueries or reference anything other than the current row in any way.
- A generation expression cannot reference another generated column.
- A generation expression cannot reference a system column, except `tableoid`.
- A generated column cannot have a column default or an identity definition.
- A generated column cannot be part of a partition key.
- Foreign tables can have generated columns. See `CREATE FOREIGN TABLE` for details.
- For inheritance:
  - If a parent column is a generated column, a child column must also be a generated column using the same expression. In the definition of the child column, leave off the `GENERATED` clause, as it will be copied from the parent.
  - In case of multiple inheritance, if one parent column is a generated column, then all parent columns must be generated columns and with the same expression.
  - If a parent column is not a generated column, a child column may be defined to be a generated column or not.

Additional considerations apply to the use of generated columns.

- Generated columns maintain access privileges separately from their underlying base columns. So, it is possible to arrange it so that a particular role can read from a generated column but not from the underlying base columns.
- Generated columns are, conceptually, updated after `BEFORE` triggers have run. Therefore, changes made to base columns in a `BEFORE` trigger will be reflected in generated columns. But conversely, it is not allowed to access generated columns in `BEFORE` triggers.

## 5.4. Constraints

Data types are a way to limit the kind of data that can be stored in a table. For many applications, however, the constraint they provide is too coarse. For example, a column containing a product price should probably only accept positive values. But there is no standard data type that accepts only positive numbers. Another issue is that you might want to constrain column data with respect to other columns or rows. For example, in a table containing product information, there should be only one row for each product number.

To that end, SQL allows you to define constraints on columns and tables. Constraints give you as much control over the data in your tables as you wish. If a user attempts to store data in a column that would violate a constraint, an error is raised. This applies even if the value came from the default value definition.

### 5.4.1. Check Constraints

A check constraint is the most generic constraint type. It allows you to specify that the value in a certain column must satisfy a Boolean (truth-value) expression. For instance, to require positive product prices, you could use:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0)  
);
```

As you see, the constraint definition comes after the data type, just like default value definitions. Default values and constraints can be listed in any order. A check constraint consists of the key word **CHECK** followed by an expression in parentheses. The check constraint expression should involve the column thus constrained, otherwise the constraint would not make too much sense.

You can also give the constraint a separate name. This clarifies error messages and allows you to refer to the constraint when you need to change it. The syntax is:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CONSTRAINT positive_price CHECK (price > 0)  
);
```

So, to specify a named constraint, use the key word **CONSTRAINT** followed by an identifier followed by the constraint definition. (If you don't specify a constraint name in this way, the system chooses a name for you.)

A check constraint can also refer to several columns. Say you store a regular price and a discounted price, and you want to ensure that the discounted price is lower than the regular price:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0),  
    discounted_price numeric CHECK (discounted_price > 0),  
    CHECK (price > discounted_price)  
);
```

The first two constraints should look familiar. The third one uses a new syntax. It is not attached to a particular column, instead it appears as a separate item in the comma-separated column list. Column definitions and these constraint definitions can be listed in mixed order.

We say that the first two constraints are column constraints, whereas the third one is a table constraint because it is written separately from any one column definition. Column constraints can also be written as table constraints, while the reverse is not necessarily possible, since a column constraint is supposed to refer to only the column it is attached to. (LightDB doesn't enforce that rule, but you should follow it if you want your table definitions to work with other database systems.) The above example could also be written as:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0),  
    CHECK (price > discounted_price)  
);
```



or even:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0 AND price > discounted_price)  
);
```

It's a matter of taste.

Names can be assigned to table constraints in the same way as column constraints:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0),  
    CONSTRAINT valid_discount CHECK (price > discounted_price)  
);
```

It should be noted that a check constraint is satisfied if the check expression evaluates to true or the null value. Since most expressions will evaluate to the null value if any operand is null, they will not prevent null values in the constrained columns. To ensure that a column does not contain null values, the not-null constraint described in the next section can be used.

### Note

LightDB does not support CHECK constraints that reference table data other than the new or updated row being checked. While a CHECK constraint that violates this rule may appear to work in simple tests, it cannot guarantee that the database will not reach a state in which the constraint condition is false (due to subsequent changes of the other row(s) involved). This would cause a database dump and restore to fail. The restore could fail even when the complete database state is consistent with the constraint, due to rows not being loaded in an order that will satisfy the constraint. If possible, use UNIQUE, EXCLUDE, or FOREIGN KEY constraints to express cross-row and cross-table restrictions.

If what you desire is a one-time check against other rows at row insertion, rather than a continuously-maintained consistency guarantee, a custom trigger can be used to implement that. (This approach avoids the dump/restore problem because `lt_dump` does not reinstall triggers until after restoring data, so that the check will not be enforced during a dump/restore.)

### Note

LightDB assumes that CHECK constraints' conditions are immutable, that is, they will always give the same result for the same input row. This assumption is what justifies examining CHECK constraints only when rows are inserted or updated, and not at other times. (The warning above about not referencing other table data is really a special case of this restriction.)

An example of a common way to break this assumption is to reference a user-defined function in a CHECK expression, and then change the behavior of that function. LightDB does not disallow that, but it will not notice if there are rows in the table that now violate the CHECK constraint. That would cause a subsequent database dump and restore to fail. The recommended way to handle such a change is to drop the constraint (using ALTER TABLE), adjust the function definition, and re-add the constraint, thereby rechecking it against all table rows.

## 5.4.2. Not-Null Constraints

A not-null constraint simply specifies that a column must not assume the null value. A syntax example:

```
CREATE TABLE products (  
    product_no integer NOT NULL,  
    name text NOT NULL,  
    price numeric  
);
```

A not-null constraint is always written as a column constraint. A not-null constraint is functionally equivalent to creating a check constraint CHECK (*column\_name* IS NOT NULL), but in LightDB creating an explicit not-null constraint is more efficient. The drawback is that you cannot give explicit names to not-null constraints created this way.

Of course, a column can have more than one constraint. Just write the constraints one after another:

```
CREATE TABLE products (  
    product_no integer NOT NULL,  
    name text NOT NULL,  
    price numeric NOT NULL CHECK (price > 0)  
);
```

The order doesn't matter. It does not necessarily determine in which order the constraints are checked.

The NOT NULL constraint has an inverse: the NULL constraint. This does not mean that the column must be null, which would surely be useless. Instead, this simply selects the default behavior that the column might be null. The NULL constraint is not present in the SQL standard and should not be used in portable applications. (It was only added to LightDB to be compatible with some other database systems.) Some users, however, like it because it makes it easy to toggle the constraint in a script file. For example, you could start with:

```
CREATE TABLE products (  
    product_no integer NULL,  
    name text NULL,  
    price numeric NULL  
);
```

and then insert the NOT key word where desired.

### Tip

In most database designs the majority of columns should be marked not null.

## 5.4.3. Unique Constraints

Unique constraints ensure that the data contained in a column, or a group of columns, is unique among all the rows in the table. The syntax is:

```
CREATE TABLE products (  
    product_no integer UNIQUE,  
    name text,  
    price numeric  
);
```

when written as a column constraint, and:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    UNIQUE (product_no)  
);
```

when written as a table constraint.

To define a unique constraint for a group of columns, write it as a table constraint with the column names separated by commas:

```
CREATE TABLE example (  
    a integer,  
    b integer,  
    c integer,  
    UNIQUE (a, c)  
);
```

This specifies that the combination of values in the indicated columns is unique across the whole table, though any one of the columns need not be (and ordinarily isn't) unique.

You can assign your own name for a unique constraint, in the usual way:

```
CREATE TABLE products (  
    product_no integer CONSTRAINT must_be_different UNIQUE,  
    name text,  
    price numeric  
);
```

Adding a unique constraint will automatically create a unique B-tree index on the column or group of columns listed in the constraint. A uniqueness restriction covering only some rows cannot be written as a unique constraint, but it is possible to enforce such a restriction by creating a unique partial index.

In general, a unique constraint is violated if there is more than one row in the table where the values of all of the columns included in the constraint are equal. However, two null values are never considered equal in this comparison. That means even in the presence of a unique constraint it is possible to store duplicate rows that contain a null value in at least one of the constrained columns. This behavior conforms to the SQL standard, but we have heard that other SQL databases might not follow this rule. So be careful when developing applications that are intended to be portable.

## 5.4.4. Primary Keys

A primary key constraint indicates that a column, or group of columns, can be used as a unique identifier for rows in the table. This requires that the values be both unique and not null. So, the following two table definitions accept the same data:

```
CREATE TABLE products (  
    product_no integer UNIQUE NOT NULL,  
    name text,  
    price numeric  
);
```

```
CREATE TABLE products (  
    product_no integer PRIMARY KEY,  
    name text,  
    price numeric  
);
```

Primary keys can span more than one column; the syntax is similar to unique constraints:

```
CREATE TABLE example (  
    a integer,  
    b integer,  
    c integer,  
    PRIMARY KEY (a, c)  
);
```

Adding a primary key will automatically create a unique B-tree index on the column or group of columns listed in the primary key, and will force the column(s) to be marked NOT NULL.

A table can have at most one primary key. (There can be any number of unique and not-null constraints, which are functionally almost the same thing, but only one can be identified as the primary key.) Relational database theory dictates that every table must have a primary key. This rule is not enforced by LightDB, but it is usually best to follow it.

Primary keys are useful both for documentation purposes and for client applications. For example, a GUI application that allows modifying row values probably needs to know the primary key of a table to be able to identify rows uniquely. There are also various ways in which the database system makes use of a primary key if one has been declared; for example, the primary key defines the default target column(s) for foreign keys referencing its table.

## 5.4.5. Foreign Keys

A foreign key constraint specifies that the values in a column (or a group of columns) must match the values appearing in some row of another table. We say this maintains the *referential integrity* between two related tables.

Say you have the product table that we have used several times already:

```
CREATE TABLE products (  
    product_no integer PRIMARY KEY,  
    name text,  
    price numeric  
);
```

Let's also assume you have a table storing orders of those products. We want to ensure that the orders table only contains orders of products that actually exist. So we define a foreign key constraint in the orders table that references the products table:

```
CREATE TABLE orders (  
    order_id integer PRIMARY KEY,  
    product_no integer REFERENCES products (product_no),  
    quantity integer  
);
```

Now it is impossible to create orders with non-NULL `product_no` entries that do not appear in the `products` table.

We say that in this situation the `orders` table is the *referencing* table and the `products` table is the *referenced* table. Similarly, there are referencing and referenced columns.

You can also shorten the above command to:

```
CREATE TABLE orders (  
    order_id integer PRIMARY KEY,  
    product_no integer REFERENCES products,  
    quantity integer  
);
```

because in absence of a column list the primary key of the referenced table is used as the referenced column(s).

You can assign your own name for a foreign key constraint, in the usual way.

A foreign key can also constrain and reference a group of columns. As usual, it then needs to be written in table constraint form. Here is a contrived syntax example:

```
CREATE TABLE t1 (  
    a integer PRIMARY KEY,  
    b integer,  
    c integer,  
    FOREIGN KEY (b, c) REFERENCES other_table (c1, c2)  
);
```

Of course, the number and type of the constrained columns need to match the number and type of the referenced columns.

Sometimes it is useful for the “other table” of a foreign key constraint to be the same table; this is called a *self-referential* foreign key. For example, if you want rows of a table to represent nodes of a tree structure, you could write

```
CREATE TABLE tree (  
    node_id integer PRIMARY KEY,  
    parent_id integer REFERENCES tree,  
    name text,  
    ...  
);
```

A top-level node would have NULL `parent_id`, but non-NULL `parent_id` entries would be constrained to reference valid rows of the table.

A table can have more than one foreign key constraint. This is used to implement many-to-many relationships between tables. Say you have tables about products and orders, but now you want to allow one order to contain possibly many products (which the structure above did not allow). You could use this table structure:

```
CREATE TABLE products (  
    product_no integer PRIMARY KEY,  
    name text,  
    price numeric  
);  
  
CREATE TABLE orders (  
    order_id integer PRIMARY KEY,  
    shipping_address text,  
    ...  
);  
  
CREATE TABLE order_items (  
    product_no integer REFERENCES products,  
    order_id integer REFERENCES orders,  
    quantity integer,  
    PRIMARY KEY (product_no, order_id)  
);
```

Notice that the primary key overlaps with the foreign keys in the last table.

We know that the foreign keys disallow creation of orders that do not relate to any products. But what if a product is removed after an order is created that references it? SQL allows you to handle that as well. Intuitively, we have a few options:

- Disallow deleting a referenced product
- Delete the orders as well
- Something else?

To illustrate this, let's implement the following policy on the many-to-many relationship example above: when someone wants to remove a product that is still referenced by an order (via `order_items`), we disallow it. If someone removes an order, the order items are removed as well:

```
CREATE TABLE products (  
    product_no integer PRIMARY KEY,  
    name text,  
    price numeric  
);  
  
CREATE TABLE orders (  
    order_id integer PRIMARY KEY,  
    shipping_address text,  
    ...  
);  
  
CREATE TABLE order_items (  
    product_no integer REFERENCES products ON DELETE RESTRICT,  
    order_id integer REFERENCES orders ON DELETE CASCADE,  
    quantity integer,  
    PRIMARY KEY (product_no, order_id)  
);
```

Restricting and cascading deletes are the two most common options. `RESTRICT` prevents deletion of a referenced row. `NO ACTION` means that if any referencing rows still exist when the constraint is checked, an error is raised; this is the default behavior if you do not specify anything. (The essential difference between these two choices is that `NO ACTION` allows the check to be deferred until later

in the transaction, whereas `RESTRICT` does not.) `CASCADE` specifies that when a referenced row is deleted, row(s) referencing it should be automatically deleted as well. There are two other options: `SET NULL` and `SET DEFAULT`. These cause the referencing column(s) in the referencing row(s) to be set to nulls or their default values, respectively, when the referenced row is deleted. Note that these do not excuse you from observing any constraints. For example, if an action specifies `SET DEFAULT` but the default value would not satisfy the foreign key constraint, the operation will fail.

Analogous to `ON DELETE` there is also `ON UPDATE` which is invoked when a referenced column is changed (updated). The possible actions are the same. In this case, `CASCADE` means that the updated values of the referenced column(s) should be copied into the referencing row(s).

Normally, a referencing row need not satisfy the foreign key constraint if any of its referencing columns are null. If `MATCH FULL` is added to the foreign key declaration, a referencing row escapes satisfying the constraint only if all its referencing columns are null (so a mix of null and non-null values is guaranteed to fail a `MATCH FULL` constraint). If you don't want referencing rows to be able to avoid satisfying the foreign key constraint, declare the referencing column(s) as `NOT NULL`.

A foreign key must reference columns that either are a primary key or form a unique constraint. This means that the referenced columns always have an index (the one underlying the primary key or unique constraint); so checks on whether a referencing row has a match will be efficient. Since a `DELETE` of a row from the referenced table or an `UPDATE` of a referenced column will require a scan of the referencing table for rows matching the old value, it is often a good idea to index the referencing columns too. Because this is not always needed, and there are many choices available on how to index, declaration of a foreign key constraint does not automatically create an index on the referencing columns.

More information about updating and deleting data is in Chapter 6. Also see the description of foreign key constraint syntax in the reference documentation for `CREATE TABLE`.

## 5.4.6. Exclusion Constraints

Exclusion constraints ensure that if any two rows are compared on the specified columns or expressions using the specified operators, at least one of these operator comparisons will return false or null. The syntax is:

```
CREATE TABLE circles (
    c circle,
    EXCLUDE USING gist (c WITH &&)
);
```

See also `CREATE TABLE ... CONSTRAINT ... EXCLUDE` for details.

Adding an exclusion constraint will automatically create an index of the type specified in the constraint declaration.

## 5.5. System Columns

Every table has several *system columns* that are implicitly defined by the system. Therefore, these names cannot be used as names of user-defined columns. (Note that these restrictions are separate from whether the name is a key word or not; quoting a name will not allow you to escape these restrictions.) You do not really need to be concerned about these columns; just know they exist.

`tableoid`

The OID of the table containing this row. This column is particularly handy for queries that select from inheritance hierarchies (see Section 5.10), since without it, it's difficult to tell which

individual table a row came from. The `tableoid` can be joined against the `oid` column of `pg_class` to obtain the table name.

`xmin`

The identity (transaction ID) of the inserting transaction for this row version. (A row version is an individual state of a row; each update of a row creates a new row version for the same logical row.)

`cmin`

The command identifier (starting at zero) within the inserting transaction.

`xmax`

The identity (transaction ID) of the deleting transaction, or zero for an undeleted row version. It is possible for this column to be nonzero in a visible row version. That usually indicates that the deleting transaction hasn't committed yet, or that an attempted deletion was rolled back.

`cmax`

The command identifier within the deleting transaction, or zero.

`ctid`

The physical location of the row version within its table. Note that although the `ctid` can be used to locate the row version very quickly, a row's `ctid` will change if it is updated or moved by `VACUUM FULL`. Therefore `ctid` is useless as a long-term row identifier. A primary key should be used to identify logical rows.

`rowid`

As a compatible field of Oracle, it is consistent with `ctid` function. You can use it when the value of `lightdb_dblevel_syntax_compatible_type` is `oracle`.

Transaction identifiers are also 32-bit quantities. In a long-lived database it is possible for transaction IDs to wrap around. This is not a fatal problem given appropriate maintenance procedures; see Chapter 22 for details. It is unwise, however, to depend on the uniqueness of transaction IDs over the long term (more than one billion transactions).

Command identifiers are also 32-bit quantities. This creates a hard limit of  $2^{32}$  (4 billion) SQL commands within a single transaction. In practice this limit is not a problem — note that the limit is on the number of SQL commands, not the number of rows processed. Also, only commands that actually modify the database contents will consume a command identifier.

## 5.6. Modifying Tables

When you create a table and you realize that you made a mistake, or the requirements of the application change, you can drop the table and create it again. But this is not a convenient option if the table is already filled with data, or if the table is referenced by other database objects (for instance a foreign key constraint). Therefore LightDB provides a family of commands to make modifications to existing tables. Note that this is conceptually distinct from altering the data contained in the table: here we are interested in altering the definition, or structure, of the table.

You can:

- Add columns
- Remove columns
- Add constraints
- Remove constraints



- Change default values
- Change column data types
- Rename columns
- Rename tables

All these actions are performed using the `ALTER TABLE` command, whose reference page contains details beyond those given here.

## 5.6.1. Adding a Column

To add a column, use a command like:

```
ALTER TABLE products ADD COLUMN description text;
```

The new column is initially filled with whatever default value is given (null if you don't specify a `DEFAULT` clause).

### Tip

From LightDB 11, adding a column with a constant default value no longer means that each row of the table needs to be updated when the `ALTER TABLE` statement is executed. Instead, the default value will be returned the next time the row is accessed, and applied when the table is rewritten, making the `ALTER TABLE` very fast even on large tables.

However, if the default value is volatile (e.g., `clock_timestamp()`) each row will need to be updated with the value calculated at the time `ALTER TABLE` is executed. To avoid a potentially lengthy update operation, particularly if you intend to fill the column with mostly nondefault values anyway, it may be preferable to add the column with no default, insert the correct values using `UPDATE`, and then add any desired default as described below.

You can also define constraints on the column at the same time, using the usual syntax:

```
ALTER TABLE products ADD COLUMN description text CHECK (description <> '');
```

In fact all the options that can be applied to a column description in `CREATE TABLE` can be used here. Keep in mind however that the default value must satisfy the given constraints, or the `ADD` will fail. Alternatively, you can add constraints later (see below) after you've filled in the new column correctly.

## 5.6.2. Removing a Column

To remove a column, use a command like:

```
ALTER TABLE products DROP COLUMN description;
```

Whatever data was in the column disappears. Table constraints involving the column are dropped, too. However, if the column is referenced by a foreign key constraint of another table, LightDB will not silently drop that constraint. You can authorize dropping everything that depends on the column by adding `CASCADE`:

```
ALTER TABLE products DROP COLUMN description CASCADE;
```

See Section 5.14 for a description of the general mechanism behind this.

### 5.6.3. Adding a Constraint

To add a constraint, the table constraint syntax is used. For example:

```
ALTER TABLE products ADD CHECK (name <> '');  
ALTER TABLE products ADD CONSTRAINT some_name UNIQUE (product_no);  
ALTER TABLE products ADD FOREIGN KEY (product_group_id) REFERENCES  
product_groups;
```

To add a not-null constraint, which cannot be written as a table constraint, use this syntax:

```
ALTER TABLE products ALTER COLUMN product_no SET NOT NULL;
```

The constraint will be checked immediately, so the table data must satisfy the constraint before it can be added.

### 5.6.4. Removing a Constraint

To remove a constraint you need to know its name. If you gave it a name then that's easy. Otherwise the system assigned a generated name, which you need to find out. The `ltsql` command `\d tablename` can be helpful here; other interfaces might also provide a way to inspect table details. Then the command is:

```
ALTER TABLE products DROP CONSTRAINT some_name;
```

(If you are dealing with a generated constraint name like `$2`, don't forget that you'll need to double-quote it to make it a valid identifier.)

As with dropping a column, you need to add `CASCADE` if you want to drop a constraint that something else depends on. An example is that a foreign key constraint depends on a unique or primary key constraint on the referenced column(s).

This works the same for all constraint types except not-null constraints. To drop a not null constraint use:

```
ALTER TABLE products ALTER COLUMN product_no DROP NOT NULL;
```

(Recall that not-null constraints do not have names.)

### 5.6.5. Changing a Column's Default Value

To set a new default for a column, use a command like:

```
ALTER TABLE products ALTER COLUMN price SET DEFAULT 7.77;
```

Note that this doesn't affect any existing rows in the table, it just changes the default for future `INSERT` commands.

To remove any default value, use:

```
ALTER TABLE products ALTER COLUMN price DROP DEFAULT;
```

This is effectively the same as setting the default to null. As a consequence, it is not an error to drop a default where one hadn't been defined, because the default is implicitly the null value.

## 5.6.6. Changing a Column's Data Type

To convert a column to a different data type, use a command like:

```
ALTER TABLE products ALTER COLUMN price TYPE numeric(10,2);
```

This will succeed only if each existing entry in the column can be converted to the new type by an implicit cast. If a more complex conversion is needed, you can add a `USING` clause that specifies how to compute the new values from the old.

LightDB will attempt to convert the column's default value (if any) to the new type, as well as any constraints that involve the column. But these conversions might fail, or might produce surprising results. It's often best to drop any constraints on the column before altering its type, and then add back suitably modified constraints afterwards.

## 5.6.7. Renaming a Column

To rename a column:

```
ALTER TABLE products RENAME COLUMN product_no TO product_number;
```

## 5.6.8. Renaming a Table

To rename a table:

```
ALTER TABLE products RENAME TO items;
```

# 5.7. Privileges

When an object is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, *privileges* must be granted.

There are different kinds of privileges: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, `REFERENCES`, `TRIGGER`, `CREATE`, `CONNECT`, `TEMPORARY`, `EXECUTE`, and `USAGE`. The privileges applicable to a particular object vary depending on the object's type (table, function, etc). More detail about the meanings of these privileges appears below. The following sections and chapters will also show you how these privileges are used.

The right to modify or destroy an object is inherent in being the object's owner, and cannot be granted or revoked in itself. (However, like all privileges, that right can be inherited by members of the owning role; see Section 19.3.)

An object can be assigned to a new owner with an `ALTER` command of the appropriate kind for the object, for example

```
ALTER TABLE table_name OWNER TO new_owner;
```

Superusers can always do this; ordinary roles can only do it if they are both the current owner of the object (or a member of the owning role) and a member of the new owning role.

To assign privileges, the GRANT command is used. For example, if `joe` is an existing role, and `accounts` is an existing table, the privilege to update the table can be granted with:

```
GRANT UPDATE ON accounts TO joe;
```

Writing ALL in place of a specific privilege grants all privileges that are relevant for the object type.

The special “role” name PUBLIC can be used to grant a privilege to every role on the system. Also, “group” roles can be set up to help manage privileges when there are many users of a database — for details see Chapter 19.

To revoke a previously-granted privilege, use the fittingly named REVOKE command:

```
REVOKE ALL ON accounts FROM PUBLIC;
```

Ordinarily, only the object's owner (or a superuser) can grant or revoke privileges on an object. However, it is possible to grant a privilege “with grant option”, which gives the recipient the right to grant it in turn to others. If the grant option is subsequently revoked then all who received the privilege from that recipient (directly or through a chain of grants) will lose the privilege. For details see the GRANT and REVOKE reference pages.

An object's owner can choose to revoke their own ordinary privileges, for example to make a table read-only for themselves as well as others. But owners are always treated as holding all grant options, so they can always re-grant their own privileges.

The available privileges are:

SELECT

Allows SELECT from any column, or specific column(s), of a table, view, materialized view, or other table-like object. Also allows use of COPY TO. This privilege is also needed to reference existing column values in UPDATE or DELETE. For sequences, this privilege also allows use of the `currval` function. For large objects, this privilege allows the object to be read.

INSERT

Allows INSERT of a new row into a table, view, etc. Can be granted on specific column(s), in which case only those columns may be assigned to in the INSERT command (other columns will therefore receive default values). Also allows use of COPY FROM.

UPDATE

Allows UPDATE of any column, or specific column(s), of a table, view, etc. (In practice, any nontrivial UPDATE command will require SELECT privilege as well, since it must reference table columns to determine which rows to update, and/or to compute new values for columns.) SELECT ... FOR UPDATE and SELECT ... FOR SHARE also require this privilege on at least one column, in addition to the SELECT privilege. For sequences, this privilege allows use of the `nextval` and `setval` functions. For large objects, this privilege allows writing or truncating the object.

DELETE

Allows DELETE of a row from a table, view, etc. (In practice, any nontrivial DELETE command will require SELECT privilege as well, since it must reference table columns to determine which rows to delete.)

TRUNCATE

Allows TRUNCATE on a table.

REFERENCES

Allows creation of a foreign key constraint referencing a table, or specific column(s) of a table.

TRIGGER

Allows creation of a trigger on a table, view, etc.

CREATE

For databases, allows new schemas and publications to be created within the database, and allows trusted extensions to be installed within the database.

For schemas, allows new objects to be created within the schema. To rename an existing object, you must own the object *and* have this privilege for the containing schema.

For tablespaces, allows tables, indexes, and temporary files to be created within the tablespace, and allows databases to be created that have the tablespace as their default tablespace.

Note that revoking this privilege will not alter the existence or location of existing objects.

CONNECT

Allows the grantee to connect to the database. This privilege is checked at connection startup (in addition to checking any restrictions imposed by `lt_hba.conf`).

TEMPORARY

Allows temporary tables to be created while using the database.

EXECUTE

Allows calling a function or procedure, including use of any operators that are implemented on top of the function. This is the only type of privilege that is applicable to functions and procedures.

USAGE

For procedural languages, allows use of the language for the creation of functions in that language. This is the only type of privilege that is applicable to procedural languages.

For schemas, allows access to objects contained in the schema (assuming that the objects' own privilege requirements are also met). Essentially this allows the grantee to “look up” objects within the schema. Without this permission, it is still possible to see the object names, e.g., by querying system catalogs. Also, after revoking this permission, existing sessions might have statements that have previously performed this lookup, so this is not a completely secure way to prevent object access.

For sequences, allows use of the `currval` and `nextval` functions.

For types and domains, allows use of the type or domain in the creation of tables, functions, and other schema objects. (Note that this privilege does not control all “usage” of the type, such as values of the type appearing in queries. It only prevents objects from being created that depend on the type. The main purpose of this privilege is controlling which users can create dependencies on a type, which could prevent the owner from changing the type later.)

For foreign-data wrappers, allows creation of new servers using the foreign-data wrapper.

For foreign servers, allows creation of foreign tables using the server. Grantees may also create, alter, or drop their own user mappings associated with that server.

The privileges required by other commands are listed on the reference page of the respective command.

LightDB grants privileges on some types of objects to PUBLIC by default when the objects are created. No privileges are granted to PUBLIC by default on tables, table columns, sequences, foreign data wrappers, foreign servers, large objects, schemas, or tablespaces. For other types of objects, the default privileges granted to PUBLIC are as follows: CONNECT and TEMPORARY (create temporary tables) privileges for databases; EXECUTE privilege for functions and procedures; and USAGE privilege for languages and data types (including domains). The object owner can, of course, REVOKE both default and expressly granted privileges. (For maximum security, issue the REVOKE in the same transaction that creates the object; then there is no window in which another user can use the object.) Also, these default privilege settings can be overridden using the ALTER DEFAULT PRIVILEGES command.

Table 5.1 shows the one-letter abbreviations that are used for these privilege types in ACL (Access Control List) values. You will see these letters in the output of the ltsql commands listed below, or when looking at ACL columns of system catalogs.

**Table 5.1. ACL Privilege Abbreviations**

Privilege	Abbreviation	Applicable Object Types
SELECT	r (“read”)	LARGE OBJECT, SEQUENCE, TABLE (and table-like objects), table column
INSERT	a (“append”)	TABLE, table column
UPDATE	w (“write”)	LARGE OBJECT, SEQUENCE, TABLE, table column
DELETE	d	TABLE
TRUNCATE	D	TABLE
REFERENCES	x	TABLE, table column
TRIGGER	t	TABLE
CREATE	C	DATABASE, SCHEMA, TABLESPACE
CONNECT	c	DATABASE
TEMPORARY	T	DATABASE
EXECUTE	X	FUNCTION, PROCEDURE
USAGE	U	DOMAIN, FOREIGN DATA WRAPPER, FOREIGN SERVER, LANGUAGE, SCHEMA, SEQUENCE, TYPE

Table 5.2 summarizes the privileges available for each type of SQL object, using the abbreviations shown above. It also shows the ltsql command that can be used to examine privilege settings for each object type.

**Table 5.2. Summary of Access Privileges**

Object Type	All Privileges	Default PUBLIC Privileges	ltsql Command
DATABASE	CTc	Tc	\l
DOMAIN	U	U	\dD+
FUNCTION or PROCEDURE	X	X	\df+
FOREIGN DATA WRAPPER	U	none	\dew+
FOREIGN SERVER	U	none	\des+
LANGUAGE	U	U	\dL+
LARGE OBJECT	rw	none	

Object Type	All Privileges	Default PUBLIC Privileges	Itsql Command
SCHEMA	UC	none	\dn+
SEQUENCE	rwU	none	\dp
TABLE (and table-like objects)	arwdDxt	none	\dp
Table column	arwx	none	\dp
TABLESPACE	C	none	\db+
TYPE	U	U	\dT+

The privileges that have been granted for a particular object are displayed as a list of `aclitem` entries, where each `aclitem` describes the permissions of one grantee that have been granted by a particular grantor. For example, `calvin=r*w/hobbes` specifies that the role `calvin` has the privilege `SELECT` (`r`) with grant option (`*`) as well as the non-grantable privilege `UPDATE` (`w`), both granted by the role `hobbes`. If `calvin` also has some privileges on the same object granted by a different grantor, those would appear as a separate `aclitem` entry. An empty grantee field in an `aclitem` stands for `PUBLIC`.

As an example, suppose that user `miriam` creates table `mytable` and does:

```
GRANT SELECT ON mytable TO PUBLIC;
GRANT SELECT, UPDATE, INSERT ON mytable TO admin;
GRANT SELECT (coll), UPDATE (coll) ON mytable TO miriam_rw;
```

Then `itsql`'s `\dp` command would show:

```
=> \dp mytable
                                     Access privileges
 Schema | Name   | Type | Access privileges | Column
 privileges | Policies
-----+-----+-----+-----+-----
public | mytable | table | miriam=arwdDxt/miriam+ | coll:
      + |
miriam |         |      | =r/miriam           + | miriam_rw=rw/
      |         |      | admin=arw/miriam   |
      |         |      |
(1 row)
```

If the “Access privileges” column is empty for a given object, it means the object has default privileges (that is, its privileges entry in the relevant system catalog is null). Default privileges always include all privileges for the owner, and can include some privileges for `PUBLIC` depending on the object type, as explained above. The first `GRANT` or `REVOKE` on an object will instantiate the default privileges (producing, for example, `miriam=arwdDxt/miriam`) and then modify them per the specified request. Similarly, entries are shown in “Column privileges” only for columns with nondefault privileges. (Note: for this purpose, “default privileges” always means the built-in default privileges for the object's type. An object whose privileges have been affected by an `ALTER DEFAULT PRIVILEGES` command will always be shown with an explicit privilege entry that includes the effects of the `ALTER`.)

Notice that the owner's implicit grant options are not marked in the access privileges display. A `*` will appear only when grant options have been explicitly granted to someone.

## 5.8. Row Security Policies

In addition to the SQL-standard privilege system available through GRANT, tables can have *row security policies* that restrict, on a per-user basis, which rows can be returned by normal queries or inserted, updated, or deleted by data modification commands. This feature is also known as *Row-Level Security*. By default, tables do not have any policies, so that if a user has access privileges to a table according to the SQL privilege system, all rows within it are equally available for querying or updating.

When row security is enabled on a table (with ALTER TABLE ... ENABLE ROW LEVEL SECURITY), all normal access to the table for selecting rows or modifying rows must be allowed by a row security policy. (However, the table's owner is typically not subject to row security policies.) If no policy exists for the table, a default-deny policy is used, meaning that no rows are visible or can be modified. Operations that apply to the whole table, such as TRUNCATE and REFERENCES, are not subject to row security.

Row security policies can be specific to commands, or to roles, or to both. A policy can be specified to apply to ALL commands, or to SELECT, INSERT, UPDATE, or DELETE. Multiple roles can be assigned to a given policy, and normal role membership and inheritance rules apply.

To specify which rows are visible or modifiable according to a policy, an expression is required that returns a Boolean result. This expression will be evaluated for each row prior to any conditions or functions coming from the user's query. (The only exceptions to this rule are leakproof functions, which are guaranteed to not leak information; the optimizer may choose to apply such functions ahead of the row-security check.) Rows for which the expression does not return true will not be processed. Separate expressions may be specified to provide independent control over the rows which are visible and the rows which are allowed to be modified. Policy expressions are run as part of the query and with the privileges of the user running the query, although security-definer functions can be used to access data not available to the calling user.

Superusers and roles with the BYPASSRLS attribute always bypass the row security system when accessing a table. Table owners normally bypass row security as well, though a table owner can choose to be subject to row security with ALTER TABLE ... FORCE ROW LEVEL SECURITY.

Enabling and disabling row security, as well as adding policies to a table, is always the privilege of the table owner only.

Policies are created using the CREATE POLICY command, altered using the ALTER POLICY command, and dropped using the DROP POLICY command. To enable and disable row security for a given table, use the ALTER TABLE command.

Each policy has a name and multiple policies can be defined for a table. As policies are table-specific, each policy for a table must have a unique name. Different tables may have policies with the same name.

When multiple policies apply to a given query, they are combined using either OR (for permissive policies, which are the default) or using AND (for restrictive policies). This is similar to the rule that a given role has the privileges of all roles that they are a member of. Permissive vs. restrictive policies are discussed further below.

As a simple example, here is how to create a policy on the account relation to allow only members of the managers role to access rows, and only rows of their accounts:

```
CREATE TABLE accounts (manager text, company text, contact_email
    text);

ALTER TABLE accounts ENABLE ROW LEVEL SECURITY;

CREATE POLICY account_managers ON accounts TO managers
    USING (manager = current_user);
```



The policy above implicitly provides a `WITH CHECK` clause identical to its `USING` clause, so that the constraint applies both to rows selected by a command (so a manager cannot `SELECT`, `UPDATE`, or `DELETE` existing rows belonging to a different manager) and to rows modified by a command (so rows belonging to a different manager cannot be created via `INSERT` or `UPDATE`).

If no role is specified, or the special user name `PUBLIC` is used, then the policy applies to all users on the system. To allow all users to access only their own row in a `users` table, a simple policy can be used:

```
CREATE POLICY user_policy ON users
    USING (user_name = current_user);
```

This works similarly to the previous example.

To use a different policy for rows that are being added to the table compared to those rows that are visible, multiple policies can be combined. This pair of policies would allow all users to view all rows in the `users` table, but only modify their own:

```
CREATE POLICY user_sel_policy ON users
    FOR SELECT
    USING (true);
CREATE POLICY user_mod_policy ON users
    USING (user_name = current_user);
```

In a `SELECT` command, these two policies are combined using `OR`, with the net effect being that all rows can be selected. In other command types, only the second policy applies, so that the effects are the same as before.

Row security can also be disabled with the `ALTER TABLE` command. Disabling row security does not remove any policies that are defined on the table; they are simply ignored. Then all rows in the table are visible and modifiable, subject to the standard SQL privileges system.

Below is a larger example of how this feature can be used in production environments. The table `passwd` emulates a Unix password file:

```
-- Simple passwd-file based example
CREATE TABLE passwd (
    user_name          text UNIQUE NOT NULL,
    pwhash             text,
    uid                int PRIMARY KEY,
    gid                int NOT NULL,
    real_name          text NOT NULL,
    home_phone         text,
    extra_info         text,
    home_dir           text NOT NULL,
    shell              text NOT NULL
);

CREATE ROLE admin; -- Administrator
CREATE ROLE bob;   -- Normal user
CREATE ROLE alice; -- Normal user

-- Populate the table
INSERT INTO passwd VALUES
    ('admin', 'xxx', 0, 0, 'Admin', '111-222-3333', null, '/root', '/bin/
dash');
INSERT INTO passwd VALUES
```

```

    ('bob','xxx',1,1,'Bob','123-456-7890',null,'/home/bob','/bin/
zsh');
INSERT INTO passwd VALUES
    ('alice','xxx',2,1,'Alice','098-765-4321',null,'/home/alice','/
bin/zsh');

-- Be sure to enable row level security on the table
ALTER TABLE passwd ENABLE ROW LEVEL SECURITY;

-- Create policies
-- Administrator can see all rows and add any rows
CREATE POLICY admin_all ON passwd TO admin USING (true) WITH CHECK
    (true);
-- Normal users can view all rows
CREATE POLICY all_view ON passwd FOR SELECT USING (true);
-- Normal users can update their own records, but
-- limit which shells a normal user is allowed to set
CREATE POLICY user_mod ON passwd FOR UPDATE
    USING (current_user = user_name)
    WITH CHECK (
        current_user = user_name AND
        shell IN ('/bin/bash','/bin/sh','/bin/dash','/bin/zsh','/bin/
tcsh')
    );

-- Allow admin all normal rights
GRANT SELECT, INSERT, UPDATE, DELETE ON passwd TO admin;
-- Users only get select access on public columns
GRANT SELECT
    (user_name, uid, gid, real_name, home_phone, extra_info,
    home_dir, shell)
    ON passwd TO public;
-- Allow users to update certain columns
GRANT UPDATE
    (pwhash, real_name, home_phone, extra_info, shell)
    ON passwd TO public;

```

As with any security settings, it's important to test and ensure that the system is behaving as expected. Using the example above, this demonstrates that the permission system is working properly.

```

-- admin can view all rows and fields
lightdb@postgres=> set role admin;
SET
lightdb@postgres=> table passwd;
 user_name | pwhash | uid | gid | real_name | home_phone |
 extra_info | home_dir | shell
-----+-----+-----+-----+-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----+-----+-----+-----+
 admin     | xxx    | 0  | 0  | Admin     | 111-222-3333 |
           | /root  |    |    |           |               |
 bob       | xxx    | 1  | 1  | Bob       | 123-456-7890 |
           | /home/bob |    |    |           |               |
 alice     | xxx    | 2  | 1  | Alice     | 098-765-4321 |
           | /home/alice |    |    |           |               |
(3 rows)

-- Test what Alice is able to do

```

```

lightdb@postgres=> set role alice;
SET
lightdb@postgres=> table passwd;
ERROR: permission denied for relation passwd
lightdb@postgres=> select
  user_name,real_name,home_phone,extra_info,home_dir,shell from
  passwd;
 user_name | real_name | home_phone | extra_info | home_dir |
  shell
-----+-----+-----+-----+-----+
+-----+
admin      | Admin    | 111-222-3333 |          | /root   |
| /bin/dash
bob        | Bob      | 123-456-7890 |          | /home/bob
| /bin/zsh
alice      | Alice    | 098-765-4321 |          | /home/alice
| /bin/zsh
(3 rows)

lightdb@postgres=> update passwd set user_name = 'joe';
ERROR: permission denied for relation passwd
-- Alice is allowed to change her own real_name, but no others
lightdb@postgres=> update passwd set real_name = 'Alice Doe';
UPDATE 1
lightdb@postgres=> update passwd set real_name = 'John Doe' where
  user_name = 'admin';
UPDATE 0
lightdb@postgres=> update passwd set shell = '/bin/xx';
ERROR: new row violates WITH CHECK OPTION for "passwd"
lightdb@postgres=> delete from passwd;
ERROR: permission denied for relation passwd
lightdb@postgres=> insert into passwd (user_name) values ('xxx');
ERROR: permission denied for relation passwd
-- Alice can change her own password; RLS silently prevents
  updating other rows
lightdb@postgres=> update passwd set pwhash = 'abc';
UPDATE 1

```

All of the policies constructed thus far have been permissive policies, meaning that when multiple policies are applied they are combined using the “OR” Boolean operator. While permissive policies can be constructed to only allow access to rows in the intended cases, it can be simpler to combine permissive policies with restrictive policies (which the records must pass and which are combined using the “AND” Boolean operator). Building on the example above, we add a restrictive policy to require the administrator to be connected over a local Unix socket to access the records of the passwd table:

```

CREATE POLICY admin_local_only ON passwd AS RESTRICTIVE TO admin
  USING (pg_catalog.inet_client_addr() IS NULL);

```

We can then see that an administrator connecting over a network will not see any records, due to the restrictive policy:

```

=> SELECT current_user;
  current_user
-----
admin
(1 row)

```

```

=> select inet_client_addr();
   inet_client_addr
-----
   127.0.0.1
(1 row)

=> SELECT current_user;
   current_user
-----
   admin
(1 row)

=> TABLE passwd;
 user_name | pwhash | uid | gid | real_name | home_phone |
 extra_info | home_dir | shell
-----+-----+-----+-----+-----+-----+-----
(0 rows)

=> UPDATE passwd set pwhash = NULL;
UPDATE 0

```

Referential integrity checks, such as unique or primary key constraints and foreign key references, always bypass row security to ensure that data integrity is maintained. Care must be taken when developing schemas and row level policies to avoid “covert channel” leaks of information through such referential integrity checks.

In some contexts it is important to be sure that row security is not being applied. For example, when taking a backup, it could be disastrous if row security silently caused some rows to be omitted from the backup. In such a situation, you can set the `row_security` configuration parameter to `off`. This does not in itself bypass row security; what it does is throw an error if any query's results would get filtered by a policy. The reason for the error can then be investigated and fixed.

In the examples above, the policy expressions consider only the current values in the row to be accessed or updated. This is the simplest and best-performing case; when possible, it's best to design row security applications to work this way. If it is necessary to consult other rows or other tables to make a policy decision, that can be accomplished using sub-SELECTs, or functions that contain SELECTs, in the policy expressions. Be aware however that such accesses can create race conditions that could allow information leakage if care is not taken. As an example, consider the following table design:

```

-- definition of privilege groups
CREATE TABLE groups (group_id int PRIMARY KEY,
                    group_name text NOT NULL);

INSERT INTO groups VALUES
    (1, 'low'),
    (2, 'medium'),
    (5, 'high');

GRANT ALL ON groups TO alice; -- alice is the administrator
GRANT SELECT ON groups TO public;

-- definition of users' privilege levels
CREATE TABLE users (user_name text PRIMARY KEY,
                   group_id int NOT NULL REFERENCES groups);

INSERT INTO users VALUES

```

```

('alice', 5),
('bob', 2),
('mallory', 2);

GRANT ALL ON users TO alice;
GRANT SELECT ON users TO public;

-- table holding the information to be protected
CREATE TABLE information (info text,
                           group_id int NOT NULL REFERENCES groups);

INSERT INTO information VALUES
  ('barely secret', 1),
  ('slightly secret', 2),
  ('very secret', 5);

ALTER TABLE information ENABLE ROW LEVEL SECURITY;

-- a row should be visible to/updatable by users whose security
group_id is
-- greater than or equal to the row's group_id
CREATE POLICY fp_s ON information FOR SELECT
  USING (group_id <= (SELECT group_id FROM users WHERE user_name =
  current_user));
CREATE POLICY fp_u ON information FOR UPDATE
  USING (group_id <= (SELECT group_id FROM users WHERE user_name =
  current_user));

-- we rely only on RLS to protect the information table
GRANT ALL ON information TO public;

```

Now suppose that alice wishes to change the “slightly secret” information, but decides that mallory should not be trusted with the new content of that row, so she does:

```

BEGIN;
UPDATE users SET group_id = 1 WHERE user_name = 'mallory';
UPDATE information SET info = 'secret from mallory' WHERE group_id
= 2;
COMMIT;

```

That looks safe; there is no window wherein mallory should be able to see the “secret from mallory” string. However, there is a race condition here. If mallory is concurrently doing, say,

```

SELECT * FROM information WHERE group_id = 2 FOR UPDATE;

```

and her transaction is in READ COMMITTED mode, it is possible for her to see “secret from mallory”. That happens if her transaction reaches the `information` row just after alice's does. It blocks waiting for alice's transaction to commit, then fetches the updated row contents thanks to the `FOR UPDATE` clause. However, it does *not* fetch an updated row for the implicit `SELECT` from `users`, because that sub-`SELECT` did not have `FOR UPDATE`; instead the `users` row is read with the snapshot taken at the start of the query. Therefore, the policy expression tests the old value of mallory's privilege level and allows her to see the updated row.

There are several ways around this problem. One simple answer is to use `SELECT . . . FOR SHARE` in sub-`SELECT`s in row security policies. However, that requires granting `UPDATE` privilege on the referenced table (here `users`) to the affected users, which might be undesirable. (But another row security policy could be applied to prevent them from actually exercising that privilege; or the sub-

`SELECT` could be embedded into a security definer function.) Also, heavy concurrent use of row share locks on the referenced table could pose a performance problem, especially if updates of it are frequent. Another solution, practical if updates of the referenced table are infrequent, is to take an `ACCESS EXCLUSIVE` lock on the referenced table when updating it, so that no concurrent transactions could be examining old row values. Or one could just wait for all concurrent transactions to end after committing an update of the referenced table and before making changes that rely on the new security situation.

For additional details see `CREATE POLICY` and `ALTER TABLE`.

## 5.9. Schemas

A LightDB database cluster contains one or more named databases. Roles and a few other object types are shared across the entire cluster. A client connection to the server can only access data in a single database, the one specified in the connection request.

### Note

Users of a cluster do not necessarily have the privilege to access every database in the cluster. Sharing of role names means that there cannot be different roles named, say, `joe` in two databases in the same cluster; but the system can be configured to allow `joe` access to only some of the databases.

A database contains one or more named *schemas*, which in turn contain tables. Schemas also contain other kinds of named objects, including data types, functions, and operators. The same object name can be used in different schemas without conflict; for example, both `schema1` and `myschema` can contain tables named `mytable`. Unlike databases, schemas are not rigidly separated: a user can access objects in any of the schemas in the database they are connected to, if they have privileges to do so.

There are several reasons why one might want to use schemas:

- To allow many users to use one database without interfering with each other.
- To organize database objects into logical groups to make them more manageable.
- Third-party applications can be put into separate schemas so they do not collide with the names of other objects.

Schemas are analogous to directories at the operating system level, except that schemas cannot be nested.

### 5.9.1. Creating a Schema

To create a schema, use the `CREATE SCHEMA` command. Give the schema a name of your choice. For example:

```
CREATE SCHEMA myschema;
```

To create or access objects in a schema, write a *qualified name* consisting of the schema name and table name separated by a dot:

```
schema.table
```

This works anywhere a table name is expected, including the table modification commands and the data access commands discussed in the following chapters. (For brevity we will speak of tables only, but the same ideas apply to other kinds of named objects, such as types and functions.)

Actually, the even more general syntax

```
database.schema.table
```

can be used too, but at present this is just for *pro forma* compliance with the SQL standard. If you write a database name, it must be the same as the database you are connected to.

So to create a table in the new schema, use:

```
CREATE TABLE myschema.mytable (  
    ...  
);
```

To drop a schema if it's empty (all objects in it have been dropped), use:

```
DROP SCHEMA myschema;
```

To drop a schema including all contained objects, use:

```
DROP SCHEMA myschema CASCADE;
```

See Section 5.14 for a description of the general mechanism behind this.

Often you will want to create a schema owned by someone else (since this is one of the ways to restrict the activities of your users to well-defined namespaces). The syntax for that is:

```
CREATE SCHEMA schema_name AUTHORIZATION user_name;
```

You can even omit the schema name, in which case the schema name will be the same as the user name. See Section 5.9.6 for how this can be useful.

Schema names beginning with `pg_` are reserved for system purposes and cannot be created by users.

## 5.9.2. The Public Schema

In the previous sections we created tables without specifying any schema names. By default such tables (and other objects) are automatically put into a schema named “public”. Every new database contains such a schema. Thus, the following are equivalent:

```
CREATE TABLE products ( ... );
```

and:

```
CREATE TABLE public.products ( ... );
```

## 5.9.3. The Schema Search Path

Qualified names are tedious to write, and it's often best not to wire a particular schema name into applications anyway. Therefore tables are often referred to by *unqualified names*, which consist of just the table name. The system determines which table is meant by following a *search path*, which is a list of schemas to look in. The first matching table in the search path is taken to be the one wanted. If there is no match in the search path, an error is reported, even if matching table names exist in other schemas in the database.

The ability to create like-named objects in different schemas complicates writing a query that references precisely the same objects every time. It also opens up the potential for users to change the behavior of other users' queries, maliciously or accidentally. Due to the prevalence of unqualified names in queries and their use in LightDB internals, adding a schema to `search_path` effectively trusts all users having `CREATE` privilege on that schema. When you run an ordinary query, a malicious user able to create objects in a schema of your search path can take control and execute arbitrary SQL functions as though you executed them.

The first schema named in the search path is called the current schema. Aside from being the first schema searched, it is also the schema in which new tables will be created if the `CREATE TABLE` command does not specify a schema name.

To show the current search path, use the following command:

```
SHOW search_path;
```

In the default setup this returns:

```
search_path
-----
"$user", public, "$lt_syntax_compatible_type", lt_catalog
```

The first element specifies that a schema with the same name as the current user is to be searched. If no such schema exists, the entry is ignored. The second element refers to the public schema that we have seen already.

The first schema in the search path that exists is the default location for creating new objects. That is the reason that by default objects are created in the public schema. When objects are referenced in any other context without schema qualification (table modification, data modification, or query commands) the search path is traversed until a matching object is found. Therefore, in the default configuration, any unqualified access again can only refer to the public schema.

To put our new schema in the path, we use:

```
SET search_path TO myschema,public;
```

(We omit the `$user` here because we have no immediate need for it.) And then we can access the table without schema qualification:

```
DROP TABLE mytable;
```

Also, since `myschema` is the first element in the path, new objects would by default be created in it.

We could also have written:

```
SET search_path TO myschema;
```

Then we no longer have access to the public schema without explicit qualification. There is nothing special about the public schema except that it exists by default. It can be dropped, too.

Note that no matter whether `lt_catalog` schema is configured in `search_path`, it will actually include `lt_catalog` schema by default. When `Oracle/MySQL` schema is configured, `Oracle/MySQL` schema will be placed before `lt_catalog` schema by default.



Note that when using `ALTER DATABASE/ROLE` to set `search_path`, the Oracle/MySQL schema contained in it will not take effect, and `LightDB` will delete the Oracle/MySQL schema by default.

See also Section 9.26 for other ways to manipulate the schema search path.

The search path works in the same way for data type names, function names, and operator names as it does for table names. Data type and function names can be qualified in exactly the same way as table names. If you need to write a qualified operator name in an expression, there is a special provision: you must write

```
OPERATOR(schema.operator)
```

This is needed to avoid syntactic ambiguity. An example is:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

In practice one usually relies on the search path for operators, so as not to have to write anything so ugly as that.

## 5.9.4. Schemas and Privileges

By default, users cannot access any objects in schemas they do not own. To allow that, the owner of the schema must grant the `USAGE` privilege on the schema. To allow users to make use of the objects in the schema, additional privileges might need to be granted, as appropriate for the object.

A user can also be allowed to create objects in someone else's schema. To allow that, the `CREATE` privilege on the schema needs to be granted. Note that by default, everyone has `CREATE` and `USAGE` privileges on the schema `public`. This allows all users that are able to connect to a given database to create objects in its `public` schema. Some usage patterns call for revoking that privilege:

```
REVOKE CREATE ON SCHEMA public FROM PUBLIC;
```

(The first “public” is the schema, the second “public” means “every user”. In the first sense it is an identifier, in the second sense it is a key word, hence the different capitalization; recall the guidelines from Section 4.1.1.)

## 5.9.5. The System Catalog Schema

In addition to `public` and user-created schemas, each database contains a `pg_catalog` schema, which contains the system tables and all the built-in data types, functions, and operators. `pg_catalog` is always effectively part of the search path. If it is not named explicitly in the path then it is implicitly searched *before* searching the path's schemas. This ensures that built-in names will always be findable. However, you can explicitly place `pg_catalog` at the end of your search path if you prefer to have user-defined names override built-in names.

Since system table names begin with `pg_`, it is best to avoid such names to ensure that you won't suffer a conflict if some future version defines a system table named the same as your table. (With the default search path, an unqualified reference to your table name would then be resolved as the system table instead.) System tables will continue to follow the convention of having names beginning with `pg_`, so that they will not conflict with unqualified user-table names so long as users avoid the `pg_` prefix.

## 5.9.6. Usage Patterns

Schemas can be used to organize your data in many ways. A *secure schema usage pattern* prevents untrusted users from changing the behavior of other users' queries. When a database does not use

a secure schema usage pattern, users wishing to securely query that database would take protective action at the beginning of each session. Specifically, they would begin each session by setting `search_path` to the empty string or otherwise removing non-superuser-writable schemas from `search_path`. There are a few usage patterns easily supported by the default configuration:

- Constrain ordinary users to user-private schemas. To implement this, issue `REVOKE CREATE ON SCHEMA public FROM PUBLIC`, and create a schema for each user with the same name as that user. Recall that the default search path starts with `$user`, which resolves to the user name. Therefore, if each user has a separate schema, they access their own schemas by default. After adopting this pattern in a database where untrusted users had already logged in, consider auditing the public schema for objects named like objects in schema `pg_catalog`. This pattern is a secure schema usage pattern unless an untrusted user is the database owner or holds the `CREATEROLE` privilege, in which case no secure schema usage pattern exists.
- Remove the public schema from the default search path, by modifying `lightdb.conf` or by issuing `ALTER ROLE ALL SET search_path = "$user"`. Everyone retains the ability to create objects in the public schema, but only qualified names will choose those objects. While qualified table references are fine, calls to functions in the public schema will be unsafe or unreliable. If you create functions or extensions in the public schema, use the first pattern instead. Otherwise, like the first pattern, this is secure unless an untrusted user is the database owner or holds the `CREATEROLE` privilege.
- Keep the default. All users access the public schema implicitly. This simulates the situation where schemas are not available at all, giving a smooth transition from the non-schema-aware world. However, this is never a secure pattern. It is acceptable only when the database has a single user or a few mutually-trusting users.

For any pattern, to install shared applications (tables to be used by everyone, additional functions provided by third parties, etc.), put them into separate schemas. Remember to grant appropriate privileges to allow the other users to access them. Users can then refer to these additional objects by qualifying the names with a schema name, or they can put the additional schemas into their search path, as they choose.

## 5.9.7. Portability

In the SQL standard, the notion of objects in the same schema being owned by different users does not exist. Moreover, some implementations do not allow you to create schemas that have a different name than their owner. In fact, the concepts of schema and user are nearly equivalent in a database system that implements only the basic schema support specified in the standard. Therefore, many users consider qualified names to really consist of `user_name.table_name`. This is how LightDB will effectively behave if you create a per-user schema for every user.

Also, there is no concept of a `public` schema in the SQL standard. For maximum conformance to the standard, you should not use the `public` schema.

Of course, some SQL database systems might not implement schemas at all, or provide namespace support by allowing (possibly limited) cross-database access. If you need to work with those systems, then maximum portability would be achieved by not using schemas at all.

## 5.10. Inheritance

LightDB implements table inheritance, which can be a useful tool for database designers. (SQL:1999 and later define a type inheritance feature, which differs in many respects from the features described here.)

Let's start with an example: suppose we are trying to build a data model for cities. Each state has many cities, but only one capital. We want to be able to quickly retrieve the capital city for any particular

state. This can be done by creating two tables, one for state capitals and one for cities that are not capitals. However, what happens when we want to ask for data about a city, regardless of whether it is a capital or not? The inheritance feature can help to resolve this problem. We define the `capitals` table so that it inherits from `cities`:

```
CREATE TABLE cities (
    name          text,
    population    float,
    elevation     int    -- in feet
);

CREATE TABLE capitals (
    state         char(2)
) INHERITS (cities);
```

In this case, the `capitals` table *inherits* all the columns of its parent table, `cities`. State capitals also have an extra column, `state`, that shows their state.

In LightDB, a table can inherit from zero or more other tables, and a query can reference either all rows of a table or all rows of a table plus all of its descendant tables. The latter behavior is the default. For example, the following query finds the names of all cities, including state capitals, that are located at an elevation over 500 feet:

```
SELECT name, elevation
FROM cities
WHERE elevation > 500;
```

Given the sample data from the LightDB tutorial (see Section 2.1), this returns:

name	elevation
Las Vegas	2174
Mariposa	1953
Madison	845

On the other hand, the following query finds all the cities that are not state capitals and are situated at an elevation over 500 feet:

```
SELECT name, elevation
FROM ONLY cities
WHERE elevation > 500;
```

name	elevation
Las Vegas	2174
Mariposa	1953

Here the `ONLY` keyword indicates that the query should apply only to `cities`, and not any tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE` and `DELETE` — support the `ONLY` keyword.

You can also write the table name with a trailing `*` to explicitly specify that descendant tables are included:

```
SELECT name, elevation
```

```
FROM cities*
WHERE elevation > 500;
```

Writing `*` is not necessary, since this behavior is always the default. However, this syntax is still supported for compatibility with older releases where the default could be changed.

In some cases you might wish to know which table a particular row originated from. There is a system column called `tableoid` in each table which can tell you the originating table:

```
SELECT c.tableoid, c.name, c.elevation
FROM cities c
WHERE c.elevation > 500;
```

which returns:

tableoid	name	elevation
139793	Las Vegas	2174
139793	Mariposa	1953
139798	Madison	845

(If you try to reproduce this example, you will probably get different numeric OIDs.) By doing a join with `pg_class` you can see the actual table names:

```
SELECT p.relname, c.name, c.elevation
FROM cities c, pg_class p
WHERE c.elevation > 500 AND c.tableoid = p.oid;
```

which returns:

relname	name	elevation
cities	Las Vegas	2174
cities	Mariposa	1953
capitals	Madison	845

Another way to get the same effect is to use the `regclass` alias type, which will print the table OID symbolically:

```
SELECT c.tableoid::regclass, c.name, c.elevation
FROM cities c
WHERE c.elevation > 500;
```

Inheritance does not automatically propagate data from `INSERT` or `COPY` commands to other tables in the inheritance hierarchy. In our example, the following `INSERT` statement will fail:

```
INSERT INTO cities (name, population, elevation, state)
VALUES ('Albany', NULL, NULL, 'NY');
```

We might hope that the data would somehow be routed to the `capitals` table, but this does not happen: `INSERT` always inserts into exactly the table specified. In some cases it is possible to redirect the insertion using a rule (see Chapter 39). However that does not help for the above case because the `cities` table does not contain the column `state`, and so the command will be rejected before the rule can be applied.

All check constraints and not-null constraints on a parent table are automatically inherited by its children, unless explicitly specified otherwise with `NO INHERIT` clauses. Other types of constraints (unique, primary key, and foreign key constraints) are not inherited.

A table can inherit from more than one parent table, in which case it has the union of the columns defined by the parent tables. Any columns declared in the child table's definition are added to these. If the same column name appears in multiple parent tables, or in both a parent table and the child's definition, then these columns are “merged” so that there is only one such column in the child table. To be merged, columns must have the same data types, else an error is raised. Inheritable check constraints and not-null constraints are merged in a similar fashion. Thus, for example, a merged column will be marked not-null if any one of the column definitions it came from is marked not-null. Check constraints are merged if they have the same name, and the merge will fail if their conditions are different.

Table inheritance is typically established when the child table is created, using the `INHERITS` clause of the `CREATE TABLE` statement. Alternatively, a table which is already defined in a compatible way can have a new parent relationship added, using the `INHERIT` variant of `ALTER TABLE`. To do this the new child table must already include columns with the same names and types as the columns of the parent. It must also include check constraints with the same names and check expressions as those of the parent. Similarly an inheritance link can be removed from a child using the `NO INHERIT` variant of `ALTER TABLE`. Dynamically adding and removing inheritance links like this can be useful when the inheritance relationship is being used for table partitioning (see Section 5.11).

One convenient way to create a compatible table that will later be made a new child is to use the `LIKE` clause in `CREATE TABLE`. This creates a new table with the same columns as the source table. If there are any `CHECK` constraints defined on the source table, the `INCLUDING CONSTRAINTS` option to `LIKE` should be specified, as the new child must have constraints matching the parent to be considered compatible.

A parent table cannot be dropped while any of its children remain. Neither can columns or check constraints of child tables be dropped or altered if they are inherited from any parent tables. If you wish to remove a table and all of its descendants, one easy way is to drop the parent table with the `CASCADE` option (see Section 5.14).

`ALTER TABLE` will propagate any changes in column data definitions and check constraints down the inheritance hierarchy. Again, dropping columns that are depended on by other tables is only possible when using the `CASCADE` option. `ALTER TABLE` follows the same rules for duplicate column merging and rejection that apply during `CREATE TABLE`.

Inherited queries perform access permission checks on the parent table only. Thus, for example, granting `UPDATE` permission on the `cities` table implies permission to update rows in the `capitals` table as well, when they are accessed through `cities`. This preserves the appearance that the data is (also) in the parent table. But the `capitals` table could not be updated directly without an additional grant. In a similar way, the parent table's row security policies (see Section 5.8) are applied to rows coming from child tables during an inherited query. A child table's policies, if any, are applied only when it is the table explicitly named in the query; and in that case, any policies attached to its parent(s) are ignored.

Foreign tables (see Section 5.12) can also be part of inheritance hierarchies, either as parent or child tables, just as regular tables can be. If a foreign table is part of an inheritance hierarchy then any operations not supported by the foreign table are not supported on the whole hierarchy either.

## 5.10.1. Caveats

Note that not all SQL commands are able to work on inheritance hierarchies. Commands that are used for data querying, data modification, or schema modification (e.g., `SELECT`, `UPDATE`, `DELETE`, most variants of `ALTER TABLE`, but not `INSERT` or `ALTER TABLE . . . RENAME`) typically default to including child tables and support the `ONLY` notation to exclude them. Commands that do database maintenance and tuning (e.g., `REINDEX`, `VACUUM`) typically only work on individual, physical tables

and do not support recursing over inheritance hierarchies. The respective behavior of each individual command is documented in its reference page (SQL Commands).

A serious limitation of the inheritance feature is that indexes (including unique constraints) and foreign key constraints only apply to single tables, not to their inheritance children. This is true on both the referencing and referenced sides of a foreign key constraint. Thus, in the terms of the above example:

- If we declared `cities.name` to be `UNIQUE` or a `PRIMARY KEY`, this would not stop the `capitals` table from having rows with names duplicating rows in `cities`. And those duplicate rows would by default show up in queries from `cities`. In fact, by default `capitals` would have no unique constraint at all, and so could contain multiple rows with the same name. You could add a unique constraint to `capitals`, but this would not prevent duplication compared to `cities`.
- Similarly, if we were to specify that `cities.name` `REFERENCES` some other table, this constraint would not automatically propagate to `capitals`. In this case you could work around it by manually adding the same `REFERENCES` constraint to `capitals`.
- Specifying that another table's column `REFERENCES cities(name)` would allow the other table to contain city names, but not capital names. There is no good workaround for this case.

Some functionality not implemented for inheritance hierarchies is implemented for declarative partitioning. Considerable care is needed in deciding whether partitioning with legacy inheritance is useful for your application.

## 5.11. Table Partitioning

LightDB supports basic table partitioning. This section describes why and how to implement partitioning as part of your database design.

### 5.11.1. Overview

Partitioning refers to splitting what is logically one large table into smaller physical pieces. Partitioning can provide several benefits:

- Query performance can be improved dramatically in certain situations, particularly when most of the heavily accessed rows of the table are in a single partition or a small number of partitions. Partitioning effectively substitutes for the upper tree levels of indexes, making it more likely that the heavily-used parts of the indexes fit in memory.
- When queries or updates access a large percentage of a single partition, performance can be improved by using a sequential scan of that partition instead of using an index, which would require random-access reads scattered across the whole table.
- Bulk loads and deletes can be accomplished by adding or removing partitions, if the usage pattern is accounted for in the partitioning design. Dropping an individual partition using `DROP TABLE`, or doing `ALTER TABLE DETACH PARTITION`, is far faster than a bulk operation. These commands also entirely avoid the `VACUUM` overhead caused by a bulk `DELETE`.
- Seldom-used data can be migrated to cheaper and slower storage media.

These benefits will normally be worthwhile only when a table would otherwise be very large. The exact point at which a table will benefit from partitioning depends on the application, although a rule of thumb is that the size of the table should exceed the physical memory of the database server.

LightDB offers built-in support for the following forms of partitioning:

#### Range Partitioning

The table is partitioned into “ranges” defined by a key column or set of columns, with no overlap between the ranges of values assigned to different partitions. For example, one might partition by

date ranges, or by ranges of identifiers for particular business objects. Each range's bounds are understood as being inclusive at the lower end and exclusive at the upper end. For example, if one partition's range is from 1 to 10, and the next one's range is from 10 to 20, then value 10 belongs to the second partition not the first.

#### List Partitioning

The table is partitioned by explicitly listing which key value(s) appear in each partition.

#### Hash Partitioning

The table is partitioned by specifying a modulus and a remainder for each partition. Each partition will hold the rows for which the hash value of the partition key divided by the specified modulus will produce the specified remainder.

If your application needs to use other forms of partitioning not listed above, alternative methods such as inheritance and `UNION ALL` views can be used instead. Such methods offer flexibility but do not have some of the performance benefits of built-in declarative partitioning.

## 5.11.2. Declarative Partitioning

LightDB allows you to declare that a table is divided into partitions. The table that is divided is referred to as a *partitioned table*. The declaration includes the *partitioning method* as described above, plus a list of columns or expressions to be used as the *partition key*.

The partitioned table itself is a “virtual” table having no storage of its own. Instead, the storage belongs to *partitions*, which are otherwise-ordinary tables associated with the partitioned table. Each partition stores a subset of the data as defined by its *partition bounds*. All rows inserted into a partitioned table will be routed to the appropriate one of the partitions based on the values of the partition key column(s). Updating the partition key of a row will cause it to be moved into a different partition if it no longer satisfies the partition bounds of its original partition.

Partitions may themselves be defined as partitioned tables, resulting in *sub-partitioning*. Although all partitions must have the same columns as their partitioned parent, partitions may have their own indexes, constraints and default values, distinct from those of other partitions. See `CREATE TABLE` for more details on creating partitioned tables and partitions.

It is not possible to turn a regular table into a partitioned table or vice versa. However, it is possible to add an existing regular or partitioned table as a partition of a partitioned table, or remove a partition from a partitioned table turning it into a standalone table; this can simplify and speed up many maintenance processes. See `ALTER TABLE` to learn more about the `ATTACH PARTITION` and `DETACH PARTITION` sub-commands.

Partitions can also be foreign tables, although considerable care is needed because it is then the user's responsibility that the contents of the foreign table satisfy the partitioning rule. There are some other restrictions as well. See `CREATE FOREIGN TABLE` for more information.

### 5.11.2.1. Example

Suppose we are constructing a database for a large ice cream company. The company measures peak temperatures every day as well as ice cream sales in each region. Conceptually, we want a table like:

```
CREATE TABLE measurement (  
  city_id      int not null,  
  logdate     date not null,  
  peaktemp    int,  
  unitsales   int
```

```
);
```

We know that most queries will access just the last week's, month's or quarter's data, since the main use of this table will be to prepare online reports for management. To reduce the amount of old data that needs to be stored, we decide to keep only the most recent 3 years worth of data. At the beginning of each month we will remove the oldest month's data. In this situation we can use partitioning to help us meet all of our different requirements for the measurements table.

To use declarative partitioning in this case, use the following steps:

1. Create the measurement table as a partitioned table by specifying the `PARTITION BY` clause, which includes the partitioning method (`RANGE` in this case) and the list of column(s) to use as the partition key.

```
CREATE TABLE measurement (
    city_id      int not null,
    logdate     date not null,
    peaktemp    int,
    unitsales   int
) PARTITION BY RANGE (logdate);
```

2. Create partitions. Each partition's definition must specify bounds that correspond to the partitioning method and partition key of the parent. Note that specifying bounds such that the new partition's values would overlap with those in one or more existing partitions will cause an error.

Partitions thus created are in every way normal LightDB tables (or, possibly, foreign tables). It is possible to specify a tablespace and storage parameters for each partition separately.

For our example, each partition should hold one month's worth of data, to match the requirement of deleting one month's data at a time. So the commands might look like:

```
CREATE TABLE measurement_y2006m02 PARTITION OF measurement
    FOR VALUES FROM ('2006-02-01') TO ('2006-03-01');

CREATE TABLE measurement_y2006m03 PARTITION OF measurement
    FOR VALUES FROM ('2006-03-01') TO ('2006-04-01');

...

CREATE TABLE measurement_y2007m11 PARTITION OF measurement
    FOR VALUES FROM ('2007-11-01') TO ('2007-12-01');

CREATE TABLE measurement_y2007m12 PARTITION OF measurement
    FOR VALUES FROM ('2007-12-01') TO ('2008-01-01')
    TABLESPACE fasttablespace;

CREATE TABLE measurement_y2008m01 PARTITION OF measurement
    FOR VALUES FROM ('2008-01-01') TO ('2008-02-01')
    WITH (parallel_workers = 4)
    TABLESPACE fasttablespace;
```

(Recall that adjacent partitions can share a bound value, since range upper bounds are treated as exclusive bounds.)

If you wish to implement sub-partitioning, again specify the `PARTITION BY` clause in the commands used to create individual partitions, for example:

```
CREATE TABLE measurement_y2006m02 PARTITION OF measurement
    FOR VALUES FROM ('2006-02-01') TO ('2006-03-01')
```



```
PARTITION BY RANGE (peaktemp);
```

After creating partitions of `measurement_y2006m02`, any data inserted into `measurement` that is mapped to `measurement_y2006m02` (or data that is directly inserted into `measurement_y2006m02`, which is allowed provided its partition constraint is satisfied) will be further redirected to one of its partitions based on the `peaktemp` column. The partition key specified may overlap with the parent's partition key, although care should be taken when specifying the bounds of a sub-partition such that the set of data it accepts constitutes a subset of what the partition's own bounds allow; the system does not try to check whether that's really the case.

Inserting data into the parent table that does not map to one of the existing partitions will cause an error; an appropriate partition must be added manually.

It is not necessary to manually create table constraints describing the partition boundary conditions for partitions. Such constraints will be created automatically.

3. Create an index on the key column(s), as well as any other indexes you might want, on the partitioned table. (The key index is not strictly necessary, but in most scenarios it is helpful.) This automatically creates a matching index on each partition, and any partitions you create or attach later will also have such an index. An index or unique constraint declared on a partitioned table is “virtual” in the same way that the partitioned table is: the actual data is in child indexes on the individual partition tables.

```
CREATE INDEX ON measurement (logdate);
```

4. Ensure that the `enable_partition_pruning` configuration parameter is not disabled in `lightdb.conf`. If it is, queries will not be optimized as desired.

In the above example we would be creating a new partition each month, so it might be wise to write a script that generates the required DDL automatically.

### 5.11.2.2. Partition Maintenance

Normally the set of partitions established when initially defining the table is not intended to remain static. It is common to want to remove partitions holding old data and periodically add new partitions for new data. One of the most important advantages of partitioning is precisely that it allows this otherwise painful task to be executed nearly instantaneously by manipulating the partition structure, rather than physically moving large amounts of data around.

The simplest option for removing old data is to drop the partition that is no longer necessary:

```
DROP TABLE measurement_y2006m02;
```

This can very quickly delete millions of records because it doesn't have to individually delete every record. Note however that the above command requires taking an `ACCESS EXCLUSIVE` lock on the parent table.

Another option that is often preferable is to remove the partition from the partitioned table but retain access to it as a table in its own right:

```
ALTER TABLE measurement DETACH PARTITION measurement_y2006m02;
```

This allows further operations to be performed on the data before it is dropped. For example, this is often a useful time to back up the data using `COPY`, `lt_dump`, or similar tools. It might also be a useful time to aggregate data into smaller formats, perform other data manipulations, or run reports.

Similarly we can add a new partition to handle new data. We can create an empty partition in the partitioned table just as the original partitions were created above:

```
CREATE TABLE measurement_y2008m02 PARTITION OF measurement
  FOR VALUES FROM ('2008-02-01') TO ('2008-03-01')
  TABLESPACE fasttablespace;
```

As an alternative, it is sometimes more convenient to create the new table outside the partition structure, and make it a proper partition later. This allows new data to be loaded, checked, and transformed prior to it appearing in the partitioned table. The `CREATE TABLE ... LIKE` option is helpful to avoid tediously repeating the parent table's definition:

```
CREATE TABLE measurement_y2008m02
  (LIKE measurement INCLUDING DEFAULTS INCLUDING CONSTRAINTS)
  TABLESPACE fasttablespace;
```

```
ALTER TABLE measurement_y2008m02 ADD CONSTRAINT y2008m02
  CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
  '2008-03-01' );
```

```
\copy measurement_y2008m02 from 'measurement_y2008m02'
-- possibly some other data preparation work
```

```
ALTER TABLE measurement ATTACH PARTITION measurement_y2008m02
  FOR VALUES FROM ('2008-02-01') TO ('2008-03-01' );
```

The `ATTACH PARTITION` command requires taking a `SHARE UPDATE EXCLUSIVE` lock on the partitioned table.

Before running the `ATTACH PARTITION` command, it is recommended to create a `CHECK` constraint on the table to be attached that matches the expected partition constraint, as illustrated above. That way, the system will be able to skip the scan which is otherwise needed to validate the implicit partition constraint. Without the `CHECK` constraint, the table will be scanned to validate the partition constraint while holding an `ACCESS EXCLUSIVE` lock on that partition. It is recommended to drop the now-redundant `CHECK` constraint after the `ATTACH PARTITION` is complete. If the table being attached is itself a partitioned table, then each of its sub-partitions will be recursively locked and scanned until either a suitable `CHECK` constraint is encountered or the leaf partitions are reached.

Similarly, if the partitioned table has a `DEFAULT` partition, it is recommended to create a `CHECK` constraint which excludes the to-be-attached partition's constraint. If this is not done then the `DEFAULT` partition will be scanned to verify that it contains no records which should be located in the partition being attached. This operation will be performed whilst holding an `ACCESS EXCLUSIVE` lock on the `DEFAULT` partition. If the `DEFAULT` partition is itself a partitioned table, then each of its partitions will be recursively checked in the same way as the table being attached, as mentioned above.

As explained above, it is possible to create indexes on partitioned tables so that they are applied automatically to the entire hierarchy. This is very convenient, as not only will the existing partitions become indexed, but also any partitions that are created in the future will. One limitation is that it's not possible to use the `CONCURRENTLY` qualifier when creating such a partitioned index. To avoid long lock times, it is possible to use `CREATE INDEX ON ONLY` the partitioned table; such an index is marked invalid, and the partitions do not get the index applied automatically. The indexes on partitions can be created individually using `CONCURRENTLY`, and then *attached* to the index on the parent using `ALTER INDEX .. ATTACH PARTITION`. Once indexes for all partitions are attached to the parent index, the parent index is marked valid automatically. Example:

```
CREATE INDEX measurement_usls_idx ON ONLY measurement (unitsales);

CREATE INDEX measurement_usls_200602_idx
  ON measurement_y2006m02 (unitsales);
```

```
ALTER INDEX measurement_usls_idx
  ATTACH PARTITION measurement_usls_200602_idx;
...
```

This technique can be used with `UNIQUE` and `PRIMARY KEY` constraints too; the indexes are created implicitly when the constraint is created. Example:

```
ALTER TABLE ONLY measurement ADD UNIQUE (city_id, logdate);

ALTER TABLE measurement_y2006m02 ADD UNIQUE (city_id, logdate);
ALTER INDEX measurement_city_id_logdate_key
  ATTACH PARTITION measurement_y2006m02_city_id_logdate_key;
...
```

### 5.11.2.3. Limitations

The following limitations apply to partitioned tables:

- Unique constraints (and hence primary keys) on partitioned tables must include all the partition key columns. This limitation exists because the individual indexes making up the constraint can only directly enforce uniqueness within their own partitions; therefore, the partition structure itself must guarantee that there are not duplicates in different partitions.
- There is no way to create an exclusion constraint spanning the whole partitioned table. It is only possible to put such a constraint on each leaf partition individually. Again, this limitation stems from not being able to enforce cross-partition restrictions.
- `BEFORE ROW` triggers on `INSERT` cannot change which partition is the final destination for a new row.
- Mixing temporary and permanent relations in the same partition tree is not allowed. Hence, if the partitioned table is permanent, so must be its partitions and likewise if the partitioned table is temporary. When using temporary relations, all members of the partition tree have to be from the same session.

Individual partitions are linked to their partitioned table using inheritance behind-the-scenes. However, it is not possible to use all of the generic features of inheritance with declaratively partitioned tables or their partitions, as discussed below. Notably, a partition cannot have any parents other than the partitioned table it is a partition of, nor can a table inherit from both a partitioned table and a regular table. That means partitioned tables and their partitions never share an inheritance hierarchy with regular tables.

Since a partition hierarchy consisting of the partitioned table and its partitions is still an inheritance hierarchy, `tableoid` and all the normal rules of inheritance apply as described in Section 5.10, with a few exceptions:

- Partitions cannot have columns that are not present in the parent. It is not possible to specify columns when creating partitions with `CREATE TABLE`, nor is it possible to add columns to partitions after-the-fact using `ALTER TABLE`. Tables may be added as a partition with `ALTER TABLE ... ATTACH PARTITION` only if their columns exactly match the parent.
- Both `CHECK` and `NOT NULL` constraints of a partitioned table are always inherited by all its partitions. `CHECK` constraints that are marked `NO INHERIT` are not allowed to be created on partitioned tables. You cannot drop a `NOT NULL` constraint on a partition's column if the same constraint is present in the parent table.
- Using `ONLY` to add or drop a constraint on only the partitioned table is supported as long as there are no partitions. Once partitions exist, using `ONLY` will result in an error. Instead, constraints on the partitions themselves can be added and (if they are not present in the parent table) dropped.

- As a partitioned table does not have any data itself, attempts to use `TRUNCATE ONLY` on a partitioned table will always return an error.

### 5.11.3. Partitioning Using Inheritance

While the built-in declarative partitioning is suitable for most common use cases, there are some circumstances where a more flexible approach may be useful. Partitioning can be implemented using table inheritance, which allows for several features not supported by declarative partitioning, such as:

- For declarative partitioning, partitions must have exactly the same set of columns as the partitioned table, whereas with table inheritance, child tables may have extra columns not present in the parent.
- Table inheritance allows for multiple inheritance.
- Declarative partitioning only supports range, list and hash partitioning, whereas table inheritance allows data to be divided in a manner of the user's choosing. (Note, however, that if constraint exclusion is unable to prune child tables effectively, query performance might be poor.)
- Some operations require a stronger lock when using declarative partitioning than when using table inheritance. For example, removing a partition from a partitioned table requires taking an `ACCESS EXCLUSIVE` lock on the parent table, whereas a `SHARE UPDATE EXCLUSIVE` lock is enough in the case of regular inheritance.

#### 5.11.3.1. Example

This example builds a partitioning structure equivalent to the declarative partitioning example above. Use the following steps:

1. Create the “master” table, from which all of the “child” tables will inherit. This table will contain no data. Do not define any check constraints on this table, unless you intend them to be applied equally to all child tables. There is no point in defining any indexes or unique constraints on it, either. For our example, the master table is the `measurement` table as originally defined:

```
CREATE TABLE measurement (
    city_id          int not null,
    logdate          date not null,
    peaktemp         int,
    unitsales        int
);
```

2. Create several “child” tables that each inherit from the master table. Normally, these tables will not add any columns to the set inherited from the master. Just as with declarative partitioning, these tables are in every way normal LightDB tables (or foreign tables).

```
CREATE TABLE measurement_y2006m02 () INHERITS (measurement);
CREATE TABLE measurement_y2006m03 () INHERITS (measurement);
...
CREATE TABLE measurement_y2007m11 () INHERITS (measurement);
CREATE TABLE measurement_y2007m12 () INHERITS (measurement);
CREATE TABLE measurement_y2008m01 () INHERITS (measurement);
```

3. Add non-overlapping table constraints to the child tables to define the allowed key values in each.

Typical examples would be:

```
CHECK ( x = 1 )
CHECK ( county IN ( 'Oxfordshire', 'Buckinghamshire',
    'Warwickshire' ))
CHECK ( outletID >= 100 AND outletID < 200 )
```

Ensure that the constraints guarantee that there is no overlap between the key values permitted in different child tables. A common mistake is to set up range constraints like:

```
CHECK ( outletID BETWEEN 100 AND 200 )
CHECK ( outletID BETWEEN 200 AND 300 )
```

This is wrong since it is not clear which child table the key value 200 belongs in. Instead, ranges should be defined in this style:

```
CREATE TABLE measurement_y2006m02 (
    CHECK ( logdate >= DATE '2006-02-01' AND logdate < DATE
    '2006-03-01' )
) INHERITS (measurement);
```

```
CREATE TABLE measurement_y2006m03 (
    CHECK ( logdate >= DATE '2006-03-01' AND logdate < DATE
    '2006-04-01' )
) INHERITS (measurement);
```

...

```
CREATE TABLE measurement_y2007m11 (
    CHECK ( logdate >= DATE '2007-11-01' AND logdate < DATE
    '2007-12-01' )
) INHERITS (measurement);
```

```
CREATE TABLE measurement_y2007m12 (
    CHECK ( logdate >= DATE '2007-12-01' AND logdate < DATE
    '2008-01-01' )
) INHERITS (measurement);
```

```
CREATE TABLE measurement_y2008m01 (
    CHECK ( logdate >= DATE '2008-01-01' AND logdate < DATE
    '2008-02-01' )
) INHERITS (measurement);
```

4. For each child table, create an index on the key column(s), as well as any other indexes you might want.

```
CREATE INDEX measurement_y2006m02_logdate ON
measurement_y2006m02 (logdate);
CREATE INDEX measurement_y2006m03_logdate ON
measurement_y2006m03 (logdate);
CREATE INDEX measurement_y2007m11_logdate ON
measurement_y2007m11 (logdate);
CREATE INDEX measurement_y2007m12_logdate ON
measurement_y2007m12 (logdate);
CREATE INDEX measurement_y2008m01_logdate ON
measurement_y2008m01 (logdate);
```

5. We want our application to be able to say `INSERT INTO measurement ...` and have the data be redirected into the appropriate child table. We can arrange that by attaching a suitable trigger function to the master table. If data will be added only to the latest child, we can use a very simple trigger function:

```
CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
```

```

BEGIN
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;

```

After creating the function, we create a trigger which calls the trigger function:

```

CREATE TRIGGER insert_measurement_trigger
    BEFORE INSERT ON measurement
    FOR EACH ROW EXECUTE FUNCTION measurement_insert_trigger();

```

We must redefine the trigger function each month so that it always inserts into the current child table. The trigger definition does not need to be updated, however.

We might want to insert data and have the server automatically locate the child table into which the row should be added. We could do this with a more complex trigger function, for example:

```

CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
BEGIN
    IF ( NEW.logdate >= DATE '2006-02-01' AND
        NEW.logdate < DATE '2006-03-01' ) THEN
        INSERT INTO measurement_y2006m02 VALUES (NEW.*);
    ELSIF ( NEW.logdate >= DATE '2006-03-01' AND
        NEW.logdate < DATE '2006-04-01' ) THEN
        INSERT INTO measurement_y2006m03 VALUES (NEW.*);
    . . .
    ELSIF ( NEW.logdate >= DATE '2008-01-01' AND
        NEW.logdate < DATE '2008-02-01' ) THEN
        INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    ELSE
        RAISE EXCEPTION 'Date out of range. Fix the
measurement_insert_trigger() function!';
    END IF;
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;

```

The trigger definition is the same as before. Note that each IF test must exactly match the CHECK constraint for its child table.

While this function is more complex than the single-month case, it doesn't need to be updated as often, since branches can be added in advance of being needed.

### Note

In practice, it might be best to check the newest child first, if most inserts go into that child. For simplicity, we have shown the trigger's tests in the same order as in other parts of this example.

A different approach to redirecting inserts into the appropriate child table is to set up rules, instead of a trigger, on the master table. For example:

```

CREATE RULE measurement_insert_y2006m02 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2006-02-01' AND logdate < DATE
      '2006-03-01' )
DO INSTEAD
    INSERT INTO measurement_y2006m02 VALUES (NEW.*);
...
CREATE RULE measurement_insert_y2008m01 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2008-01-01' AND logdate < DATE
      '2008-02-01' )
DO INSTEAD
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);

```

A rule has significantly more overhead than a trigger, but the overhead is paid once per query rather than once per row, so this method might be advantageous for bulk-insert situations. In most cases, however, the trigger method will offer better performance.

Be aware that `COPY` ignores rules. If you want to use `COPY` to insert data, you'll need to copy into the correct child table rather than directly into the master. `COPY` does fire triggers, so you can use it normally if you use the trigger approach.

Another disadvantage of the rule approach is that there is no simple way to force an error if the set of rules doesn't cover the insertion date; the data will silently go into the master table instead.

6. Ensure that the `constraint_exclusion` configuration parameter is not disabled in `lightdb.conf`; otherwise child tables may be accessed unnecessarily.

As we can see, a complex table hierarchy could require a substantial amount of DDL. In the above example we would be creating a new child table each month, so it might be wise to write a script that generates the required DDL automatically.

### 5.11.3.2. Maintenance for Inheritance Partitioning

To remove old data quickly, simply drop the child table that is no longer necessary:

```
DROP TABLE measurement_y2006m02;
```

To remove the child table from the inheritance hierarchy table but retain access to it as a table in its own right:

```
ALTER TABLE measurement_y2006m02 NO INHERIT measurement;
```

To add a new child table to handle new data, create an empty child table just as the original children were created above:

```

CREATE TABLE measurement_y2008m02 (
    CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
      '2008-03-01' )
) INHERITS (measurement);

```

Alternatively, one may want to create and populate the new child table before adding it to the table hierarchy. This could allow data to be loaded, checked, and transformed before being made visible to queries on the parent table.

```

CREATE TABLE measurement_y2008m02
  (LIKE measurement INCLUDING DEFAULTS INCLUDING CONSTRAINTS);
ALTER TABLE measurement_y2008m02 ADD CONSTRAINT y2008m02
  CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
    '2008-03-01' );
\copy measurement_y2008m02 from 'measurement_y2008m02'
-- possibly some other data preparation work
ALTER TABLE measurement_y2008m02 INHERIT measurement;

```

### 5.11.3.3. Caveats

The following caveats apply to partitioning implemented using inheritance:

- There is no automatic way to verify that all of the CHECK constraints are mutually exclusive. It is safer to create code that generates child tables and creates and/or modifies associated objects than to write each by hand.
- Indexes and foreign key constraints apply to single tables and not to their inheritance children, hence they have some caveats to be aware of.
- The schemes shown here assume that the values of a row's key column(s) never change, or at least do not change enough to require it to move to another partition. An UPDATE that attempts to do that will fail because of the CHECK constraints. If you need to handle such cases, you can put suitable update triggers on the child tables, but it makes management of the structure much more complicated.
- If you are using manual VACUUM or ANALYZE commands, don't forget that you need to run them on each child table individually. A command like:

```
ANALYZE measurement;
```

will only process the master table.

- INSERT statements with ON CONFLICT clauses are unlikely to work as expected, as the ON CONFLICT action is only taken in case of unique violations on the specified target relation, not its child relations.
- Triggers or rules will be needed to route rows to the desired child table, unless the application is explicitly aware of the partitioning scheme. Triggers may be complicated to write, and will be much slower than the tuple routing performed internally by declarative partitioning.

### 5.11.4. Partition Pruning

*Partition pruning* is a query optimization technique that improves performance for declaratively partitioned tables. As an example:

```

SET enable_partition_pruning = on;           -- the default
SELECT count(*) FROM measurement WHERE logdate >= DATE
  '2008-01-01';

```

Without partition pruning, the above query would scan each of the partitions of the measurement table. With partition pruning enabled, the planner will examine the definition of each partition and prove that the partition need not be scanned because it could not contain any rows meeting the query's WHERE clause. When the planner can prove this, it excludes (*prunes*) the partition from the query plan.

By using the EXPLAIN command and the enable\_partition\_pruning configuration parameter, it's possible to show the difference between a plan for which partitions have been pruned and one for which they have not. A typical unoptimized plan for this type of table setup is:



```
SET enable_partition_pruning = off;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE
'2008-01-01';
```

QUERY PLAN

```
-----
Aggregate (cost=188.76..188.77 rows=1 width=8)
-> Append (cost=0.00..181.05 rows=3085 width=0)
    -> Seq Scan on measurement_y2006m02 (cost=0.00..33.12
rows=617 width=0)
        Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2006m03 (cost=0.00..33.12
rows=617 width=0)
        Filter: (logdate >= '2008-01-01'::date)
...
    -> Seq Scan on measurement_y2007m11 (cost=0.00..33.12
rows=617 width=0)
        Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2007m12 (cost=0.00..33.12
rows=617 width=0)
        Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2008m01 (cost=0.00..33.12
rows=617 width=0)
        Filter: (logdate >= '2008-01-01'::date)
```

Some or all of the partitions might use index scans instead of full-table sequential scans, but the point here is that there is no need to scan the older partitions at all to answer this query. When we enable partition pruning, we get a significantly cheaper plan that will deliver the same answer:

```
SET enable_partition_pruning = on;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE
'2008-01-01';
```

QUERY PLAN

```
-----
Aggregate (cost=37.75..37.76 rows=1 width=8)
-> Seq Scan on measurement_y2008m01 (cost=0.00..33.12 rows=617
width=0)
    Filter: (logdate >= '2008-01-01'::date)
```

Note that partition pruning is driven only by the constraints defined implicitly by the partition keys, not by the presence of indexes. Therefore it isn't necessary to define indexes on the key columns. Whether an index needs to be created for a given partition depends on whether you expect that queries that scan the partition will generally scan a large part of the partition or just a small part. An index will be helpful in the latter case but not the former.

Partition pruning can be performed not only during the planning of a given query, but also during its execution. This is useful as it can allow more partitions to be pruned when clauses contain expressions whose values are not known at query planning time, for example, parameters defined in a PREPARE statement, using a value obtained from a subquery, or using a parameterized value on the inner side of a nested loop join. Partition pruning during execution can be performed at any of the following times:

- During initialization of the query plan. Partition pruning can be performed here for parameter values which are known during the initialization phase of execution. Partitions which are pruned during this stage will not show up in the query's EXPLAIN or EXPLAIN ANALYZE. It is possible to determine the number of partitions which were removed during this phase by observing the "Subplans Removed" property in the EXPLAIN output.

- During actual execution of the query plan. Partition pruning may also be performed here to remove partitions using values which are only known during actual query execution. This includes values from subqueries and values from execution-time parameters such as those from parameterized nested loop joins. Since the value of these parameters may change many times during the execution of the query, partition pruning is performed whenever one of the execution parameters being used by partition pruning changes. Determining if partitions were pruned during this phase requires careful inspection of the `loops` property in the `EXPLAIN ANALYZE` output. Subplans corresponding to different partitions may have different values for it depending on how many times each of them was pruned during execution. Some may be shown as `(never executed)` if they were pruned every time.

Partition pruning can be disabled using the `enable_partition_pruning` setting.

### Note

Execution-time partition pruning currently only occurs for the `Append` and `MergeAppend` node types. It is not yet implemented for the `ModifyTable` node type, but that is likely to be changed in a future release of LightDB.

## 5.11.5. Partitioning and Constraint Exclusion

*Constraint exclusion* is a query optimization technique similar to partition pruning. While it is primarily used for partitioning implemented using the legacy inheritance method, it can be used for other purposes, including with declarative partitioning.

Constraint exclusion works in a very similar way to partition pruning, except that it uses each table's `CHECK` constraints — which gives it its name — whereas partition pruning uses the table's partition bounds, which exist only in the case of declarative partitioning. Another difference is that constraint exclusion is only applied at plan time; there is no attempt to remove partitions at execution time.

The fact that constraint exclusion uses `CHECK` constraints, which makes it slow compared to partition pruning, can sometimes be used as an advantage: because constraints can be defined even on declaratively-partitioned tables, in addition to their internal partition bounds, constraint exclusion may be able to elide additional partitions from the query plan.

The default (and recommended) setting of `constraint_exclusion` is neither `on` nor `off`, but an intermediate setting called `partition`, which causes the technique to be applied only to queries that are likely to be working on inheritance partitioned tables. The `on` setting causes the planner to examine `CHECK` constraints in all queries, even simple ones that are unlikely to benefit.

The following caveats apply to constraint exclusion:

- Constraint exclusion is only applied during query planning, unlike partition pruning, which can also be applied during query execution.
- Constraint exclusion only works when the query's `WHERE` clause contains constants (or externally supplied parameters). For example, a comparison against a non-immutable function such as `CURRENT_TIMESTAMP` cannot be optimized, since the planner cannot know which child table the function's value might fall into at run time.
- Keep the partitioning constraints simple, else the planner may not be able to prove that child tables might not need to be visited. Use simple equality conditions for list partitioning, or simple range tests for range partitioning, as illustrated in the preceding examples. A good rule of thumb is that partitioning constraints should contain only comparisons of the partitioning column(s) to constants using B-tree-indexable operators, because only B-tree-indexable column(s) are allowed in the partition key.

- All constraints on all children of the parent table are examined during constraint exclusion, so large numbers of children are likely to increase query planning time considerably. So the legacy inheritance based partitioning will work well with up to perhaps a hundred child tables; don't try to use many thousands of children.

## 5.11.6. Best Practices for Declarative Partitioning

The choice of how to partition a table should be made carefully, as the performance of query planning and execution can be negatively affected by poor design.

One of the most critical design decisions will be the column or columns by which you partition your data. Often the best choice will be to partition by the column or set of columns which most commonly appear in `WHERE` clauses of queries being executed on the partitioned table. `WHERE` clauses that are compatible with the partition bound constraints can be used to prune unneeded partitions. However, you may be forced into making other decisions by requirements for the `PRIMARY KEY` or a `UNIQUE` constraint. Removal of unwanted data is also a factor to consider when planning your partitioning strategy. An entire partition can be detached fairly quickly, so it may be beneficial to design the partition strategy in such a way that all data to be removed at once is located in a single partition.

Choosing the target number of partitions that the table should be divided into is also a critical decision to make. Not having enough partitions may mean that indexes remain too large and that data locality remains poor which could result in low cache hit ratios. However, dividing the table into too many partitions can also cause issues. Too many partitions can mean longer query planning times and higher memory consumption during both query planning and execution, as further described below. When choosing how to partition your table, it's also important to consider what changes may occur in the future. For example, if you choose to have one partition per customer and you currently have a small number of large customers, consider the implications if in several years you instead find yourself with a large number of small customers. In this case, it may be better to choose to partition by `HASH` and choose a reasonable number of partitions rather than trying to partition by `LIST` and hoping that the number of customers does not increase beyond what it is practical to partition the data by.

Sub-partitioning can be useful to further divide partitions that are expected to become larger than other partitions. Another option is to use range partitioning with multiple columns in the partition key. Either of these can easily lead to excessive numbers of partitions, so restraint is advisable.

It is important to consider the overhead of partitioning during query planning and execution. The query planner is generally able to handle partition hierarchies with up to a few thousand partitions fairly well, provided that typical queries allow the query planner to prune all but a small number of partitions. Planning times become longer and memory consumption becomes higher when more partitions remain after the planner performs partition pruning. This is particularly true for the `UPDATE` and `DELETE` commands. Another reason to be concerned about having a large number of partitions is that the server's memory consumption may grow significantly over time, especially if many sessions touch large numbers of partitions. That's because each partition requires its metadata to be loaded into the local memory of each session that touches it.

With data warehouse type workloads, it can make sense to use a larger number of partitions than with an OLTP type workload. Generally, in data warehouses, query planning time is less of a concern as the majority of processing time is spent during query execution. With either of these two types of workload, it is important to make the right decisions early, as re-partitioning large quantities of data can be painfully slow. Simulations of the intended workload are often beneficial for optimizing the partitioning strategy. Never just assume that more partitions are better than fewer partitions, nor vice-versa.

## 5.12. Foreign Data

LightDB implements portions of the SQL/MED specification, allowing you to access data that resides outside LightDB using regular SQL queries. Such data is referred to as *foreign data*. (Note that this usage is not to be confused with foreign keys, which are a type of constraint within the database.)

Foreign data is accessed with help from a *foreign data wrapper*. A foreign data wrapper is a library that can communicate with an external data source, hiding the details of connecting to the data source and obtaining data from it. There are some foreign data wrappers available as `contrib` modules; see Appendix F. Other kinds of foreign data wrappers might be found as third party products. If none of the existing foreign data wrappers suit your needs, you can write your own; see Chapter 53.

To access foreign data, you need to create a *foreign server* object, which defines how to connect to a particular external data source according to the set of options used by its supporting foreign data wrapper. Then you need to create one or more *foreign tables*, which define the structure of the remote data. A foreign table can be used in queries just like a normal table, but a foreign table has no storage in the LightDB server. Whenever it is used, LightDB asks the foreign data wrapper to fetch data from the external source, or transmit data to the external source in the case of update commands.

Accessing remote data may require authenticating to the external data source. This information can be provided by a *user mapping*, which can provide additional data such as user names and passwords based on the current LightDB role.

For additional information, see `CREATE FOREIGN DATA WRAPPER`, `CREATE SERVER`, `CREATE USER MAPPING`, `CREATE FOREIGN TABLE`, and `IMPORT FOREIGN SCHEMA`.

## 5.13. Other Database Objects

Tables are the central objects in a relational database structure, because they hold your data. But they are not the only objects that exist in a database. Many other kinds of objects can be created to make the use and management of the data more efficient or convenient. They are not discussed in this chapter, but we give you a list here so that you are aware of what is possible:

- Views
- Functions, procedures, and operators
- Data types and domains
- Triggers and rewrite rules

Detailed information on these topics appears in Part V.

## 5.14. Dependency Tracking

When you create complex database structures involving many tables with foreign key constraints, views, triggers, functions, etc. you implicitly create a net of dependencies between the objects. For instance, a table with a foreign key constraint depends on the table it references.

To ensure the integrity of the entire database structure, LightDB makes sure that you cannot drop objects that other objects still depend on. For example, attempting to drop the `products` table we considered in Section 5.4.5, with the `orders` table depending on it, would result in an error message like this:

```
DROP TABLE products;
```

```
ERROR:  cannot drop table products because other objects depend on
it
```

```
DETAIL:  constraint orders_product_no_fkey on table orders depends
on table products
```

```
HINT:   Use DROP ... CASCADE to drop the dependent objects too.
```

The error message contains a useful hint: if you do not want to bother deleting all the dependent objects individually, you can run:

```
DROP TABLE products CASCADE;
```

and all the dependent objects will be removed, as will any objects that depend on them, recursively. In this case, it doesn't remove the orders table, it only removes the foreign key constraint. It stops there because nothing depends on the foreign key constraint. (If you want to check what `DROP . . . CASCADE` will do, run `DROP` without `CASCADE` and read the `DETAIL` output.)

Almost all `DROP` commands in LightDB support specifying `CASCADE`. Of course, the nature of the possible dependencies varies with the type of the object. You can also write `RESTRICT` instead of `CASCADE` to get the default behavior, which is to prevent dropping objects that any other objects depend on.

### Note

According to the SQL standard, specifying either `RESTRICT` or `CASCADE` is required in a `DROP` command. No database system actually enforces that rule, but whether the default behavior is `RESTRICT` or `CASCADE` varies across systems.

If a `DROP` command lists multiple objects, `CASCADE` is only required when there are dependencies outside the specified group. For example, when saying `DROP TABLE tab1, tab2` the existence of a foreign key referencing `tab1` from `tab2` would not mean that `CASCADE` is needed to succeed.

For user-defined functions, LightDB tracks dependencies associated with a function's externally-visible properties, such as its argument and result types, but *not* dependencies that could only be known by examining the function body. As an example, consider this situation:

```
CREATE TYPE rainbow AS ENUM ('red', 'orange', 'yellow',
                             'green', 'blue', 'purple');

CREATE TABLE my_colors (color rainbow, note text);

CREATE FUNCTION get_color_note (rainbow) RETURNS text AS
  'SELECT note FROM my_colors WHERE color = $1'
  LANGUAGE SQL;
```

(See Section 36.5 for an explanation of SQL-language functions.) LightDB will be aware that the `get_color_note` function depends on the `rainbow` type: dropping the type would force dropping the function, because its argument type would no longer be defined. But LightDB will not consider `get_color_note` to depend on the `my_colors` table, and so will not drop the function if the table is dropped. While there are disadvantages to this approach, there are also benefits. The function is still valid in some sense if the table is missing, though executing it would cause an error; creating a new table of the same name would allow the function to work again.

## 5.15. LightDB DDL Specification Check

When you use DDL statements, LightDB will first check whether your statements comply with the specification.

Refer `lt_sql_inspect` for details.

---

# Chapter 6. Data Manipulation

The previous chapter discussed how to create tables and other structures to hold your data. Now it is time to fill the tables with data. This chapter covers how to insert, update, and delete table data. The chapter after this will finally explain how to extract your long-lost data from the database.

## 6.1. Inserting Data

When a table is created, it contains no data. The first thing to do before a database can be of much use is to insert data. Data is conceptually inserted one row at a time. Of course you can also insert more than one row, but there is no way to insert less than one row. Even if you know only some column values, a complete row must be created.

To create a new row, use the `INSERT` command. The command requires the table name and column values. For example, consider the `products` table from Chapter 5:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric  
);
```

An example command to insert a row would be:

```
INSERT INTO products VALUES (1, 'Cheese', 9.99);
```

The data values are listed in the order in which the columns appear in the table, separated by commas. Usually, the data values will be literals (constants), but scalar expressions are also allowed.

The above syntax has the drawback that you need to know the order of the columns in the table. To avoid this you can also list the columns explicitly. For example, both of the following commands have the same effect as the one above:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese',  
9.99);  
INSERT INTO products (name, price, product_no) VALUES ('Cheese',  
9.99, 1);
```

Many users consider it good practice to always list the column names.

If you don't have values for all the columns, you can omit some of them. In that case, the columns will be filled with their default values. For example:

```
INSERT INTO products (product_no, name) VALUES (1, 'Cheese');  
INSERT INTO products VALUES (1, 'Cheese');
```

The second form is a LightDB extension. It fills the columns from the left with as many values as are given, and the rest will be defaulted.

For clarity, you can also request default values explicitly, for individual columns or for the entire row:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese',  
DEFAULT);
```

```
INSERT INTO products DEFAULT VALUES;
```

You can insert multiple rows in a single command:

```
INSERT INTO products (product_no, name, price) VALUES
  (1, 'Cheese', 9.99),
  (2, 'Bread', 1.99),
  (3, 'Milk', 2.99);
```

It is also possible to insert the result of a query (which might be no rows, one row, or many rows):

```
INSERT INTO products (product_no, name, price)
  SELECT product_no, name, price FROM new_products
  WHERE release_date = 'today';
```

This provides the full power of the SQL query mechanism (Chapter 7) for computing the rows to be inserted.

### Tip

When inserting a lot of data at the same time, consider using the COPY command. It is not as flexible as the INSERT command, but is more efficient. Refer to Section 14.4 for more information on improving bulk loading performance.

## 6.2. Updating Data

The modification of data that is already in the database is referred to as updating. You can update individual rows, all the rows in a table, or a subset of all rows. Each column can be updated separately; the other columns are not affected.

To update existing rows, use the UPDATE command. This requires three pieces of information:

1. The name of the table and column to update
2. The new value of the column
3. Which row(s) to update

Recall from Chapter 5 that SQL does not, in general, provide a unique identifier for rows. Therefore it is not always possible to directly specify which row to update. Instead, you specify which conditions a row must meet in order to be updated. Only if you have a primary key in the table (independent of whether you declared it or not) can you reliably address individual rows by choosing a condition that matches the primary key. Graphical database access tools rely on this fact to allow you to update rows individually.

For example, this command updates all products that have a price of 5 to have a price of 10:

```
UPDATE products SET price = 10 WHERE price = 5;
```

This might cause zero, one, or many rows to be updated. It is not an error to attempt an update that does not match any rows.

Let's look at that command in detail. First is the key word UPDATE followed by the table name. As usual, the table name can be schema-qualified, otherwise it is looked up in the path. Next is the key word SET followed by the column name, an equal sign, and the new column value. The new column value can be any scalar expression, not just a constant. For example, if you want to raise the price of all products by 10% you could use:

```
UPDATE products SET price = price * 1.10;
```

As you see, the expression for the new value can refer to the existing value(s) in the row. We also left out the `WHERE` clause. If it is omitted, it means that all rows in the table are updated. If it is present, only those rows that match the `WHERE` condition are updated. Note that the equals sign in the `SET` clause is an assignment while the one in the `WHERE` clause is a comparison, but this does not create any ambiguity. Of course, the `WHERE` condition does not have to be an equality test. Many other operators are available (see Chapter 9). But the expression needs to evaluate to a Boolean result.

You can update more than one column in an `UPDATE` command by listing more than one assignment in the `SET` clause. For example:

```
UPDATE mytable SET a = 5, b = 3, c = 1 WHERE a > 0;
```

## 6.3. Deleting Data

So far we have explained how to add data to tables and how to change data. What remains is to discuss how to remove data that is no longer needed. Just as adding data is only possible in whole rows, you can only remove entire rows from a table. In the previous section we explained that SQL does not provide a way to directly address individual rows. Therefore, removing rows can only be done by specifying conditions that the rows to be removed have to match. If you have a primary key in the table then you can specify the exact row. But you can also remove groups of rows matching a condition, or you can remove all rows in the table at once.

You use the `DELETE` command to remove rows; the syntax is very similar to the `UPDATE` command. For instance, to remove all rows from the `products` table that have a price of 10, use:

```
DELETE FROM products WHERE price = 10;
```

If you simply write:

```
DELETE FROM products;
```

then all rows in the table will be deleted! Caveat programmer.

## 6.4. Returning Data from Modified Rows

Sometimes it is useful to obtain data from modified rows while they are being manipulated. The `INSERT`, `UPDATE`, and `DELETE` commands all have an optional `RETURNING` clause that supports this. Use of `RETURNING` avoids performing an extra database query to collect the data, and is especially valuable when it would otherwise be difficult to identify the modified rows reliably.

The allowed contents of a `RETURNING` clause are the same as a `SELECT` command's output list (see Section 7.3). It can contain column names of the command's target table, or value expressions using those columns. A common shorthand is `RETURNING *`, which selects all columns of the target table in order.

In an `INSERT`, the data available to `RETURNING` is the row as it was inserted. This is not so useful in trivial inserts, since it would just repeat the data provided by the client. But it can be very handy when relying on computed default values. For example, when using a `serial` column to provide unique identifiers, `RETURNING` can return the ID assigned to a new row:

```
CREATE TABLE users (firstname text, lastname text, id serial  
primary key);
```



```
INSERT INTO users (firstname, lastname) VALUES ('Joe', 'Cool')
RETURNING id;
```

The RETURNING clause is also very useful with INSERT ... SELECT.

In an UPDATE, the data available to RETURNING is the new content of the modified row. For example:

```
UPDATE products SET price = price * 1.10
WHERE price <= 99.99
RETURNING name, price AS new_price;
```

In a DELETE, the data available to RETURNING is the content of the deleted row. For example:

```
DELETE FROM products
WHERE obsolescence_date = 'today'
RETURNING *;
```

If there are triggers (Chapter 37) on the target table, the data available to RETURNING is the row as modified by the triggers. Thus, inspecting columns computed by triggers is another common use-case for RETURNING.

## 6.5. LightDB DML Specification Check

When you use DML statements, LightDB will first check whether your statements comply with the specification.

Refer `lt_sql_inspect` for details.

---

# Chapter 7. Queries

The previous chapters explained how to create tables, how to fill them with data, and how to manipulate that data. Now we finally discuss how to retrieve the data from the database.

## 7.1. Overview

The process of retrieving or the command to retrieve data from a database is called a *query*. In SQL the `SELECT` command is used to specify queries. The general syntax of the `SELECT` command is

```
[WITH with_queries] SELECT select_list FROM table_expression
[sort_specification]
```

The following sections describe the details of the select list, the table expression, and the sort specification. `WITH` queries are treated last since they are an advanced feature.

A simple kind of query has the form:

```
SELECT * FROM table1;
```

Assuming that there is a table called `table1`, this command would retrieve all rows and all user-defined columns from `table1`. (The method of retrieval depends on the client application. For example, the `lsql` program will display an ASCII-art table on the screen, while client libraries will offer functions to extract individual values from the query result.) The select list specification `*` means all columns that the table expression happens to provide. A select list can also select a subset of the available columns or make calculations using the columns. For example, if `table1` has columns named `a`, `b`, and `c` (and perhaps others) you can make the following query:

```
SELECT a, b + c FROM table1;
```

(assuming that `b` and `c` are of a numerical data type). See Section 7.3 for more details.

`FROM table1` is a simple kind of table expression: it reads just one table. In general, table expressions can be complex constructs of base tables, joins, and subqueries. But you can also omit the table expression entirely and use the `SELECT` command as a calculator:

```
SELECT 3 * 4;
```

This is more useful if the expressions in the select list return varying results. For example, you could call a function this way:

```
SELECT random();
```

## 7.2. Table Expressions

A *table expression* computes a table. The table expression contains a `FROM` clause that is optionally followed by `WHERE`, `GROUP BY`, and `HAVING` clauses. Trivial table expressions simply refer to a table on disk, a so-called base table, but more complex expressions can be used to modify or combine base tables in various ways.

The optional `WHERE`, `GROUP BY`, and `HAVING` clauses in the table expression specify a pipeline of successive transformations performed on the table derived in the `FROM` clause. All these

transformations produce a virtual table that provides the rows that are passed to the select list to compute the output rows of the query.

## 7.2.1. The FROM Clause

The FROM clause derives a table from one or more other tables given in a comma-separated table reference list.

```
FROM table_reference [, table_reference [, ...]]
```

A table reference can be a table name (possibly schema-qualified), or a derived table such as a subquery, a JOIN construct, or complex combinations of these. If more than one table reference is listed in the FROM clause, the tables are cross-joined (that is, the Cartesian product of their rows is formed; see below). The result of the FROM list is an intermediate virtual table that can then be subject to transformations by the WHERE, GROUP BY, and HAVING clauses and is finally the result of the overall table expression.

When a table reference names a table that is the parent of a table inheritance hierarchy, the table reference produces rows of not only that table but all of its descendant tables, unless the key word ONLY precedes the table name. However, the reference produces only the columns that appear in the named table — any columns added in subtables are ignored.

Instead of writing ONLY before the table name, you can write \* after the table name to explicitly specify that descendant tables are included. There is no real reason to use this syntax any more, because searching descendant tables is now always the default behavior. However, it is supported for compatibility with older releases.

### 7.2.1.1. Joined Tables

A joined table is a table derived from two other (real or derived) tables according to the rules of the particular join type. Inner, outer, and cross-joins are available. The general syntax of a joined table is

```
T1 join_type T2 [ join_condition ]
```

Joins of all types can be chained together, or nested: either or both *T1* and *T2* can be joined tables. Parentheses can be used around JOIN clauses to control the join order. In the absence of parentheses, JOIN clauses nest left-to-right.

#### Join Types

Cross join

```
T1 CROSS JOIN T2
```

For every possible combination of rows from *T1* and *T2* (i.e., a Cartesian product), the joined table will contain a row consisting of all columns in *T1* followed by all columns in *T2*. If the tables have N and M rows respectively, the joined table will have N \* M rows.

FROM *T1* CROSS JOIN *T2* is equivalent to FROM *T1* INNER JOIN *T2* ON TRUE (see below). It is also equivalent to FROM *T1*, *T2*.

#### Note

This latter equivalence does not hold exactly when more than two tables appear, because JOIN binds more tightly than comma. For example FROM *T1* CROSS JOIN *T2* INNER JOIN *T3* ON *condition* is not the same as FROM

*T1*, *T2* INNER JOIN *T3* ON *condition* because the *condition* can reference *T1* in the first case but not the second.

### Qualified joins

```
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2
  ON boolean_expression
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2 USING
  ( join column list )
T1 NATURAL { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2
```

The words INNER and OUTER are optional in all forms. INNER is the default; LEFT, RIGHT, and FULL imply an outer join.

The *join condition* is specified in the ON or USING clause, or implicitly by the word NATURAL. The join condition determines which rows from the two source tables are considered to “match”, as explained in detail below.

The possible types of qualified join are:

#### INNER JOIN

For each row R1 of T1, the joined table has a row for each row in T2 that satisfies the join condition with R1.

#### LEFT OUTER JOIN

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Thus, the joined table always has at least one row for each row in T1.

#### RIGHT OUTER JOIN

First, an inner join is performed. Then, for each row in T2 that does not satisfy the join condition with any row in T1, a joined row is added with null values in columns of T1. This is the converse of a left join: the result table will always have a row for each row in T2.

#### FULL OUTER JOIN

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Also, for each row of T2 that does not satisfy the join condition with any row in T1, a joined row with null values in the columns of T1 is added.

The ON clause is the most general kind of join condition: it takes a Boolean value expression of the same kind as is used in a WHERE clause. A pair of rows from *T1* and *T2* match if the ON expression evaluates to true.

The USING clause is a shorthand that allows you to take advantage of the specific situation where both sides of the join use the same name for the joining column(s). It takes a comma-separated list of the shared column names and forms a join condition that includes an equality comparison for each one. For example, joining *T1* and *T2* with USING (*a*, *b*) produces the join condition ON *T1.a* = *T2.a* AND *T1.b* = *T2.b*.

Furthermore, the output of JOIN USING suppresses redundant columns: there is no need to print both of the matched columns, since they must have equal values. While JOIN ON produces all columns from *T1* followed by all columns from *T2*, JOIN USING produces one output column for each of the listed column pairs (in the listed order), followed by any remaining columns from *T1*, followed by any remaining columns from *T2*.

Finally, `NATURAL` is a shorthand form of `USING`: it forms a `USING` list consisting of all column names that appear in both input tables. As with `USING`, these columns appear only once in the output table. If there are no common column names, `NATURAL JOIN` behaves like `JOIN . . . ON TRUE`, producing a cross-product join.

**Note**

`USING` is reasonably safe from column changes in the joined relations since only the listed columns are combined. `NATURAL` is considerably more risky since any schema changes to either relation that cause a new matching column name to be present will cause the join to combine that new column as well.

To put this together, assume we have tables `t1`:

num	name
1	a
2	b
3	c

and `t2`:

num	value
1	xxx
3	YYY
5	zzz

then we get the following results for the various joins:

```
=> SELECT * FROM t1 CROSS JOIN t2;
```

num	name	num	value
1	a	1	xxx
1	a	3	YYY
1	a	5	zzz
2	b	1	xxx
2	b	3	YYY
2	b	5	zzz
3	c	1	xxx
3	c	3	YYY
3	c	5	zzz

(9 rows)

```
=> SELECT * FROM t1 INNER JOIN t2 ON t1.num = t2.num;
```

num	name	num	value
1	a	1	xxx
3	c	3	YYY

(2 rows)

```
=> SELECT * FROM t1 INNER JOIN t2 USING (num);
```

num	name	value
1	a	xxx

```

  3 | c      | YYY
(2 rows)

```

```
=> SELECT * FROM t1 NATURAL INNER JOIN t2;
```

```

 num | name | value
-----+-----+-----
  1  | a    | xxx
  3  | c    | YYY
(2 rows)

```

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1  | a    |    1 | xxx
  2  | b    |    3 |
  3  | c    |    3 | YYY
(3 rows)

```

```
=> SELECT * FROM t1 LEFT JOIN t2 USING (num);
```

```

 num | name | value
-----+-----+-----
  1  | a    | xxx
  2  | b    |
  3  | c    | YYY
(3 rows)

```

```
=> SELECT * FROM t1 RIGHT JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1  | a    |    1 | xxx
  3  | c    |    3 | YYY
    |      |    5 | zzz
(3 rows)

```

```
=> SELECT * FROM t1 FULL JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1  | a    |    1 | xxx
  2  | b    |    3 |
  3  | c    |    3 | YYY
    |      |    5 | zzz
(4 rows)

```

The join condition specified with ON can also contain conditions that do not relate directly to the join. This can prove useful for some queries but needs to be thought out carefully. For example:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num AND t2.value = 'xxx';
```

```

 num | name | num | value
-----+-----+-----+-----
  1  | a    |    1 | xxx
  2  | b    |    3 |
  3  | c    |    3 |
(3 rows)

```

Notice that placing the restriction in the WHERE clause produces a different result:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num WHERE t2.value
   = 'xxx';
   num | name | num | value
   ----+-----+-----+-----
     1 | a    |  1 | xxx
(1 row)
```

This is because a restriction placed in the ON clause is processed *before* the join, while a restriction placed in the WHERE clause is processed *after* the join. That does not matter with inner joins, but it matters a lot with outer joins.

### 7.2.1.2. Table and Column Aliases

A temporary name can be given to tables and complex table references to be used for references to the derived table in the rest of the query. This is called a *table alias*.

To create a table alias, write

```
FROM table_reference AS alias
```

or

```
FROM table_reference alias
```

The AS key word is optional noise. *alias* can be any identifier.

A typical application of table aliases is to assign short identifiers to long table names to keep the join clauses readable. For example:

```
SELECT * FROM some_very_long_table_name s JOIN
   another_fairly_long_name a ON s.id = a.num;
```

The alias becomes the new name of the table reference so far as the current query is concerned — it is not allowed to refer to the table by the original name elsewhere in the query. Thus, this is not valid:

```
SELECT * FROM my_table AS m WHERE my_table.a > 5;    -- wrong
```

Table aliases are mainly for notational convenience, but it is necessary to use them when joining a table to itself, e.g.:

```
SELECT * FROM people AS mother JOIN people AS child ON mother.id =
   child.mother_id;
```

Additionally, an alias is required if the table reference is a subquery (see Section 7.2.1.3).

Parentheses are used to resolve ambiguities. In the following example, the first statement assigns the alias *b* to the second instance of *my\_table*, but the second statement assigns the alias to the result of the join:

```
SELECT * FROM my_table AS a CROSS JOIN my_table AS b ...
SELECT * FROM (my_table AS a CROSS JOIN my_table) AS b ...
```

Another form of table aliasing gives temporary names to the columns of the table, as well as the table itself:

```
FROM table_reference [AS] alias ( column1 [, column2 [, ...]] )
```

If fewer column aliases are specified than the actual table has columns, the remaining columns are not renamed. This syntax is especially useful for self-joins or subqueries.

When an alias is applied to the output of a JOIN clause, the alias hides the original name(s) within the JOIN. For example:

```
SELECT a.* FROM my_table AS a JOIN your_table AS b ON ...
```

is valid SQL, but:

```
SELECT a.* FROM (my_table AS a JOIN your_table AS b ON ...) AS c
```

is not valid; the table alias a is not visible outside the alias c.

### 7.2.1.3. Subqueries

Subqueries specifying a derived table must be enclosed in parentheses and *must* be assigned a table alias name (as in Section 7.2.1.2). For example:

```
FROM (SELECT * FROM table1) AS alias_name
```

This example is equivalent to `FROM table1 AS alias_name`. More interesting cases, which cannot be reduced to a plain join, arise when the subquery involves grouping or aggregation.

A subquery can also be a VALUES list:

```
FROM (VALUES ('anne', 'smith'), ('bob', 'jones'), ('joe', 'blow'))
      AS names(first, last)
```

Again, a table alias is required. Assigning alias names to the columns of the VALUES list is optional, but is good practice. For more information see Section 7.7.

### 7.2.1.4. Table Functions

Table functions are functions that produce a set of rows, made up of either base data types (scalar types) or composite data types (table rows). They are used like a table, view, or subquery in the FROM clause of a query. Columns returned by table functions can be included in SELECT, JOIN, or WHERE clauses in the same manner as columns of a table, view, or subquery.

Table functions may also be combined using the ROWS FROM syntax, with the results returned in parallel columns; the number of result rows in this case is that of the largest function result, with smaller results padded with null values to match.

```
function_call [WITH ORDINALITY] [[AS] table_alias [(column_alias
  [, ... ])] ]
ROWS FROM( function_call [, ... ] ) [WITH ORDINALITY]
  [[AS] table_alias [(column_alias [, ... ])] ]
```

If the WITH ORDINALITY clause is specified, an additional column of type bigint will be added to the function result columns. This column numbers the rows of the function result set, starting from 1. (This is a generalization of the SQL-standard syntax for UNNEST ... WITH ORDINALITY.) By default, the ordinal column is called ordinality, but a different column name can be assigned to it using an AS clause.



The special table function UNNEST may be called with any number of array parameters, and it returns a corresponding number of columns, as if UNNEST (Section 9.19) had been called on each parameter separately and combined using the ROWS FROM construct.

```
UNNEST( array_expression [, ... ] ) [WITH ORDINALITY]
  [[AS] table_alias [(column_alias [, ... ])]]
```

If no *table\_alias* is specified, the function name is used as the table name; in the case of a ROWS FROM() construct, the first function's name is used.

If column aliases are not supplied, then for a function returning a base data type, the column name is also the same as the function name. For a function returning a composite type, the result columns get the names of the individual attributes of the type.

Some examples:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);
```

```
CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
  SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;
```

```
SELECT * FROM getfoo(1) AS t1;
```

```
SELECT * FROM foo
  WHERE foosubid IN (
                        SELECT foosubid
                        FROM getfoo(foo.fooid) z
                        WHERE z.fooid = foo.fooid
                      );
```

```
CREATE VIEW vw_getfoo AS SELECT * FROM getfoo(1);
```

```
SELECT * FROM vw_getfoo;
```

In some cases it is useful to define table functions that can return different column sets depending on how they are invoked. To support this, the table function can be declared as returning the pseudo-type *record* with no OUT parameters. When such a function is used in a query, the expected row structure must be specified in the query itself, so that the system can know how to parse and plan the query. This syntax looks like:

```
function_call [AS] alias (column_definition [, ... ])
function_call AS [alias] (column_definition [, ... ])
ROWS FROM( ... function_call AS (column_definition [, ... ])
  [, ... ] )
```

When not using the ROWS FROM() syntax, the *column\_definition* list replaces the column alias list that could otherwise be attached to the FROM item; the names in the column definitions serve as column aliases. When using the ROWS FROM() syntax, a *column\_definition* list can be attached to each member function separately; or if there is only one member function and no WITH ORDINALITY clause, a *column\_definition* list can be written in place of a column alias list following ROWS FROM().

Consider this example:

```
SELECT *
```

```

FROM dblink('dbname=mydb', 'SELECT proname, prosrc FROM
pg_proc')
  AS t1(proname name, prosrc text)
WHERE proname LIKE 'bytea%';

```

The `dblink` function (part of the `dblink` module) executes a remote query. It is declared to return `record` since it might be used for any kind of query. The actual column set must be specified in the calling query so that the parser knows, for example, what `*` should expand to.

This example uses `ROWS FROM`:

```

SELECT *
FROM ROWS FROM
  (
    json_to_recordset(' [{"a":40,"b":"foo"} ,
{"a":"100","b":"bar"} ]')
      AS (a INTEGER, b TEXT),
    generate_series(1, 3)
  ) AS x (p, q, s)
ORDER BY p;

```

p	q	s
40	foo	1
100	bar	2
		3

It joins two functions into a single `FROM` target. `json_to_recordset()` is instructed to return two columns, the first integer and the second text. The result of `generate_series()` is used directly. The `ORDER BY` clause sorts the column values as integers.

### 7.2.1.5. LATERAL Subqueries

Subqueries appearing in `FROM` can be preceded by the key word `LATERAL`. This allows them to reference columns provided by preceding `FROM` items. (Without `LATERAL`, each subquery is evaluated independently and so cannot cross-reference any other `FROM` item.)

Table functions appearing in `FROM` can also be preceded by the key word `LATERAL`, but for functions the key word is optional; the function's arguments can contain references to columns provided by preceding `FROM` items in any case.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

A trivial example of `LATERAL` is

```

SELECT * FROM foo, LATERAL (SELECT * FROM bar WHERE bar.id =
foo.bar_id) ss;

```

This is not especially useful since it has exactly the same result as the more conventional

```
SELECT * FROM foo, bar WHERE bar.id = foo.bar_id;
```

LATERAL is primarily useful when the cross-referenced column is necessary for computing the row(s) to be joined. A common application is providing an argument value for a set-returning function. For example, supposing that `vertices(polygon)` returns the set of vertices of a polygon, we could identify close-together vertices of polygons stored in a table with:

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1, polygons p2,
     LATERAL vertices(p1.poly) v1,
     LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

This query could also be written

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1 CROSS JOIN LATERAL vertices(p1.poly) v1,
     polygons p2 CROSS JOIN LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

or in several other equivalent formulations. (As already mentioned, the LATERAL key word is unnecessary in this example, but we use it for clarity.)

It is often particularly handy to LEFT JOIN to a LATERAL subquery, so that source rows will appear in the result even if the LATERAL subquery produces no rows for them. For example, if `get_product_names()` returns the names of products made by a manufacturer, but some manufacturers in our table currently produce no products, we could find out which ones those are like this:

```
SELECT m.name
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id)
     pname ON true
WHERE pname IS NULL;
```

## 7.2.2. The WHERE Clause

The syntax of the WHERE clause is

```
WHERE search_condition
```

where *search\_condition* is any value expression (see Section 4.2) that returns a value of type boolean.

After the processing of the FROM clause is done, each row of the derived virtual table is checked against the search condition. If the result of the condition is true, the row is kept in the output table, otherwise (i.e., if the result is false or null) it is discarded. The search condition typically references at least one column of the table generated in the FROM clause; this is not required, but otherwise the WHERE clause will be fairly useless.

### Note

The join condition of an inner join can be written either in the WHERE clause or in the JOIN clause. For example, these table expressions are equivalent:

```
FROM a, b WHERE a.id = b.id AND b.val > 5
```

and:

```
FROM a INNER JOIN b ON (a.id = b.id) WHERE b.val > 5
```

or perhaps even:

```
FROM a NATURAL JOIN b WHERE b.val > 5
```

Which one of these you use is mainly a matter of style. The JOIN syntax in the FROM clause is probably not as portable to other SQL database management systems, even though it is in the SQL standard. For outer joins there is no choice: they must be done in the FROM clause. The ON or USING clause of an outer join is *not* equivalent to a WHERE condition, because it results in the addition of rows (for unmatched input rows) as well as the removal of rows in the final result.

Here are some examples of WHERE clauses:

```
SELECT ... FROM fdt WHERE c1 > 5
```

```
SELECT ... FROM fdt WHERE c1 IN (1, 2, 3)
```

```
SELECT ... FROM fdt WHERE c1 IN (SELECT c1 FROM t2)
```

```
SELECT ... FROM fdt WHERE c1 IN (SELECT c3 FROM t2 WHERE c2 =
    fdt.c1 + 10)
```

```
SELECT ... FROM fdt WHERE c1 BETWEEN (SELECT c3 FROM t2 WHERE c2 =
    fdt.c1 + 10) AND 100
```

```
SELECT ... FROM fdt WHERE EXISTS (SELECT c1 FROM t2 WHERE c2 >
    fdt.c1)
```

`fdt` is the table derived in the FROM clause. Rows that do not meet the search condition of the WHERE clause are eliminated from `fdt`. Notice the use of scalar subqueries as value expressions. Just like any other query, the subqueries can employ complex table expressions. Notice also how `fdt` is referenced in the subqueries. Qualifying `c1` as `fdt.c1` is only necessary if `c1` is also the name of a column in the derived input table of the subquery. But qualifying the column name adds clarity even when it is not needed. This example shows how the column naming scope of an outer query extends into its inner queries.

### 7.2.3. The GROUP BY and HAVING Clauses

After passing the WHERE filter, the derived input table might be subject to grouping, using the GROUP BY clause, and elimination of group rows using the HAVING clause.

```
SELECT select_list
    FROM ...
    [WHERE ...]
    GROUP BY grouping_column_reference
    [, grouping_column_reference]...
```

The GROUP BY clause is used to group together those rows in a table that have the same values in all the columns listed. The order in which the columns are listed does not matter. The effect is to

combine each set of rows having common values into one group row that represents all rows in the group. This is done to eliminate redundancy in the output and/or compute aggregates that apply to these groups. For instance:

```
=> SELECT * FROM test1;
```

```
x | y
---+---
a | 3
c | 2
b | 5
a | 1
(4 rows)
```

```
=> SELECT x FROM test1 GROUP BY x;
```

```
x
---
a
b
c
(3 rows)
```

In the second query, we could not have written `SELECT * FROM test1 GROUP BY x`, because there is no single value for the column `y` that could be associated with each group. The grouped-by columns can be referenced in the select list since they have a single value in each group.

In general, if a table is grouped, columns that are not listed in `GROUP BY` cannot be referenced except in aggregate expressions. An example with aggregate expressions is:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x;
```

```
x | sum
---+-----
a | 4
b | 5
c | 2
(3 rows)
```

Here `sum` is an aggregate function that computes a single value over the entire group. More information about the available aggregate functions can be found in Section 9.21.

**Tip**

Grouping without aggregate expressions effectively calculates the set of distinct values in a column. This can also be achieved using the `DISTINCT` clause (see Section 7.3.3).

Here is another example: it calculates the total sales for each product (rather than the total sales of all products):

```
SELECT product_id, p.name, (sum(s.units) * p.price) AS sales
FROM products p LEFT JOIN sales s USING (product_id)
GROUP BY product_id, p.name, p.price;
```

In this example, the columns `product_id`, `p.name`, and `p.price` must be in the `GROUP BY` clause since they are referenced in the query select list (but see below). The column `s.units` does not have to be in the `GROUP BY` list since it is only used in an aggregate expression (`sum(...)`),

which represents the sales of a product. For each product, the query returns a summary row about all sales of the product.

If the products table is set up so that, say, `product_id` is the primary key, then it would be enough to group by `product_id` in the above example, since name and price would be *functionally dependent* on the product ID, and so there would be no ambiguity about which name and price value to return for each product ID group.

In strict SQL, `GROUP BY` can only group by columns of the source table but LightDB extends this to also allow `GROUP BY` to group by columns in the select list. Grouping by value expressions instead of simple column names is also allowed.

If a table has been grouped using `GROUP BY`, but only certain groups are of interest, the `HAVING` clause can be used, much like a `WHERE` clause, to eliminate groups from the result. The syntax is:

```
SELECT select_list FROM ... [WHERE ...] GROUP BY ...
      boolean_expression
```

Expressions in the `HAVING` clause can refer both to grouped expressions and to ungrouped expressions (which necessarily involve an aggregate function).

Example:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING sum(y) > 3;
```

```
x | sum
---+-----
a |    4
b |    5
(2 rows)
```

```
=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING x < 'c';
```

```
x | sum
---+-----
a |    4
b |    5
(2 rows)
```

Again, a more realistic example:

```
SELECT product_id, p.name, (sum(s.units) * (p.price - p.cost)) AS
profit
      FROM products p LEFT JOIN sales s USING (product_id)
      WHERE s.date > CURRENT_DATE - INTERVAL '4 weeks'
      GROUP BY product_id, p.name, p.price, p.cost
      HAVING sum(p.price * s.units) > 5000;
```

In the example above, the `WHERE` clause is selecting rows by a column that is not grouped (the expression is only true for sales during the last four weeks), while the `HAVING` clause restricts the output to groups with total gross sales over 5000. Note that the aggregate expressions do not necessarily need to be the same in all parts of the query.

If a query contains aggregate function calls, but no `GROUP BY` clause, grouping still occurs: the result is a single group row (or perhaps no rows at all, if the single row is then eliminated by `HAVING`). The same is true if it contains a `HAVING` clause, even without any aggregate function calls or `GROUP BY` clause.

## 7.2.4. GROUPING SETS, CUBE, and ROLLUP

More complex grouping operations than those described above are possible using the concept of *grouping sets*. The data selected by the FROM and WHERE clauses is grouped separately by each specified grouping set, aggregates computed for each group just as for simple GROUP BY clauses, and then the results returned. For example:

```
=> SELECT * FROM items_sold;
```

brand	size	sales
Foo	L	10
Foo	M	20
Bar	M	15
Bar	L	5

(4 rows)

```
=> SELECT brand, size, sum(sales) FROM items_sold GROUP BY GROUPING
SETS ((brand), (size), ());
```

brand	size	sum
Foo		30
Bar		20
	L	15
	M	35
		50

(5 rows)

Each sublist of GROUPING SETS may specify zero or more columns or expressions and is interpreted the same way as though it were directly in the GROUP BY clause. An empty grouping set means that all rows are aggregated down to a single group (which is output even if no input rows were present), as described above for the case of aggregate functions with no GROUP BY clause.

References to the grouping columns or expressions are replaced by null values in result rows for grouping sets in which those columns do not appear. To distinguish which grouping a particular output row resulted from, see Table 9.60.

A shorthand notation is provided for specifying two common types of grouping set. A clause of the form

```
ROLLUP ( e1, e2, e3, ... )
```

represents the given list of expressions and all prefixes of the list including the empty list; thus it is equivalent to

```
GROUPING SETS (
  ( e1, e2, e3, ... ),
  ...
  ( e1, e2 ),
  ( e1 ),
  ( )
)
```

This is commonly used for analysis over hierarchical data; e.g., total salary by department, division, and company-wide total.

A clause of the form

CUBE ( e1, e2, ... )

represents the given list and all of its possible subsets (i.e., the power set). Thus

CUBE ( a, b, c )

is equivalent to

```
GROUPING SETS (
  ( a, b, c ),
  ( a, b   ),
  ( a,   c ),
  ( a     ),
  (   b, c ),
  (   b   ),
  (     c ),
  (     )
)
```

The individual elements of a CUBE or ROLLUP clause may be either individual expressions, or sublists of elements in parentheses. In the latter case, the sublists are treated as single units for the purposes of generating the individual grouping sets. For example:

CUBE ( (a, b), (c, d) )

is equivalent to

```
GROUPING SETS (
  ( a, b, c, d ),
  ( a, b       ),
  (     c, d   ),
  (           )
)
```

and

ROLLUP ( a, (b, c), d )

is equivalent to

```
GROUPING SETS (
  ( a, b, c, d ),
  ( a, b, c     ),
  ( a           ),
  (           )
)
```

The CUBE and ROLLUP constructs can be used either directly in the GROUP BY clause, or nested inside a GROUPING SETS clause. If one GROUPING SETS clause is nested inside another, the effect is the same as if all the elements of the inner clause had been written directly in the outer clause.

If multiple grouping items are specified in a single GROUP BY clause, then the final list of grouping sets is the cross product of the individual items. For example:



```
GROUP BY a, CUBE (b, c), GROUPING SETS ((d), (e))
```

is equivalent to

```
GROUP BY GROUPING SETS (
    (a, b, c, d), (a, b, c, e),
    (a, b, d),   (a, b, e),
    (a, c, d),   (a, c, e),
    (a, d),     (a, e)
)
```

### Note

The construct (a, b) is normally recognized in expressions as a row constructor. Within the GROUP BY clause, this does not apply at the top levels of expressions, and (a, b) is parsed as a list of expressions as described above. If for some reason you need a row constructor in a grouping expression, use ROW(a, b).

## 7.2.5. Window Function Processing

If the query contains any window functions (see Section 3.5, Section 9.22 and Section 4.2.8), these functions are evaluated after any grouping, aggregation, and HAVING filtering is performed. That is, if the query uses any aggregates, GROUP BY, or HAVING, then the rows seen by the window functions are the group rows instead of the original table rows from FROM/WHERE.

When multiple window functions are used, all the window functions having syntactically equivalent PARTITION BY and ORDER BY clauses in their window definitions are guaranteed to be evaluated in a single pass over the data. Therefore they will see the same sort ordering, even if the ORDER BY does not uniquely determine an ordering. However, no guarantees are made about the evaluation of functions having different PARTITION BY or ORDER BY specifications. (In such cases a sort step is typically required between the passes of window function evaluations, and the sort is not guaranteed to preserve ordering of rows that its ORDER BY sees as equivalent.)

Currently, window functions always require presorted data, and so the query output will be ordered according to one or another of the window functions' PARTITION BY/ORDER BY clauses. It is not recommended to rely on this, however. Use an explicit top-level ORDER BY clause if you want to be sure the results are sorted in a particular way.

## 7.3. Select Lists

As shown in the previous section, the table expression in the SELECT command constructs an intermediate virtual table by possibly combining tables, views, eliminating rows, grouping, etc. This table is finally passed on to processing by the *select list*. The select list determines which *columns* of the intermediate table are actually output.

### 7.3.1. Select-List Items

The simplest kind of select list is \* which emits all columns that the table expression produces. Otherwise, a select list is a comma-separated list of value expressions (as defined in Section 4.2). For instance, it could be a list of column names:

```
SELECT a, b, c FROM ...
```

The column names `a`, `b`, and `c` are either the actual names of the columns of tables referenced in the `FROM` clause, or the aliases given to them as explained in Section 7.2.1.2. The name space available in the select list is the same as in the `WHERE` clause, unless grouping is used, in which case it is the same as in the `HAVING` clause.

If more than one table has a column of the same name, the table name must also be given, as in:

```
SELECT tbl1.a, tbl2.a, tbl1.b FROM ...
```

When working with multiple tables, it can also be useful to ask for all the columns of a particular table:

```
SELECT tbl1.*, tbl2.a FROM ...
```

See Section 8.16.5 for more about the `table_name.*` notation.

If an arbitrary value expression is used in the select list, it conceptually adds a new virtual column to the returned table. The value expression is evaluated once for each result row, with the row's values substituted for any column references. But the expressions in the select list do not have to reference any columns in the table expression of the `FROM` clause; they can be constant arithmetic expressions, for instance.

## 7.3.2. Column Labels

The entries in the select list can be assigned names for subsequent processing, such as for use in an `ORDER BY` clause or for display by the client application. For example:

```
SELECT a AS value, b + c AS sum FROM ...
```

If no output column name is specified using `AS`, the system assigns a default column name. For simple column references, this is the name of the referenced column. For function calls, this is the name of the function. For complex expressions, the system will generate a generic name.

The `AS` keyword is optional, but only if the new column name does not match any `LightDB` keyword (see Appendix C). To avoid an accidental match to a keyword, you can double-quote the column name. For example, `VALUE` is a keyword, so this does not work:

```
SELECT a value, b + c AS sum FROM ...
```

but this does:

```
SELECT a "value", b + c AS sum FROM ...
```

For protection against possible future keyword additions, it is recommended that you always either write `AS` or double-quote the output column name.

### Note

The naming of output columns here is different from that done in the `FROM` clause (see Section 7.2.1.2). It is possible to rename the same column twice, but the name assigned in the select list is the one that will be passed on.

## 7.3.3. DISTINCT

After the select list has been processed, the result table can optionally be subject to the elimination of duplicate rows. The `DISTINCT` key word is written directly after `SELECT` to specify this:

```
SELECT DISTINCT select_list ...
```

(Instead of `DISTINCT` the key word `ALL` can be used to specify the default behavior of retaining all rows.)

Obviously, two rows are considered distinct if they differ in at least one column value. Null values are considered equal in this comparison.

Alternatively, an arbitrary expression can determine what rows are to be considered distinct:

```
SELECT DISTINCT ON (expression [, expression ...]) select_list ...
```

Here *expression* is an arbitrary value expression that is evaluated for all rows. A set of rows for which all the expressions are equal are considered duplicates, and only the first row of the set is kept in the output. Note that the “first row” of a set is unpredictable unless the query is sorted on enough columns to guarantee a unique ordering of the rows arriving at the `DISTINCT` filter. (`DISTINCT ON` processing occurs after `ORDER BY` sorting.)

The `DISTINCT ON` clause is not part of the SQL standard and is sometimes considered bad style because of the potentially indeterminate nature of its results. With judicious use of `GROUP BY` and subqueries in `FROM`, this construct can be avoided, but it is often the most convenient alternative.

## 7.4. Combining Queries

The results of two queries can be combined using the set operations union, intersection, and difference. The syntax is

```
query1 UNION [ALL] query2
query1 INTERSECT [ALL] query2
query1 EXCEPT [ALL] query2
```

where *query1* and *query2* are queries that can use any of the features discussed up to this point.

`UNION` effectively appends the result of *query2* to the result of *query1* (although there is no guarantee that this is the order in which the rows are actually returned). Furthermore, it eliminates duplicate rows from its result, in the same way as `DISTINCT`, unless `UNION ALL` is used.

`INTERSECT` returns all rows that are both in the result of *query1* and in the result of *query2*. Duplicate rows are eliminated unless `INTERSECT ALL` is used.

`EXCEPT` returns all rows that are in the result of *query1* but not in the result of *query2*. (This is sometimes called the *difference* between two queries.) Again, duplicates are eliminated unless `EXCEPT ALL` is used.

In order to calculate the union, intersection, or difference of two queries, the two queries must be “union compatible”, which means that they return the same number of columns and the corresponding columns have compatible data types, as described in Section 10.5.

Set operations can be combined, for example

```
query1 UNION query2 EXCEPT query3
```

which is equivalent to

```
(query1 UNION query2) EXCEPT query3
```

As shown here, you can use parentheses to control the order of evaluation. Without parentheses, UNION and EXCEPT associate left-to-right, but INTERSECT binds more tightly than those two operators. Thus

```
query1 UNION query2 INTERSECT query3
```

means

```
query1 UNION (query2 INTERSECT query3)
```

You can also surround an individual *query* with parentheses. This is important if the *query* needs to use any of the clauses discussed in following sections, such as LIMIT. Without parentheses, you'll get a syntax error, or else the clause will be understood as applying to the output of the set operation rather than one of its inputs. For example,

```
SELECT a FROM b UNION SELECT x FROM y LIMIT 10
```

is accepted, but it means

```
(SELECT a FROM b UNION SELECT x FROM y) LIMIT 10
```

not

```
SELECT a FROM b UNION (SELECT x FROM y LIMIT 10)
```

## 7.5. Sorting Rows

After a query has produced an output table (after the select list has been processed) it can optionally be sorted. If sorting is not chosen, the rows will be returned in an unspecified order. The actual order in that case will depend on the scan and join plan types and the order on disk, but it must not be relied on. A particular output ordering can only be guaranteed if the sort step is explicitly chosen.

The ORDER BY clause specifies the sort order:

```
SELECT select_list
      FROM table_expression
      ORDER BY sort_expression1 [ASC | DESC] [NULLS { FIRST | LAST }]
             [, sort_expression2 [ASC | DESC] [NULLS { FIRST |
LAST }]] ...]
```

The sort expression(s) can be any expression that would be valid in the query's select list. An example is:

```
SELECT a, b FROM table1 ORDER BY a + b, c;
```

When more than one expression is specified, the later values are used to sort rows that are equal according to the earlier values. Each expression can be followed by an optional ASC or DESC keyword to set the sort direction to ascending or descending. ASC order is the default. Ascending order puts

smaller values first, where “smaller” is defined in terms of the < operator. Similarly, descending order is determined with the > operator.<sup>1</sup>

The `NULLS FIRST` and `NULLS LAST` options can be used to determine whether nulls appear before or after non-null values in the sort ordering. By default, null values sort as if larger than any non-null value; that is, `NULLS FIRST` is the default for `DESC` order, and `NULLS LAST` otherwise.

Note that the ordering options are considered independently for each sort column. For example `ORDER BY x, y DESC` means `ORDER BY x ASC, y DESC`, which is not the same as `ORDER BY x DESC, y DESC`.

A *sort\_expression* can also be the column label or number of an output column, as in:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum;
SELECT a, max(b) FROM table1 GROUP BY a ORDER BY 1;
```

both of which sort by the first output column. Note that an output column name has to stand alone, that is, it cannot be used in an expression — for example, this is *not* correct:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum + c;      --
wrong
```

This restriction is made to reduce ambiguity. There is still ambiguity if an `ORDER BY` item is a simple name that could match either an output column name or a column from the table expression. The output column is used in such cases. This would only cause confusion if you use `AS` to rename an output column to match some other table column's name.

`ORDER BY` can be applied to the result of a `UNION`, `INTERSECT`, or `EXCEPT` combination, but in this case it is only permitted to sort by output column names or numbers, not by expressions.

## 7.6. LIMIT and OFFSET

`LIMIT` and `OFFSET` allow you to retrieve just a portion of the rows that are generated by the rest of the query:

```
SELECT select_list
      FROM table_expression
      [ ORDER BY ... ]
      [ LIMIT { number | ALL } ] [ OFFSET number ]
```

```
SELECT select_list
      FROM table_expression
      [ ORDER BY ... ]
      [ LIMIT [ number, ] { number | ALL } ]
```

If a limit count is given, no more than that many rows will be returned (but possibly fewer, if the query itself yields fewer rows). `LIMIT ALL` is the same as omitting the `LIMIT` clause, as is `LIMIT` with a `NULL` argument.

`OFFSET` says to skip that many rows before beginning to return rows. `OFFSET 0` is the same as omitting the `OFFSET` clause, as is `OFFSET` with a `NULL` argument.

If both `OFFSET` and `LIMIT` appear, then `OFFSET` rows are skipped before starting to count the `LIMIT` rows that are returned.

<sup>1</sup> Actually, LightDB uses the *default B-tree operator class* for the expression's data type to determine the sort ordering for `ASC` and `DESC`. Conventionally, data types will be set up so that the < and > operators correspond to this sort ordering, but a user-defined data type's designer could choose to do something different.

When using `LIMIT`, it is important to use an `ORDER BY` clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows. You might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? The ordering is unknown, unless you specified `ORDER BY`.

The query optimizer takes `LIMIT` into account when generating query plans, so you are very likely to get different plans (yielding different row orders) depending on what you give for `LIMIT` and `OFFSET`. Thus, using different `LIMIT/OFFSET` values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with `ORDER BY`. This is not a bug; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless `ORDER BY` is used to constrain the order.

The rows skipped by an `OFFSET` clause still have to be computed inside the server; therefore a large `OFFSET` might be inefficient.

For compatibility with MySQL, LightDB also supports the `LIMIT offset, row_count` syntax.

## 7.7. VALUES Lists

`VALUES` provides a way to generate a “constant table” that can be used in a query without having to actually create and populate a table on-disk. The syntax is

```
VALUES ( expression [, ...] ) [, ...]
```

Each parenthesized list of expressions generates a row in the table. The lists must all have the same number of elements (i.e., the number of columns in the table), and corresponding entries in each list must have compatible data types. The actual data type assigned to each column of the result is determined using the same rules as for `UNION` (see Section 10.5).

As an example:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

By default, LightDB assigns the names `column1`, `column2`, etc. to the columns of a `VALUES` table. The column names are not specified by the SQL standard and different database systems do it differently, so it's usually better to override the default names with a table alias list, like this:

```
=> SELECT * FROM (VALUES (1, 'one'), (2, 'two'), (3, 'three')) AS t
   (num,letter);
 num | letter
-----+-----
   1 | one
   2 | two
   3 | three
(3 rows)
```

Syntactically, `VALUES` followed by expression lists is treated as equivalent to:

```
SELECT select_list FROM table_expression
```

and can appear anywhere a SELECT can. For example, you can use it as part of a UNION, or attach a *sort\_specification* (ORDER BY, LIMIT, and/or OFFSET) to it. VALUES is most commonly used as the data source in an INSERT command, and next most commonly as a subquery.

For more information see VALUES.

## 7.8. WITH Queries (Common Table Expressions)

WITH provides a way to write auxiliary statements for use in a larger query. These statements, which are often referred to as Common Table Expressions or CTEs, can be thought of as defining temporary tables that exist just for one query. Each auxiliary statement in a WITH clause can be a SELECT, INSERT, UPDATE, or DELETE; and the WITH clause itself is attached to a primary statement that can also be a SELECT, INSERT, UPDATE, or DELETE.

### 7.8.1. SELECT in WITH

The basic value of SELECT in WITH is to break down complicated queries into simpler parts. An example is:

```
WITH regional_sales AS (
    SELECT region, SUM(amount) AS total_sales
    FROM orders
    GROUP BY region
), top_regions AS (
    SELECT region
    FROM regional_sales
    WHERE total_sales > (SELECT SUM(total_sales)/10 FROM
    regional_sales)
)
SELECT region,
    product,
    SUM(quantity) AS product_units,
    SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```

which displays per-product sales totals in only the top sales regions. The WITH clause defines two auxiliary statements named *regional\_sales* and *top\_regions*, where the output of *regional\_sales* is used in *top\_regions* and the output of *top\_regions* is used in the primary SELECT query. This example could have been written without WITH, but we'd have needed two levels of nested sub-SELECTs. It's a bit easier to follow this way.

The optional RECURSIVE modifier changes WITH from a mere syntactic convenience into a feature that accomplishes things not otherwise possible in standard SQL. Using RECURSIVE, a WITH query can refer to its own output. A very simple example is this query to sum the integers from 1 through 100:

```
WITH RECURSIVE t(n) AS (
    VALUES (1)
    UNION ALL
    SELECT n+1 FROM t WHERE n < 100
)
```

```
SELECT sum(n) FROM t;
```

The general form of a recursive WITH query is always a *non-recursive term*, then UNION (or UNION ALL), then a *recursive term*, where only the recursive term can contain a reference to the query's own output. Such a query is executed as follows:

### Recursive Query Evaluation

1. Evaluate the non-recursive term. For UNION (but not UNION ALL), discard duplicate rows. Include all remaining rows in the result of the recursive query, and also place them in a temporary *working table*.
2. So long as the working table is not empty, repeat these steps:
  - a. Evaluate the recursive term, substituting the current contents of the working table for the recursive self-reference. For UNION (but not UNION ALL), discard duplicate rows and rows that duplicate any previous result row. Include all remaining rows in the result of the recursive query, and also place them in a temporary *intermediate table*.
  - b. Replace the contents of the working table with the contents of the intermediate table, then empty the intermediate table.

#### Note

Strictly speaking, this process is iteration not recursion, but RECURSIVE is the terminology chosen by the SQL standards committee.

In the example above, the working table has just a single row in each step, and it takes on the values from 1 through 100 in successive steps. In the 100th step, there is no output because of the WHERE clause, and so the query terminates.

Recursive queries are typically used to deal with hierarchical or tree-structured data. A useful example is this query to find all the direct and indirect sub-parts of a product, given only a table that shows immediate inclusions:

```
WITH RECURSIVE included_parts(sub_part, part, quantity) AS (
  SELECT sub_part, part, quantity FROM parts WHERE part =
  'our_product'
  UNION ALL
  SELECT p.sub_part, p.part, p.quantity
  FROM included_parts pr, parts p
  WHERE p.part = pr.sub_part
)
SELECT sub_part, SUM(quantity) as total_quantity
FROM included_parts
GROUP BY sub_part
```

When working with recursive queries it is important to be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. Sometimes, using UNION instead of UNION ALL can accomplish this by discarding rows that duplicate previous output rows. However, often a cycle does not involve output rows that are completely duplicate: it may be necessary to check just one or a few fields to see if the same point has been reached before. The standard method for handling such situations is to compute an array of the already-visited values. For example, consider the following query that searches a table graph using a link field:

```
WITH RECURSIVE search_graph(id, link, data, depth) AS (
```



```

SELECT g.id, g.link, g.data, 1
FROM graph g
UNION ALL
SELECT g.id, g.link, g.data, sg.depth + 1
FROM graph g, search_graph sg
WHERE g.id = sg.link
)
SELECT * FROM search_graph;

```

This query will loop if the link relationships contain cycles. Because we require a “depth” output, just changing UNION ALL to UNION would not eliminate the looping. Instead we need to recognize whether we have reached the same row again while following a particular path of links. We add two columns path and cycle to the loop-prone query:

```

WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS
(
    SELECT g.id, g.link, g.data, 1,
        ARRAY[g.id],
        false
    FROM graph g
    UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
        path || g.id,
        g.id = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;

```

Aside from preventing cycles, the array value is often useful in its own right as representing the “path” taken to reach any particular row.

In the general case where more than one field needs to be checked to recognize a cycle, use an array of rows. For example, if we needed to compare fields f1 and f2:

```

WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS
(
    SELECT g.id, g.link, g.data, 1,
        ARRAY[ROW(g.f1, g.f2)],
        false
    FROM graph g
    UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
        path || ROW(g.f1, g.f2),
        ROW(g.f1, g.f2) = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;

```

### Tip

Omit the ROW( ) syntax in the common case where only one field needs to be checked to recognize a cycle. This allows a simple array rather than a composite-type array to be used, gaining efficiency.

**Tip**

The recursive query evaluation algorithm produces its output in breadth-first search order. You can display the results in depth-first search order by making the outer query ORDER BY a “path” column constructed in this way.

A helpful trick for testing queries when you are not certain if they might loop is to place a LIMIT in the parent query. For example, this query would loop forever without the LIMIT:

```
WITH RECURSIVE t(n) AS (
  SELECT 1
  UNION ALL
  SELECT n+1 FROM t
)
SELECT n FROM t LIMIT 100;
```

This works because LightDB's implementation evaluates only as many rows of a WITH query as are actually fetched by the parent query. Using this trick in production is not recommended, because other systems might work differently. Also, it usually won't work if you make the outer query sort the recursive query's results or join them to some other table, because in such cases the outer query will usually try to fetch all of the WITH query's output anyway.

A useful property of WITH queries is that they are normally evaluated only once per execution of the parent query, even if they are referred to more than once by the parent query or sibling WITH queries. Thus, expensive calculations that are needed in multiple places can be placed within a WITH query to avoid redundant work. Another possible application is to prevent unwanted multiple evaluations of functions with side-effects. However, the other side of this coin is that the optimizer is not able to push restrictions from the parent query down into a multiply-referenced WITH query, since that might affect all uses of the WITH query's output when it should affect only one. The multiply-referenced WITH query will be evaluated as written, without suppression of rows that the parent query might discard afterwards. (But, as mentioned above, evaluation might stop early if the reference(s) to the query demand only a limited number of rows.)

However, if a WITH query is non-recursive and side-effect-free (that is, it is a SELECT containing no volatile functions) then it can be folded into the parent query, allowing joint optimization of the two query levels. By default, this happens if the parent query references the WITH query just once, but not if it references the WITH query more than once. You can override that decision by specifying MATERIALIZED to force separate calculation of the WITH query, or by specifying NOT MATERIALIZED to force it to be merged into the parent query. The latter choice risks duplicate computation of the WITH query, but it can still give a net savings if each usage of the WITH query needs only a small part of the WITH query's full output.

A simple example of these rules is

```
WITH w AS (
  SELECT * FROM big_table
)
SELECT * FROM w WHERE key = 123;
```

This WITH query will be folded, producing the same execution plan as

```
SELECT * FROM big_table WHERE key = 123;
```

In particular, if there's an index on key, it will probably be used to fetch just the rows having key = 123. On the other hand, in

```
WITH w AS (
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key = w2.ref
WHERE w2.key = 123;
```

the WITH query will be materialized, producing a temporary copy of `big_table` that is then joined with itself — without benefit of any index. This query will be executed much more efficiently if written as

```
WITH w AS NOT MATERIALIZED (
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key = w2.ref
WHERE w2.key = 123;
```

so that the parent query's restrictions can be applied directly to scans of `big_table`.

An example where `NOT MATERIALIZED` could be undesirable is

```
WITH w AS (
    SELECT key, very_expensive_function(val) as f FROM some_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.f = w2.f;
```

Here, materialization of the WITH query ensures that `very_expensive_function` is evaluated only once per table row, not twice.

The examples above only show WITH being used with SELECT, but it can be attached in the same way to INSERT, UPDATE, or DELETE. In each case it effectively provides temporary table(s) that can be referred to in the main command.

## 7.8.2. Data-Modifying Statements in WITH

You can use data-modifying statements (INSERT, UPDATE, or DELETE) in WITH. This allows you to perform several different operations in the same query. An example is:

```
WITH moved_rows AS (
    DELETE FROM products
    WHERE
        "date" >= '2010-10-01' AND
        "date" < '2010-11-01'
    RETURNING *
)
INSERT INTO products_log
SELECT * FROM moved_rows;
```

This query effectively moves rows from `products` to `products_log`. The DELETE in WITH deletes the specified rows from `products`, returning their contents by means of its RETURNING clause; and then the primary query reads that output and inserts it into `products_log`.

A fine point of the above example is that the WITH clause is attached to the INSERT, not the sub-SELECT within the INSERT. This is necessary because data-modifying statements are only allowed in WITH clauses that are attached to the top-level statement. However, normal WITH visibility rules apply, so it is possible to refer to the WITH statement's output from the sub-SELECT.

Data-modifying statements in `WITH` usually have `RETURNING` clauses (see Section 6.4), as shown in the example above. It is the output of the `RETURNING` clause, *not* the target table of the data-modifying statement, that forms the temporary table that can be referred to by the rest of the query. If a data-modifying statement in `WITH` lacks a `RETURNING` clause, then it forms no temporary table and cannot be referred to in the rest of the query. Such a statement will be executed nonetheless. A not-particularly-useful example is:

```
WITH t AS (
    DELETE FROM foo
)
DELETE FROM bar;
```

This example would remove all rows from tables `foo` and `bar`. The number of affected rows reported to the client would only include rows removed from `bar`.

Recursive self-references in data-modifying statements are not allowed. In some cases it is possible to work around this limitation by referring to the output of a recursive `WITH`, for example:

```
WITH RECURSIVE included_parts(sub_part, part) AS (
    SELECT sub_part, part FROM parts WHERE part = 'our_product'
    UNION ALL
    SELECT p.sub_part, p.part
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
)
DELETE FROM parts
WHERE part IN (SELECT part FROM included_parts);
```

This query would remove all direct and indirect subparts of a product.

Data-modifying statements in `WITH` are executed exactly once, and always to completion, independently of whether the primary query reads all (or indeed any) of their output. Notice that this is different from the rule for `SELECT` in `WITH`: as stated in the previous section, execution of a `SELECT` is carried only as far as the primary query demands its output.

The sub-statements in `WITH` are executed concurrently with each other and with the main query. Therefore, when using data-modifying statements in `WITH`, the order in which the specified updates actually happen is unpredictable. All the statements are executed with the same *snapshot* (see Chapter 13), so they cannot “see” one another's effects on the target tables. This alleviates the effects of the unpredictability of the actual order of row updates, and means that `RETURNING` data is the only way to communicate changes between different `WITH` sub-statements and the main query. An example of this is that in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM products;
```

the outer `SELECT` would return the original prices before the action of the `UPDATE`, while in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM t;
```

the outer `SELECT` would return the updated data.

Trying to update the same row twice in a single statement is not supported. Only one of the modifications takes place, but it is not easy (and sometimes not possible) to reliably predict which one. This also applies to deleting a row that was already updated in the same statement: only the update is performed. Therefore you should generally avoid trying to modify a single row twice in a single statement. In particular avoid writing `WITH` sub-statements that could affect the same rows changed by the main statement or a sibling sub-statement. The effects of such a statement will not be predictable.

At present, any table used as the target of a data-modifying statement in `WITH` must not have a conditional rule, nor an `ALSO` rule, nor an `INSTEAD` rule that expands to multiple statements.

## 7.9. ROWNUM

`ROWNUM` is a pseudocolumn like oracle `ROWNUM`. A pseudocolumn behaves like a table column, but is not actually stored in the table. You can select from pseudocolumns, but you cannot insert, update, or delete their values. A pseudocolumn is also similar to a function without arguments. However, functions without arguments typically return the same value for every row in the result set, whereas pseudocolumns typically return a different value for each row.

For each row returned by a query, the `ROWNUM` pseudocolumn returns a number indicating the order in which LightDB selects the row from a table or set of joined rows. The first row selected has a `ROWNUM` of 1, the second has 2, and so on.

You can use `ROWNUM` to limit the number of rows returned by a query, as in this example:

```
SELECT * from employees WHERE ROWNUM < 10;
```

If an `ORDER BY` clause follows `ROWNUM` in the same query, then the rows will be reordered by the `ORDER BY` clause.

```
SELECT * FROM employees WHERE ROWNUM < 11 ORDER BY last_name;
```

If you embed the `ORDER BY` clause in a subquery and place the `ROWNUM` condition in the top-level query, then you can force the `ROWNUM` condition to be applied after the ordering of the rows. For example, the following query returns the employees with the 10 smallest employee numbers. This is sometimes referred to as top-N reporting:

```
SELECT * FROM
  (SELECT * FROM employees ORDER BY employee_id)
 WHERE ROWNUM < 11;
```

In the preceding example, the `ROWNUM` values are those of the top-level `SELECT` statement, so they are generated after the rows have already been ordered by `employee_id` in the subquery.

Conditions testing for `ROWNUM` values greater than a positive integer are always false. For example, this query returns no rows:

```
SELECT * FROM employees WHERE ROWNUM > 1;
```

The first row fetched is assigned a `ROWNUM` of 1 and makes the condition false. The second row to be fetched is now the first row and is also assigned a `ROWNUM` of 1 and makes the condition false. All rows subsequently fail to satisfy the condition, so no rows are returned.

You can also use `ROWNUM` in `UPDATE` and `DELETE` statements like `SELECT` statement.

```
UPDATE employees SET employee_id = 0 WHERE ROWNUM < 10;  
DELETE FROM employees WHERE ROWNUM < 10;
```

Notice, ROWNUM is not support canopy. If you sometimes referred to as top-N reporting in canopy, consider using limit instead.

---

# Chapter 8. Data Types

LightDB has a rich set of native data types available to users. Users can add new types to LightDB using the CREATE TYPE command.

Table 8.1 shows all the built-in general-purpose data types. Most of the alternative names listed in the “Aliases” column are the names used internally by LightDB for historical reasons. In addition, some internally used or deprecated types are available, but are not listed here.

**Table 8.1. Data Types**

Name	Aliases	Description
bigint	int8	signed eight-byte integer
bigserial	serial8	autoincrementing eight-byte integer
bit [ (n) ]		fixed-length bit string
bit varying [ (n) ]	varbit [ (n) ]	variable-length bit string
boolean	bool	logical Boolean (true/false)
box		rectangular box on a plane
bytea		binary data (“byte array”)
character [ (n) ]	char [ (n) ]	fixed-length character string
character varying [ (n) ]	varchar [ (n) ]	variable-length character string
cidr		IPv4 or IPv6 network address
circle		circle on a plane
date		calendar date (year, month, day)
double precision	float8	double precision floating-point number (8 bytes)
inet		IPv4 or IPv6 host address
integer	int, int4	signed four-byte integer
interval [ <i>fields</i> ] [ (p) ]		time span
json		textual JSON data
jsonb		binary JSON data, decomposed
line		infinite line on a plane
lseg		line segment on a plane
macaddr		MAC (Media Access Control) address
macaddr8		MAC (Media Access Control) address (EUI-64 format)
money		currency amount
numeric [ (p, s) ]	decimal [ (p, s) ]	exact numeric of selectable precision
path		geometric path on a plane
pg_lsn		LightDB Log Sequence Number
pg_snapshot		user-level transaction ID snapshot
point		geometric point on a plane

Name	Aliases	Description
<code>polygon</code>		closed geometric path on a plane
<code>real</code>	<code>float4</code>	single precision floating-point number (4 bytes)
<code>smallint</code>	<code>int2</code>	signed two-byte integer
<code>smallserial</code>	<code>serial2</code>	autoincrementing two-byte integer
<code>serial</code>	<code>serial4</code>	autoincrementing four-byte integer
<code>text</code>		variable-length character string
<code>time [ (p) ] [ without time zone ]</code>		time of day (no time zone)
<code>time [ (p) ] with time zone</code>	<code>timetz</code>	time of day, including time zone
<code>timestamp [ (p) ] [ without time zone ]</code>		date and time (no time zone)
<code>timestamp [ (p) ] with time zone</code>	<code>timestamptz</code>	date and time, including time zone
<code>tsquery</code>		text search query
<code>tsvector</code>		text search document
<code>txid_snapshot</code>		user-level transaction ID snapshot (deprecated; see <code>pg_snapshot</code> )
<code>uuid</code>		universally unique identifier
<code>xml</code>		XML data

### Compatibility

The following types (or spellings thereof) are specified by SQL: `bigint`, `bit`, `bit varying`, `boolean`, `char`, `character varying`, `character`, `varchar`, `date`, `double precision`, `integer`, `interval`, `numeric`, `decimal`, `real`, `smallint`, `time` (with or without time zone), `timestamp` (with or without time zone), `xml`.

Each data type has an external representation determined by its input and output functions. Many of the built-in types have obvious external formats. However, several types are either unique to LightDB, such as geometric paths, or have several possible formats, such as the date and time types. Some of the input and output functions are not invertible, i.e., the result of an output function might lose accuracy when compared to the original input.

## 8.1. Numeric Types

Numeric types consist of two-, four-, and eight-byte integers, four- and eight-byte floating-point numbers, and selectable-precision decimals. Table 8.2 lists the available types.

**Table 8.2. Numeric Types**

Name	Storage Size	Description	Range
<code>smallint</code>	2 bytes	small-range integer	-32768 to +32767
<code>integer</code>	4 bytes	typical choice for integer	-2147483648 to +2147483647



Name	Storage Size	Description	Range
<code>bigint</code>	8 bytes	large-range integer	-9223372036854775808 to +9223372036854775807
<code>decimal</code>	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
<code>numeric</code>	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
<code>real</code>	4 bytes	variable-precision, inexact	6 decimal digits precision
<code>double precision</code>	8 bytes	variable-precision, inexact	15 decimal digits precision
<code>smallserial</code>	2 bytes	small autoincrementing integer	1 to 32767
<code>serial</code>	4 bytes	autoincrementing integer	1 to 2147483647
<code>bigserial</code>	8 bytes	large autoincrementing integer	1 to 9223372036854775807

The syntax of constants for the numeric types is described in Section 4.1.2. The numeric types have a full set of corresponding arithmetic operators and functions. Refer to Chapter 9 for more information. The following sections describe the types in detail.

### 8.1.1. Integer Types

The types `smallint`, `integer`, and `bigint` store whole numbers, that is, numbers without fractional components, of various ranges. Attempts to store values outside of the allowed range will result in an error.

The type `integer` is the common choice, as it offers the best balance between range, storage size, and performance. The `smallint` type is generally only used if disk space is at a premium. The `bigint` type is designed to be used when the range of the `integer` type is insufficient.

SQL only specifies the integer types `integer` (or `int`), `smallint`, and `bigint`. The type names `int2`, `int4`, and `int8` are extensions, which are also used by some other SQL database systems.

Note that in MySQL compatibility mode, `smallint` can insert and update `boolean` (`true/false`), and use `is true/false`, `= true/false` to judge. This behavior is compatible with MySQL's use of `tinyint` to store `boolean`. After importing LightDB, `tinyint` are converted to `smallint`.

Note that,now `integer` is support `int(n)`.the range of `n` is 1~19;if `n` between 1 and 9,the type is `int4`;if `n` between 10 and 19,the type is `int8`;

### 8.1.2. Arbitrary Precision Numbers

The type `numeric` can store numbers with a very large number of digits. It is especially recommended for storing monetary amounts and other quantities where exactness is required. Calculations with `numeric` values yield exact results where possible, e.g., addition, subtraction, multiplication. However, calculations on `numeric` values are very slow compared to the integer types, or to the floating-point types described in the next section.

We use the following terms below: The *precision* of a `numeric` is the total count of significant digits in the whole number, that is, the number of digits to both sides of the decimal point. The *scale* of a `numeric` is the count of decimal digits in the fractional part, to the right of the decimal point. So the number 23.5141 has a precision of 6 and a scale of 4. Integers can be considered to have a scale of zero.

Both the maximum precision and the maximum scale of a `numeric` column can be configured. To declare a column of type `numeric` use the syntax:

```
NUMERIC(precision, scale)
```

The precision must be positive, the scale zero or positive. Alternatively:

```
NUMERIC(precision)
```

selects a scale of 0. Specifying:

```
NUMERIC
```

without any precision or scale creates a column in which numeric values of any precision and scale can be stored, up to the implementation limit on precision. A column of this kind will not coerce input values to any particular scale, whereas `numeric` columns with a declared scale will coerce input values to that scale. (The SQL standard requires a default scale of 0, i.e., coercion to integer precision. We find this a bit useless. If you're concerned about portability, always specify the precision and scale explicitly.)

### Note

The maximum allowed precision when explicitly specified in the type declaration is 1000; `NUMERIC` without a specified precision is subject to the limits described in Table 8.2.

If the scale of a value to be stored is greater than the declared scale of the column, the system will round the value to the specified number of fractional digits. Then, if the number of digits to the left of the decimal point exceeds the declared precision minus the declared scale, an error is raised.

Numeric values are physically stored without any extra leading or trailing zeroes. Thus, the declared precision and scale of a column are maximums, not fixed allocations. (In this sense the `numeric` type is more akin to `varchar(n)` than to `char(n)`.) The actual storage requirement is two bytes for each group of four decimal digits, plus three to eight bytes overhead.

In addition to ordinary numeric values, the `numeric` type allows the special value `NaN`, meaning “not-a-number”. Any operation on `NaN` yields another `NaN`. When writing this value as a constant in an SQL command, you must put quotes around it, for example `UPDATE table SET x = 'NaN'`. On input, the string `NaN` is recognized in a case-insensitive manner.

### Note

In most implementations of the “not-a-number” concept, `NaN` is not considered equal to any other numeric value (including `NaN`). In order to allow `numeric` values to be sorted and used in tree-based indexes, LightDB treats `NaN` values as equal, and greater than all non-`NaN` values.

The types `decimal` and `numeric` are equivalent. Both types are part of the SQL standard.

When rounding values, the `numeric` type rounds ties away from zero, while (on most machines) the `real` and `double precision` types round ties to the nearest even number. For example:

```

SELECT x,
       round(x::numeric) AS num_round,
       round(x::double precision) AS dbl_round
FROM generate_series(-3.5, 3.5, 1) as x;

```

x	num_round	dbl_round
-3.5	-4	-4
-2.5	-3	-2
-1.5	-2	-2
-0.5	-1	-0
0.5	1	0
1.5	2	2
2.5	3	2
3.5	4	4

(8 rows)

### 8.1.3. Floating-Point Types

The data types `real` and `double precision` are inexact, variable-precision numeric types. On all currently supported platforms, these types are implementations of IEEE Standard 754 for Binary Floating-Point Arithmetic (single and double precision, respectively), to the extent that the underlying processor, operating system, and compiler support it.

Inexact means that some values cannot be converted exactly to the internal format and are stored as approximations, so that storing and retrieving a value might show slight discrepancies. Managing these errors and how they propagate through calculations is the subject of an entire branch of mathematics and computer science and will not be discussed here, except for the following points:

- If you require exact storage and calculations (such as for monetary amounts), use the `numeric` type instead.
- If you want to do complicated calculations with these types for anything important, especially if you rely on certain behavior in boundary cases (infinity, underflow), you should evaluate the implementation carefully.
- Comparing two floating-point values for equality might not always work as expected.

On all currently supported platforms, the `real` type has a range of around  $1\text{E}-37$  to  $1\text{E}+37$  with a precision of at least 6 decimal digits. The `double precision` type has a range of around  $1\text{E}-307$  to  $1\text{E}+308$  with a precision of at least 15 digits. Values that are too large or too small will cause an error. Rounding might take place if the precision of an input number is too high. Numbers too close to zero that are not representable as distinct from zero will cause an underflow error.

By default, floating point values are output in text form in their shortest precise decimal representation; the decimal value produced is closer to the true stored binary value than to any other value representable in the same binary precision. (However, the output value is currently never *exactly* midway between two representable values, in order to avoid a widespread bug where input routines do not properly respect the round-to-nearest-even rule.) This value will use at most 17 significant decimal digits for `float8` values, and at most 9 digits for `float4` values.

#### Note

This shortest-precise output format is much faster to generate than the historical rounded format.

For compatibility with output generated by older versions of LightDB, and to allow the output precision to be reduced, the `extra_float_digits` parameter can be used to select rounded decimal output instead. Setting a value of 0 restores the previous default of rounding the value to 6 (for `float4`)

or 15 (for `float8`) significant decimal digits. Setting a negative value reduces the number of digits further; for example `-2` would round output to 4 or 13 digits respectively.

Any value of `extra_float_digits` greater than 0 selects the shortest-precise format.

### Note

Applications that wanted precise values have historically had to set `extra_float_digits` to 3 to obtain them. For maximum compatibility between versions, they should continue to do so.

In addition to ordinary numeric values, the floating-point types have several special values:

```
Infinity
-Infinity
NaN
```

These represent the IEEE 754 special values “infinity”, “negative infinity”, and “not-a-number”, respectively. When writing these values as constants in an SQL command, you must put quotes around them, for example `UPDATE table SET x = '-Infinity'`. On input, these strings are recognized in a case-insensitive manner.

### Note

IEEE754 specifies that NaN should not compare equal to any other floating-point value (including NaN). In order to allow floating-point values to be sorted and used in tree-based indexes, LightDB treats NaN values as equal, and greater than all non-NaN values.

LightDB also supports the SQL-standard notations `float` and `float(p)` for specifying inexact numeric types. Here, *p* specifies the minimum acceptable precision in *binary* digits. LightDB accepts `float(1)` to `float(24)` as selecting the real type, while `float(25)` to `float(53)` select double precision. Values of *p* outside the allowed range draw an error. `float` with no precision specified is taken to mean double precision.

## 8.1.4. Serial Types

### Note

This section describes a LightDB-specific way to create an autoincrementing column. Another way is to use the SQL-standard identity column feature, described at `CREATE TABLE`.

The data types `smallserial`, `serial` and `bigserial` are not true types, but merely a notational convenience for creating unique identifier columns (similar to the `AUTO_INCREMENT` property supported by some other databases). In the current implementation, specifying:

```
CREATE TABLE tablename (
    colname SERIAL
);
```

is equivalent to specifying:

```
CREATE SEQUENCE tablename_colname_seq AS integer;
CREATE TABLE tablename (
    colname integer NOT NULL DEFAULT
    nextval('tablename_colname_seq')
);
ALTER SEQUENCE tablename_colname_seq OWNED BY tablename.colname;
```

Thus, we have created an integer column and arranged for its default values to be assigned from a sequence generator. A NOT NULL constraint is applied to ensure that a null value cannot be inserted. (In most cases you would also want to attach a UNIQUE or PRIMARY KEY constraint to prevent duplicate values from being inserted by accident, but this is not automatic.) Lastly, the sequence is marked as “owned by” the column, so that it will be dropped if the column or table is dropped.

### Note

Because `smallserial`, `serial` and `bigserial` are implemented using sequences, there may be “holes” or gaps in the sequence of values which appears in the column, even if no rows are ever deleted. A value allocated from the sequence is still “used up” even if a row containing that value is never successfully inserted into the table column. This may happen, for example, if the inserting transaction rolls back. See `nextval()` in Section 9.17 for details.

To insert the next value of the sequence into the `serial` column, specify that the `serial` column should be assigned its default value. This can be done either by excluding the column from the list of columns in the `INSERT` statement, or through the use of the `DEFAULT` key word.

The type names `serial` and `serial4` are equivalent: both create `integer` columns. The type names `bigserial` and `serial8` work the same way, except that they create a `bigint` column. `bigserial` should be used if you anticipate the use of more than  $2^{31}$  identifiers over the lifetime of the table. The type names `smallserial` and `serial2` also work the same way, except that they create a `smallint` column.

The sequence created for a `serial` column is automatically dropped when the owning column is dropped. You can drop the sequence without dropping the column, but this will force removal of the column default expression.

## 8.2. Monetary Types

The money type stores a currency amount with a fixed fractional precision; see Table 8.3. The fractional precision is determined by the database's `lc_monetary` setting. The range shown in the table assumes there are two fractional digits. Input is accepted in a variety of formats, including integer and floating-point literals, as well as typical currency formatting, such as '\$1,000.00'. Output is generally in the latter form but depends on the locale.

**Table 8.3. Monetary Types**

Name	Storage Size	Description	Range
money	8 bytes	currency amount	-92233720368547758.08 to +92233720368547758.07

Since the output of this data type is locale-sensitive, it might not work to load money data into a database that has a different setting of `lc_monetary`. To avoid problems, before restoring a dump into a new database make sure `lc_monetary` has the same or equivalent value as in the database that was dumped.

Values of the `numeric`, `int`, and `bigint` data types can be cast to `money`. Conversion from the `real` and `double precision` data types can be done by casting to `numeric` first, for example:

```
SELECT '12.34'::float8::numeric::money;
```

However, this is not recommended. Floating point numbers should not be used to handle money due to the potential for rounding errors.

A `money` value can be cast to `numeric` without loss of precision. Conversion to other types could potentially lose precision, and must also be done in two stages:

```
SELECT '52093.89'::money::numeric::float8;
```

Division of a `money` value by an integer value is performed with truncation of the fractional part towards zero. To get a rounded result, divide by a floating-point value, or cast the `money` value to `numeric` before dividing and back to `money` afterwards. (The latter is preferable to avoid risking precision loss.) When a `money` value is divided by another `money` value, the result is `double precision` (i.e., a pure number, not `money`); the currency units cancel each other out in the division.

## 8.3. Character Types

**Table 8.4. Character Types**

Name	Description
<code>character varying(n [BYTE CHAR])</code> , <code>varchar(n [BYTE CHAR])</code>	variable-length with limit
<code>character(n [BYTE CHAR])</code> , <code>char(n [BYTE CHAR])</code>	fixed-length, blank padded
<code>text</code>	variable unlimited length

Table 8.4 shows the general-purpose character types available in LightDB.

SQL defines two primary character types: `character varying(n)` and `character(n)`, where  $n$  is a positive integer. Both of these types can store strings up to  $n$  characters (not bytes) in length. An attempt to store a longer string into a column of these types will result in an error, unless the excess characters are all spaces, in which case the string will be truncated to the maximum length. (This somewhat bizarre exception is required by the SQL standard.) If the string to be stored is shorter than the declared length, values of type `character` will be space-padded; values of type `character varying` will simply store the shorter string.

If one explicitly casts a value to `character varying(n)` or `character(n)`, then an over-length value will be truncated to  $n$  characters without raising an error. (This too is required by the SQL standard.)

The notations `varchar(n)` and `char(n)` are aliases for `character varying(n)` and `character(n)`, respectively. `character` without length specifier is equivalent to `character(1)`. If `character varying` is used without length specifier, the type accepts strings of any size. The latter is a LightDB extension.

In addition, LightDB provides the `text` type, which stores strings of any length. Although the type `text` is not in the SQL standard, several other SQL database management systems have it as well.

Values of type `character` are physically padded with spaces to the specified width  $n$ , and are stored and displayed that way. However, trailing spaces are treated as semantically insignificant and disregarded when comparing two values of type `character`. In collations where whitespace is

significant, this behavior can produce unexpected results; for example `SELECT 'a '::CHAR(2) collate "C" < E'a\n'::CHAR(2)` returns true, even though C locale would consider a space to be greater than a newline. Trailing spaces are removed when converting a character value to one of the other string types. Note that trailing spaces *are* semantically significant in character varying and text values, and when using pattern matching, that is LIKE and regular expressions.

The characters that can be stored in any of these data types are determined by the database character set, which is selected when the database is created. Regardless of the specific character set, the character with code zero (sometimes called NUL) cannot be stored. For more information refer to Section 21.3.

The storage requirement for a short string (up to 126 bytes) is 1 byte plus the actual string, which includes the space padding in the case of character. Longer strings have 4 bytes of overhead instead of 1. Long strings are compressed by the system automatically, so the physical requirement on disk might be less. Very long values are also stored in background tables so that they do not interfere with rapid access to shorter column values. In any case, the longest possible character string that can be stored is about 1 GB. (The maximum value that will be allowed for *n* in the data type declaration is less than that. It wouldn't be useful to change this because with multibyte character encodings the number of characters and bytes can be quite different. If you desire to store long strings with no specific upper limit, use text or character varying without a length specifier, rather than making up an arbitrary length limit.)

In order to be compatible with the syntax of ORACLE database, the char data type supports specifying BYTE or CHAR. This feature is just grammatical sugar and does not fulfill the actual function.

### Tip

There is no performance difference among these three types, apart from increased storage space when using the blank-padded type, and a few extra CPU cycles to check the length when storing into a length-constrained column. While character(*n*) has performance advantages in some other database systems, there is no such advantage in LightDB; in fact character(*n*) is usually the slowest of the three because of its additional storage costs. In most situations text or character varying should be used instead.

Refer to Section 4.1.2.1 for information about the syntax of string literals, and to Chapter 9 for information about available operators and functions.

### Example 8.1. Using the Character Types

```
CREATE TABLE test1 (a character(4));
INSERT INTO test1 VALUES ('ok');
SELECT a, char_length(a) FROM test1; -- 1
```

a	char_length
ok	2

```
CREATE TABLE test2 (b varchar(5));
INSERT INTO test2 VALUES ('ok');
INSERT INTO test2 VALUES ('good ');
INSERT INTO test2 VALUES ('too long');
ERROR: value too long for type character varying(5)
INSERT INTO test2 VALUES ('too long'::varchar(5)); -- explicit
truncation
```

```
SELECT b, char_length(b) FROM test2;
```

b	char_length
ok	2
good	5
too 1	5

```
create table t1(name character(10 byte));
create table t2(name char(10 char));
create table t3(name varchar(10 char));
create table t4(name character varying(10 byte));
```

**I** The `char_length` function is discussed in Section 9.4.

There are two other fixed-length character types in LightDB, shown in Table 8.5. The `name` type exists *only* for the storage of identifiers in the internal system catalogs and is not intended for use by the general user. Its length is currently defined as 64 bytes (63 usable characters plus terminator) but should be referenced using the constant `NAMEDATALEN` in C source code. The length is set at compile time (and is therefore adjustable for special uses); the default maximum length might change in a future release. The type `"char"` (note the quotes) is different from `char(1)` in that it only uses one byte of storage. It is internally used in the system catalogs as a simplistic enumeration type.

**Table 8.5. Special Character Types**

Name	Storage Size	Description
"char"	1 byte	single-byte internal type
name	64 bytes	internal type for object names

## 8.4. Binary Data Types

The `bytea` data type allows storage of binary strings; see Table 8.6.

**Table 8.6. Binary Data Types**

Name	Storage Size	Description
bytea	1 or 4 bytes plus the actual binary string	variable-length binary string

A binary string is a sequence of octets (or bytes). Binary strings are distinguished from character strings in two ways. First, binary strings specifically allow storing octets of value zero and other “non-printable” octets (usually, octets outside the decimal range 32 to 126). Character strings disallow zero octets, and also disallow any other octet values and sequences of octet values that are invalid according to the database's selected character set encoding. Second, operations on binary strings process the actual bytes, whereas the processing of character strings depends on locale settings. In short, binary strings are appropriate for storing data that the programmer thinks of as “raw bytes”, whereas character strings are appropriate for storing text.

The `bytea` type supports two formats for input and output: “hex” format and LightDB's historical “escape” format. Both of these are always accepted on input. The output format depends on the configuration parameter `bytea_output`; the default is hex. (Note that the hex format was introduced in LightDB 9.0; earlier versions and some tools don't understand it.)

The SQL standard defines a different binary string type, called `BLOB` or `BINARY LARGE OBJECT`. The input format is different from `bytea`, but the provided functions and operators are mostly the same.



## 8.4.1. `bytea` Hex Format

The “hex” format encodes binary data as 2 hexadecimal digits per byte, most significant nibble first. The entire string is preceded by the sequence `\x` (to distinguish it from the escape format). In some contexts, the initial backslash may need to be escaped by doubling it (see Section 4.1.2.1). For input, the hexadecimal digits can be either upper or lower case, and whitespace is permitted between digit pairs (but not within a digit pair nor in the starting `\x` sequence). The hex format is compatible with a wide range of external applications and protocols, and it tends to be faster to convert than the escape format, so its use is preferred.

Example:

```
SELECT '\xDEADBEEF' ;
```

## 8.4.2. `bytea` Escape Format

The “escape” format is the traditional LightDB format for the `bytea` type. It takes the approach of representing a binary string as a sequence of ASCII characters, while converting those bytes that cannot be represented as an ASCII character into special escape sequences. If, from the point of view of the application, representing bytes as characters makes sense, then this representation can be convenient. But in practice it is usually confusing because it fuzzes up the distinction between binary strings and character strings, and also the particular escape mechanism that was chosen is somewhat unwieldy. Therefore, this format should probably be avoided for most new applications.

When entering `bytea` values in escape format, octets of certain values *must* be escaped, while all octet values *can* be escaped. In general, to escape an octet, convert it into its three-digit octal value and precede it by a backslash. Backslash itself (octet decimal value 92) can alternatively be represented by double backslashes. Table 8.7 shows the characters that must be escaped, and gives the alternative escape sequences where applicable.

**Table 8.7. `bytea` Literal Escaped Octets**

Decimal Octet Value	Description	Escaped Input Representation	Example	Hex Representation
0	zero octet	'\000'	'\000'::bytea	\x00
39	single quote	'''' or '\047'	''''::bytea	\x27
92	backslash	'\\' or '\134'	'\\'::bytea	\x5c
0 to 31 and 127 to 255	“non-printable” octets	'\xxx' (octal value)	'\001'::bytea	\x01

The requirement to escape *non-printable* octets varies depending on locale settings. In some instances you can get away with leaving them unescaped.

The reason that single quotes must be doubled, as shown in Table 8.7, is that this is true for any string literal in a SQL command. The generic string-literal parser consumes the outermost single quotes and reduces any pair of single quotes to one data character. What the `bytea` input function sees is just one single quote, which it treats as a plain data character. However, the `bytea` input function treats backslashes as special, and the other behaviors shown in Table 8.7 are implemented by that function.

In some contexts, backslashes must be doubled compared to what is shown above, because the generic string-literal parser will also reduce pairs of backslashes to one data character; see Section 4.1.2.1.

`bytea` octets are output in hex format by default. If you change `bytea_output` to `escape`, “non-printable” octets are converted to their equivalent three-digit octal value and preceded by one

backslash. Most “printable” octets are output by their standard representation in the client character set, e.g.:

```
SET bytea_output = 'escape';

SELECT 'abc \153\154\155 \052\251\124'::bytea;
      bytea
-----
abc klm *\251T
```

The octet with decimal value 92 (backslash) is doubled in the output. Details are in Table 8.8.

**Table 8.8. bytea Output Escaped Octets**

Decimal Octet Value	Description	Escaped Output Representation	Example	Output Result
92	backslash	\\	'\134'::bytea	\\
0 to 31 and 127 to 255	“non-printable” octets	\xxx (octal value)	'\001'::bytea	\001
32 to 126	“printable” octets	client character set representation	'\176'::bytea	~

Depending on the front end to LightDB you use, you might have additional work to do in terms of escaping and unescaping `bytea` strings. For example, you might also have to escape line feeds and carriage returns if your interface automatically translates these.

## 8.5. Date/Time Types

LightDB supports the full set of SQL date and time types, shown in Table 8.9. The operations available on these data types are described in Section 9.9. Dates are counted according to the Gregorian calendar, even in years before that calendar was introduced (see Section B.6 for more information).

**Table 8.9. Date/Time Types**

Name	Storage Size	Description	Low Value	High Value	Resolution
timestamp [ (p) ] [ without time zone ]	8 bytes	both date and time (no time zone)	4713 BC	294276 AD	1 microsecond
timestamp [ (p) ] with time zone	8 bytes	both date and time, with time zone	4713 BC	294276 AD	1 microsecond
date	4 bytes	date (no time of day)	4713 BC	5874897 AD	1 day
time [ (p) ] [ without time zone ]	8 bytes	time of day (no date)	00:00:00	24:00:00	1 microsecond
time [ (p) ]	12 bytes	time of day (no date), with time zone	00:00:00+1559	24:00:00-1559	1 microsecond

Name	Storage Size	Description	Low Value	High Value	Resolution
with time zone					
interval [ <i>fields</i> ] [ ( <i>p</i> ) ]	16 bytes	time interval	-178000000 years	178000000 years	1 microsecond

### Note

The SQL standard requires that writing just `timestamp` be equivalent to `timestamp without time zone`, and LightDB honors that behavior. `timestamptz` is accepted as an abbreviation for `timestamp with time zone`; this is a LightDB extension.

`time`, `timestamp`, and `interval` accept an optional precision value *p* which specifies the number of fractional digits retained in the seconds field. By default, there is no explicit bound on precision. The allowed range of *p* is from 0 to 6.

The `interval` type has an additional option, which is to restrict the set of stored fields by writing one of these phrases:

YEAR  
MONTH  
DAY  
HOUR  
MINUTE  
SECOND  
YEAR TO MONTH  
DAY TO HOUR  
DAY TO MINUTE  
DAY TO SECOND  
HOUR TO MINUTE  
HOUR TO SECOND  
MINUTE TO SECOND

Note that if both *fields* and *p* are specified, the *fields* must include `SECOND`, since the precision applies only to the seconds.

The type `time with time zone` is defined by the SQL standard, but the definition exhibits properties which lead to questionable usefulness. In most cases, a combination of `date`, `time`, `timestamp without time zone`, and `timestamp with time zone` should provide a complete range of date/time functionality required by any application.

## 8.5.1. Date/Time Input

Date and time input is accepted in almost any reasonable format, including ISO 8601, SQL-compatible, traditional POSTGRES, and others. For some formats, ordering of day, month, and year in date input is ambiguous and there is support for specifying the expected ordering of these fields. Set the `DateStyle` parameter to `MDY` to select month-day-year interpretation, `DMY` to select day-month-year interpretation, or `YMD` to select year-month-day interpretation.

LightDB is more flexible in handling date/time input than the SQL standard requires. See Appendix B for the exact parsing rules of date/time input and for the recognized text fields including months, days of the week, and time zones.

Remember that any date or time literal input needs to be enclosed in single quotes, like text strings. Refer to Section 4.1.2.8 for more information. SQL requires the following syntax

```
type [ (p) ] 'value'
```

where *p* is an optional precision specification giving the number of fractional digits in the seconds field. Precision can be specified for `time`, `timestamp`, and `interval` types, and can range from 0 to 6. If no precision is specified in a constant specification, it defaults to the precision of the literal value (but not more than 6 digits).

### 8.5.1.1. Dates

Table 8.10 shows some possible inputs for the `date` type.

**Table 8.10. Date Input**

Example	Description
1999-01-08	ISO 8601; January 8 in any mode (recommended format)
January 8, 1999	unambiguous in any <code>datestyle</code> input mode
1/8/1999	January 8 in MDY mode; August 1 in DMY mode
1/18/1999	January 18 in MDY mode; rejected in other modes
01/02/03	January 2, 2003 in MDY mode; February 1, 2003 in DMY mode; February 3, 2001 in YMD mode
1999-Jan-08	January 8 in any mode
Jan-08-1999	January 8 in any mode
08-Jan-1999	January 8 in any mode
99-Jan-08	January 8 in YMD mode, else error
08-Jan-99	January 8, except error in YMD mode
Jan-08-99	January 8, except error in YMD mode
19990108	ISO 8601; January 8, 1999 in any mode
990108	ISO 8601; January 8, 1999 in any mode
1999.008	year and day of year
J2451187	Julian date
January 8, 99 BC	year 99 BC

### 8.5.1.2. Times

The time-of-day types are `time [ (p) ]` without time zone and `time [ (p) ]` with time zone. `time` alone is equivalent to `time without time zone`.

Valid input for these types consists of a time of day followed by an optional time zone. (See Table 8.11 and Table 8.12.) If a time zone is specified in the input for `time without time zone`, it is silently ignored. You can also specify a date but it will be ignored, except when you use a time zone name that involves a daylight-savings rule, such as `America/New_York`. In this case specifying the date is required in order to determine whether standard or daylight-savings time applies. The appropriate time zone offset is recorded in the `time with time zone` value.

**Table 8.11. Time Input**

Example	Description
04:05:06.789	ISO 8601

Example	Description
04:05:06	ISO 8601
04:05	ISO 8601
040506	ISO 8601
04:05 AM	same as 04:05; AM does not affect value
04:05 PM	same as 16:05; input hour must be <= 12
04:05:06.789-8	ISO 8601, with time zone as UTC offset
04:05:06-08:00	ISO 8601, with time zone as UTC offset
04:05-08:00	ISO 8601, with time zone as UTC offset
040506-08	ISO 8601, with time zone as UTC offset
040506+0730	ISO 8601, with fractional-hour time zone as UTC offset
040506+07:30:00	UTC offset specified to seconds (not allowed in ISO 8601)
04:05:06 PST	time zone specified by abbreviation
2003-04-12 04:05:06 America/New_York	time zone specified by full name

**Table 8.12. Time Zone Input**

Example	Description
PST	Abbreviation (for Pacific Standard Time)
America/New_York	Full time zone name
PST8PDT	POSIX-style time zone specification
-8:00:00	UTC offset for PST
-8:00	UTC offset for PST (ISO 8601 extended format)
-800	UTC offset for PST (ISO 8601 basic format)
-8	UTC offset for PST (ISO 8601 basic format)
zulu	Military abbreviation for UTC
z	Short form of zulu (also in ISO 8601)

Refer to Section 8.5.3 for more information on how to specify time zones.

### 8.5.1.3. Time Stamps

Valid input for the time stamp types consists of the concatenation of a date and a time, followed by an optional time zone, followed by an optional AD or BC. (Alternatively, AD/BC can appear before the time zone, but this is not the preferred ordering.) Thus:

1999-01-08 04:05:06

and:

1999-01-08 04:05:06 -8:00

are valid values, which follow the ISO 8601 standard. In addition, the common format:

```
January 8 04:05:06 1999 PST
```

is supported.

The SQL standard differentiates `timestamp without time zone` and `timestamp with time zone` literals by the presence of a “+” or “-” symbol and time zone offset after the time. Hence, according to the standard,

```
TIMESTAMP '2004-10-19 10:23:54'
```

is a `timestamp without time zone`, while

```
TIMESTAMP '2004-10-19 10:23:54+02'
```

is a `timestamp with time zone`. LightDB never examines the content of a literal string before determining its type, and therefore will treat both of the above as `timestamp without time zone`. To ensure that a literal is treated as `timestamp with time zone`, give it the correct explicit type:

```
TIMESTAMP WITH TIME ZONE '2004-10-19 10:23:54+02'
```

In a literal that has been determined to be `timestamp without time zone`, LightDB will silently ignore any time zone indication. That is, the resulting value is derived from the date/time fields in the input value, and is not adjusted for time zone.

For `timestamp with time zone`, the internally stored value is always in UTC (Universal Coordinated Time, traditionally known as Greenwich Mean Time, GMT). An input value that has an explicit time zone specified is converted to UTC using the appropriate offset for that time zone. If no time zone is stated in the input string, then it is assumed to be in the time zone indicated by the system's `TimeZone` parameter, and is converted to UTC using the offset for the `timezone` zone.

When a `timestamp with time zone` value is output, it is always converted from UTC to the current `timezone` zone, and displayed as local time in that zone. To see the time in another time zone, either change `timezone` or use the `AT TIME ZONE` construct (see Section 9.9.3).

Conversions between `timestamp without time zone` and `timestamp with time zone` normally assume that the `timestamp without time zone` value should be taken or given as `timezone` local time. A different time zone can be specified for the conversion using `AT TIME ZONE`.

### 8.5.1.4. Special Values

LightDB supports several special date/time input values for convenience, as shown in Table 8.13. The values `infinity` and `-infinity` are specially represented inside the system and will be displayed unchanged; but the others are simply notational shorthands that will be converted to ordinary date/time values when read. (In particular, `now` and related strings are converted to a specific time value as soon as they are read.) All of these values need to be enclosed in single quotes when used as constants in SQL commands.

**Table 8.13. Special Date/Time Inputs**

Input String	Valid Types	Description
<code>epoch</code>	<code>date</code> , <code>timestamp</code>	1970-01-01 00:00:00+00 (Unix system time zero)

Input String	Valid Types	Description
infinity	date, timestamp	later than all other time stamps
-infinity	date, timestamp	earlier than all other time stamps
now	date, time, timestamp	current transaction's start time
today	date, timestamp	midnight (00:00) today
tomorrow	date, timestamp	midnight (00:00) tomorrow
yesterday	date, timestamp	midnight (00:00) yesterday
allballs	time	00:00:00.00 UTC

The following SQL-compatible functions can also be used to obtain the current time value for the corresponding data type: `CURRENT_DATE`, `CURRENT_TIME`, `CURRENT_TIMESTAMP`, `LOCALTIME`, `LOCALTIMESTAMP`. (See Section 9.9.4.) Note that these are SQL functions and are *not* recognized in data input strings.

### Caution

While the input strings `now`, `today`, `tomorrow`, and `yesterday` are fine to use in interactive SQL commands, they can have surprising behavior when the command is saved to be executed later, for example in prepared statements, views, and function definitions. The string can be converted to a specific time value that continues to be used long after it becomes stale. Use one of the SQL functions instead in such contexts. For example, `CURRENT_DATE + 1` is safer than `'tomorrow'::date`.

## 8.5.2. Date/Time Output

The output format of the date/time types can be set to one of the four styles ISO 8601, SQL (Ingres), traditional POSTGRES (Unix date format), or German. The default is the ISO format. (The SQL standard requires the use of the ISO 8601 format. The name of the “SQL” output format is a historical accident.) Table 8.14 shows examples of each output style. The output of the `date` and `time` types is generally only the date or time part in accordance with the given examples. However, the POSTGRES style outputs date-only values in ISO format.

**Table 8.14. Date/Time Output Styles**

Style Specification	Description	Example
ISO	ISO 8601, SQL standard	1997-12-17 07:37:16-08
SQL	traditional style	12/17/1997 07:37:16.00 PST
Postgres	original style	Wed Dec 17 07:37:16 1997 PST
German	regional style	17.12.1997 07:37:16.00 PST

### Note

ISO 8601 specifies the use of uppercase letter T to separate the date and time. LightDB accepts that format on input, but on output it uses a space rather than T, as shown above. This is for readability and for consistency with RFC 3339 as well as some other database systems.

In the SQL and POSTGRES styles, day appears before month if DMY field ordering has been specified, otherwise month appears before day. (See Section 8.5.1 for how this setting also affects interpretation of input values.) Table 8.15 shows examples.

**Table 8.15. Date Order Conventions**

<b>datestyle Setting</b>	<b>Input Ordering</b>	<b>Example Output</b>
SQL, DMY	<i>day/month/year</i>	17/12/1997 15:37:16.00 CET
SQL, MDY	<i>month/day/year</i>	12/17/1997 07:37:16.00 PST
Postgres, DMY	<i>day/month/year</i>	Wed 17 Dec 07:37:16 1997 PST

In the ISO style, the time zone is always shown as a signed numeric offset from UTC, with positive sign used for zones east of Greenwich. The offset will be shown as *hh* (hours only) if it is an integral number of hours, else as *hh:mm* if it is an integral number of minutes, else as *hh:mm:ss*. (The third case is not possible with any modern time zone standard, but it can appear when working with timestamps that predate the adoption of standardized time zones.) In the other date styles, the time zone is shown as an alphabetic abbreviation if one is in common use in the current zone. Otherwise it appears as a signed numeric offset in ISO 8601 basic format (*hh* or *hhmm*).

The date/time style can be selected by the user using the SET `datestyle` command, the `DateStyle` parameter in the `lightdb.conf` configuration file, or the `LTDATESTYLE` environment variable on the server or client.

The formatting function `to_char` (see Section 9.8) is also available as a more flexible way to format date/time output.

### 8.5.3. Time Zones

Time zones, and time-zone conventions, are influenced by political decisions, not just earth geometry. Time zones around the world became somewhat standardized during the 1900s, but continue to be prone to arbitrary changes, particularly with respect to daylight-savings rules. LightDB uses the widely-used IANA (Olson) time zone database for information about historical time zone rules. For times in the future, the assumption is that the latest known rules for a given time zone will continue to be observed indefinitely far into the future.

LightDB endeavors to be compatible with the SQL standard definitions for typical usage. However, the SQL standard has an odd mix of date and time types and capabilities. Two obvious problems are:

- Although the `date` type cannot have an associated time zone, the `time` type can. Time zones in the real world have little meaning unless associated with a date as well as a time, since the offset can vary through the year with daylight-saving time boundaries.
- The default time zone is specified as a constant numeric offset from UTC. It is therefore impossible to adapt to daylight-saving time when doing date/time arithmetic across DST boundaries.

To address these difficulties, we recommend using date/time types that contain both date and time when using time zones. We do *not* recommend using the type `time with time zone` (though it is supported by LightDB for legacy applications and for compliance with the SQL standard). LightDB assumes your local time zone for any type containing only date or time.

All timezone-aware dates and times are stored internally in UTC. They are converted to local time in the zone specified by the `TimeZone` configuration parameter before being displayed to the client.

LightDB allows you to specify time zones in three different forms:

- A full time zone name, for example `America/New_York`. The recognized time zone names are listed in the `pg_timezone_names` view (see Section 48.100). LightDB uses the widely-used



IANA time zone data for this purpose, so the same time zone names are also recognized by other software.

- A time zone abbreviation, for example `PST`. Such a specification merely defines a particular offset from UTC, in contrast to full time zone names which can imply a set of daylight savings transition rules as well. The recognized abbreviations are listed in the `pg_timezone_abbrevs` view (see Section 48.99). You cannot set the configuration parameters `TimeZone` or `log_timezone` to a time zone abbreviation, but you can use abbreviations in date/time input values and with the `AT TIME ZONE` operator.
- In addition to the timezone names and abbreviations, LightDB will accept POSIX-style time zone specifications, as described in Section B.5. This option is not normally preferable to using a named time zone, but it may be necessary if no suitable IANA time zone entry is available.

In short, this is the difference between abbreviations and full names: abbreviations represent a specific offset from UTC, whereas many of the full names imply a local daylight-savings time rule, and so have two possible UTC offsets. As an example, `2014-06-04 12:00 America/New_York` represents noon local time in New York, which for this particular date was Eastern Daylight Time (UTC-4). So `2014-06-04 12:00 EDT` specifies that same time instant. But `2014-06-04 12:00 EST` specifies noon Eastern Standard Time (UTC-5), regardless of whether daylight savings was nominally in effect on that date.

To complicate matters, some jurisdictions have used the same timezone abbreviation to mean different UTC offsets at different times; for example, in Moscow `MSK` has meant UTC+3 in some years and UTC+4 in others. LightDB interprets such abbreviations according to whatever they meant (or had most recently meant) on the specified date; but, as with the `EST` example above, this is not necessarily the same as local civil time on that date.

In all cases, timezone names and abbreviations are recognized case-insensitively. (This is a change from LightDB versions prior to 8.2, which were case-sensitive in some contexts but not others.)

Neither timezone names nor abbreviations are hard-wired into the server; they are obtained from configuration files stored under `.../share/timezone/` and `.../share/timezonesets/` of the installation directory (see Section B.4).

The `TimeZone` configuration parameter can be set in the file `lightdb.conf`, or in any of the other standard ways described in Chapter 17. There are also some special ways to set it:

- The SQL command `SET TIME ZONE` sets the time zone for the session. This is an alternative spelling of `SET TIMEZONE TO` with a more SQL-spec-compatible syntax.
- The `LTTZ` environment variable is used by libpq clients to send a `SET TIME ZONE` command to the server upon connection.

## 8.5.4. Interval Input

interval values can be written using the following verbose syntax:

```
[@] quantity unit [quantity unit...] [direction]
```

where *quantity* is a number (possibly signed); *unit* is `microsecond`, `millisecond`, `second`, `minute`, `hour`, `day`, `week`, `month`, `year`, `decade`, `century`, `millennium`, or abbreviations or plurals of these units; *direction* can be `ago` or empty. The at sign (@) is optional noise. The amounts of the different units are implicitly added with appropriate sign accounting. `ago` negates all the fields. This syntax is also used for interval output, if `IntervalStyle` is set to `postgres_verbose`.

Quantities of days, hours, minutes, and seconds can be specified without explicit unit markings. For example, `'1 12:59:10'` is read the same as `'1 day 12 hours 59 min 10 sec'`. Also,

a combination of years and months can be specified with a dash; for example '200-10' is read the same as '200 years 10 months'. (These shorter forms are in fact the only ones allowed by the SQL standard, and are used for output when `IntervalStyle` is set to `sql_standard`.)

Interval values can also be written as ISO 8601 time intervals, using either the “format with designators” of the standard’s section 4.4.3.2 or the “alternative format” of section 4.4.3.3. The format with designators looks like this:

```
P quantity unit [ quantity unit ...] [ T [ quantity unit ...]]
```

The string must start with a P, and may include a T that introduces the time-of-day units. The available unit abbreviations are given in Table 8.16. Units may be omitted, and may be specified in any order, but units smaller than a day must appear after T. In particular, the meaning of M depends on whether it is before or after T.

**Table 8.16. ISO 8601 Interval Unit Abbreviations**

Abbreviation	Meaning
Y	Years
M	Months (in the date part)
W	Weeks
D	Days
H	Hours
M	Minutes (in the time part)
S	Seconds

In the alternative format:

```
P [ years-months-days ] [ T hours:minutes:seconds ]
```

the string must begin with P, and a T separates the date and time parts of the interval. The values are given as numbers similar to ISO 8601 dates.

When writing an interval constant with a *fields* specification, or when assigning a string to an interval column that was defined with a *fields* specification, the interpretation of unmarked quantities depends on the *fields*. For example `INTERVAL '1' YEAR` is read as 1 year, whereas `INTERVAL '1'` means 1 second. Also, field values “to the right” of the least significant field allowed by the *fields* specification are silently discarded. For example, writing `INTERVAL '1 day 2:03:04' HOUR TO MINUTE` results in dropping the seconds field, but not the day field.

According to the SQL standard all fields of an interval value must have the same sign, so a leading negative sign applies to all fields; for example the negative sign in the interval literal `'-1 2:03:04'` applies to both the days and hour/minute/second parts. LightDB allows the fields to have different signs, and traditionally treats each field in the textual representation as independently signed, so that the hour/minute/second part is considered positive in this example. If `IntervalStyle` is set to `sql_standard` then a leading sign is considered to apply to all fields (but only if no additional signs appear). Otherwise the traditional LightDB interpretation is used. To avoid ambiguity, it's recommended to attach an explicit sign to each field if any field is negative.

Field values can have fractional parts: for example, `'1.5 weeks'` or `'01:02:03.45'`. However, because interval internally stores only three integer units (months, days, microseconds), fractional units must be spilled to smaller units. Fractional parts of units greater than months are truncated to be an integer number of months, e.g. `'1.5 years'` becomes `'1 year 6 mons'`. Fractional parts of weeks and days are computed to be an integer number of days and microseconds, assuming 30 days

per month and 24 hours per day, e.g., '1.75 months' becomes 1 mon 22 days 12:00:00. Only seconds will ever be shown as fractional on output.

Table 8.17 shows some examples of valid interval input.

**Table 8.17. Interval Input**

Example	Description
1-2	SQL standard format: 1 year 2 months
3 4:05:06	SQL standard format: 3 days 4 hours 5 minutes 6 seconds
1 year 2 months 3 days 4 hours 5 minutes 6 seconds	Traditional Postgres format: 1 year 2 months 3 days 4 hours 5 minutes 6 seconds
P1Y2M3DT4H5M6S	ISO 8601 “format with designators”: same meaning as above
P0001-02-03T04:05:06	ISO 8601 “alternative format”: same meaning as above

Internally interval values are stored as months, days, and microseconds. This is done because the number of days in a month varies, and a day can have 23 or 25 hours if a daylight savings time adjustment is involved. The months and days fields are integers while the microseconds field can store fractional seconds. Because intervals are usually created from constant strings or timestamp subtraction, this storage method works well in most cases, but can cause unexpected results:

```
SELECT EXTRACT(hours from '80 minutes'::interval);
date_part
-----
          1

SELECT EXTRACT(days from '80 hours'::interval);
date_part
-----
          0
```

Functions `justify_days` and `justify_hours` are available for adjusting days and hours that overflow their normal ranges.

## 8.5.5. Interval Output

The output format of the interval type can be set to one of the four styles `sql_standard`, `postgres`, `postgres_verbose`, or `iso_8601`, using the command `SET intervalstyle`. The default is the `postgres` format. Table 8.18 shows examples of each output style.

The `sql_standard` style produces output that conforms to the SQL standard's specification for interval literal strings, if the interval value meets the standard's restrictions (either year-month only or day-time only, with no mixing of positive and negative components). Otherwise the output looks like a standard year-month literal string followed by a day-time literal string, with explicit signs added to disambiguate mixed-sign intervals.

The output of the `postgres` style matches the output of postgres releases prior to 8.4 when the `DateStyle` parameter was set to `ISO`.

The output of the `postgres_verbose` style matches the output of postgres releases prior to 8.4 when the `DateStyle` parameter was set to non-ISO output.

The output of the `iso_8601` style matches the “format with designators” described in section 4.4.3.2 of the ISO 8601 standard.

**Table 8.18. Interval Output Style Examples**

Style Specification	Year-Month Interval	Day-Time Interval	Mixed Interval
sql_standard	1-2	3 4:05:06	-1-2 +3 -4:05:06
postgres	1 year 2 mons	3 days 04:05:06	-1 year -2 mons +3 days -04:05:06
postgres_verbose	@ 1 year 2 mons	@ 3 days 4 hours 5 mins 6 secs	@ 1 year 2 mons -3 days 4 hours 5 mins 6 secs ago
iso_8601	P1Y2M	P3DT4H5M6S	P-1Y-2M3D T-4H-5M-6S

## 8.6. Boolean Type

LightDB provides the standard SQL type `boolean`; see Table 8.19. The `boolean` type can have several states: “true”, “false”, and a third state, “unknown”, which is represented by the SQL null value.

**Table 8.19. Boolean Data Type**

Name	Storage Size	Description
<code>boolean</code>	1 byte	state of true or false

Boolean constants can be represented in SQL queries by the SQL key words `TRUE`, `FALSE`, and `NULL`.

The datatype input function for type `boolean` accepts these string representations for the “true” state:

```
true
yes
on
1
```

and these representations for the “false” state:

```
false
no
off
0
```

Unique prefixes of these strings are also accepted, for example `t` or `n`. Leading or trailing whitespace is ignored, and case does not matter.

The datatype output function for type `boolean` always emits either `t` or `f`, as shown in Example 8.2.

### Example 8.2. Using the `boolean` Type

```
CREATE TABLE test1 (a boolean, b text);
INSERT INTO test1 VALUES (TRUE, 'sic est');
INSERT INTO test1 VALUES (FALSE, 'non est');
SELECT * FROM test1;
 a | b
---+-----
 t | sic est
 f | non est

SELECT * FROM test1 WHERE a;
```

```

a |      b
---+-----
t | sic est

```

The key words `TRUE` and `FALSE` are the preferred (SQL-compliant) method for writing Boolean constants in SQL queries. But you can also use the string representations by following the generic string-literal constant syntax described in Section 4.1.2.8, for example `'yes'::boolean`.

Note that the parser automatically understands that `TRUE` and `FALSE` are of type `boolean`, but this is not so for `NULL` because that can have any type. So in some contexts you might have to cast `NULL` to `boolean` explicitly, for example `NULL::boolean`. Conversely, the cast can be omitted from a string-literal Boolean value in contexts where the parser can deduce that the literal must be of type `boolean`.

## 8.7. Enumerated Types

Enumerated (enum) types are data types that comprise a static, ordered set of values. They are equivalent to the enum types supported in a number of programming languages. An example of an enum type might be the days of the week, or a set of status values for a piece of data.

### 8.7.1. Declaration of Enumerated Types

Enum types are created using the `CREATE TYPE` command, for example:

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
```

Once created, the enum type can be used in table and function definitions much like any other type:

```

CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
CREATE TABLE person (
    name text,
    current_mood mood
);
INSERT INTO person VALUES ('Moe', 'happy');
SELECT * FROM person WHERE current_mood = 'happy';
 name | current_mood
-----+-----
 Moe  | happy
(1 row)

```

### 8.7.2. Ordering

The ordering of the values in an enum type is the order in which the values were listed when the type was created. All standard comparison operators and related aggregate functions are supported for enums. For example:

```

INSERT INTO person VALUES ('Larry', 'sad');
INSERT INTO person VALUES ('Curly', 'ok');
SELECT * FROM person WHERE current_mood > 'sad';
 name | current_mood
-----+-----
 Moe  | happy
 Curly | ok
(2 rows)

```

```

SELECT * FROM person WHERE current_mood > 'sad' ORDER BY
  current_mood;
  name | current_mood
-----+-----
  Curly | ok
  Moe   | happy
(2 rows)

SELECT name
FROM person
WHERE current_mood = (SELECT MIN(current_mood) FROM person);
  name
-----
  Larry
(1 row)

```

### 8.7.3. Type Safety

Each enumerated data type is separate and cannot be compared with other enumerated types. See this example:

```

CREATE TYPE happiness AS ENUM ('happy', 'very happy', 'ecstatic');
CREATE TABLE holidays (
  num_weeks integer,
  happiness happiness
);
INSERT INTO holidays(num_weeks,happiness) VALUES (4, 'happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (6, 'very happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (8, 'ecstatic');
INSERT INTO holidays(num_weeks,happiness) VALUES (2, 'sad');
ERROR:  invalid input value for enum happiness: "sad"
SELECT person.name, holidays.num_weeks FROM person, holidays
  WHERE person.current_mood = holidays.happiness;
ERROR:  operator does not exist: mood = happiness

```

If you really need to do something like that, you can either write a custom operator or add explicit casts to your query:

```

SELECT person.name, holidays.num_weeks FROM person, holidays
  WHERE person.current_mood::text = holidays.happiness::text;
  name | num_weeks
-----+-----
  Moe   |          4
(1 row)

```

### 8.7.4. Implementation Details

Enum labels are case sensitive, so 'happy' is not the same as 'HAPPY'. White space in the labels is significant too.

Although enum types are primarily intended for static sets of values, there is support for adding new values to an existing enum type, and for renaming values (see ALTER TYPE). Existing values cannot be removed from an enum type, nor can the sort ordering of such values be changed, short of dropping and re-creating the enum type.

An enum value occupies four bytes on disk. The length of an enum value's textual label is limited by the `NAMEDATALEN` setting compiled into LightDB; in standard builds this means at most 63 bytes.

The translations from internal enum values to textual labels are kept in the system catalog `pg_enum`. Querying this catalog directly can be useful.

## 8.8. Geometric Types

Geometric data types represent two-dimensional spatial objects. Table 8.20 shows the geometric types available in LightDB.

**Table 8.20. Geometric Types**

Name	Storage Size	Description	Representation
<code>point</code>	16 bytes	Point on a plane	$(x,y)$
<code>line</code>	32 bytes	Infinite line	$\{A,B,C\}$
<code>lseg</code>	32 bytes	Finite line segment	$((x1,y1),(x2,y2))$
<code>box</code>	32 bytes	Rectangular box	$((x1,y1),(x2,y2))$
<code>path</code>	$16+16n$ bytes	Closed path (similar to polygon)	$((x1,y1),...)$
<code>path</code>	$16+16n$ bytes	Open path	$[(x1,y1),...]$
<code>polygon</code>	$40+16n$ bytes	Polygon (similar to closed path)	$((x1,y1),...)$
<code>circle</code>	24 bytes	Circle	$\langle(x,y),r\rangle$ (center point and radius)

A rich set of functions and operators is available to perform various geometric operations such as scaling, translation, rotation, and determining intersections. They are explained in Section 9.11.

### 8.8.1. Points

Points are the fundamental two-dimensional building block for geometric types. Values of type `point` are specified using either of the following syntaxes:

```
( x , y )
 x , y
```

where  $x$  and  $y$  are the respective coordinates, as floating-point numbers.

Points are output using the first syntax.

### 8.8.2. Lines

Lines are represented by the linear equation  $Ax + By + C = 0$ , where  $A$  and  $B$  are not both zero. Values of type `line` are input and output in the following form:

```
{ A , B , C }
```

Alternatively, any of the following forms can be used for input:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]
( ( x1 , y1 ) , ( x2 , y2 ) )
( x1 , y1 ) , ( x2 , y2 )
x1 , y1 , x2 , y2
```

where  $(x1, y1)$  and  $(x2, y2)$  are two different points on the line.

### 8.8.3. Line Segments

Line segments are represented by pairs of points that are the endpoints of the segment. Values of type `lseg` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]  
( ( x1 , y1 ) , ( x2 , y2 ) )  
  ( x1 , y1 ) , ( x2 , y2 )  
    x1 , y1      ,      x2 , y2
```

where  $(x1, y1)$  and  $(x2, y2)$  are the end points of the line segment.

Line segments are output using the first syntax.

### 8.8.4. Boxes

Boxes are represented by pairs of points that are opposite corners of the box. Values of type `box` are specified using any of the following syntaxes:

```
( ( x1 , y1 ) , ( x2 , y2 ) )  
  ( x1 , y1 ) , ( x2 , y2 )  
    x1 , y1      ,      x2 , y2
```

where  $(x1, y1)$  and  $(x2, y2)$  are any two opposite corners of the box.

Boxes are output using the second syntax.

Any two opposite corners can be supplied on input, but the values will be reordered as needed to store the upper right and lower left corners, in that order.

### 8.8.5. Paths

Paths are represented by lists of connected points. Paths can be *open*, where the first and last points in the list are considered not connected, or *closed*, where the first and last points are considered connected.

Values of type `path` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ... , ( xn , yn ) ]  
( ( x1 , y1 ) , ... , ( xn , yn ) )  
  ( x1 , y1 ) , ... , ( xn , yn )  
  ( x1 , y1      , ... ,      xn , yn )  
    x1 , y1      , ... ,      xn , yn
```

where the points are the end points of the line segments comprising the path. Square brackets (`[ ]`) indicate an open path, while parentheses (`( )`) indicate a closed path. When the outermost parentheses are omitted, as in the third through fifth syntaxes, a closed path is assumed.

Paths are output using the first or second syntax, as appropriate.

### 8.8.6. Polygons

Polygons are represented by lists of points (the vertexes of the polygon). Polygons are very similar to closed paths, but are stored differently and have their own set of support routines.

Values of type `polygon` are specified using any of the following syntaxes:



```
( ( x1 , y1 ) , ... , ( xn , yn ) )
( x1 , y1 ) , ... , ( xn , yn )
( x1 , y1 , ... , xn , yn )
x1 , y1 , ... , xn , yn
```

where the points are the end points of the line segments comprising the boundary of the polygon.

Polygons are output using the first syntax.

## 8.8.7. Circles

Circles are represented by a center point and radius. Values of type `circle` are specified using any of the following syntaxes:

```
< ( x , y ) , r >
( ( x , y ) , r )
( x , y ) , r
x , y , r
```

where  $(x, y)$  is the center point and  $r$  is the radius of the circle.

Circles are output using the first syntax.

## 8.9. Network Address Types

LightDB offers data types to store IPv4, IPv6, and MAC addresses, as shown in Table 8.21. It is better to use these types instead of plain text types to store network addresses, because these types offer input error checking and specialized operators and functions (see Section 9.12).

**Table 8.21. Network Address Types**

Name	Storage Size	Description
<code>cidr</code>	7 or 19 bytes	IPv4 and IPv6 networks
<code>inet</code>	7 or 19 bytes	IPv4 and IPv6 hosts and networks
<code>macaddr</code>	6 bytes	MAC addresses
<code>macaddr8</code>	8 bytes	MAC addresses (EUI-64 format)

When sorting `inet` or `cidr` data types, IPv4 addresses will always sort before IPv6 addresses, including IPv4 addresses encapsulated or mapped to IPv6 addresses, such as `::10.2.3.4` or `::ffff:10.4.3.2`.

### 8.9.1. `inet`

The `inet` type holds an IPv4 or IPv6 host address, and optionally its subnet, all in one field. The subnet is represented by the number of network address bits present in the host address (the “netmask”). If the netmask is 32 and the address is IPv4, then the value does not indicate a subnet, only a single host. In IPv6, the address length is 128 bits, so 128 bits specify a unique host address. Note that if you want to accept only networks, you should use the `cidr` type rather than `inet`.

The input format for this type is `address/y` where `address` is an IPv4 or IPv6 address and `y` is the number of bits in the netmask. If the `/y` portion is omitted, the netmask is taken to be 32 for IPv4 or 128 for IPv6, so the value represents just a single host. On display, the `/y` portion is suppressed if the netmask specifies a single host.

### 8.9.2. `cidr`

The `cidr` type holds an IPv4 or IPv6 network specification. Input and output formats follow Classless Internet Domain Routing conventions. The format for specifying networks is `address/y` where `address` is the network's lowest address represented as an IPv4 or IPv6 address, and `y` is the number of bits in the netmask. If `y` is omitted, it is calculated using assumptions from the older classful network numbering system, except it will be at least large enough to include all of the octets written in the input. It is an error to specify a network address that has bits set to the right of the specified netmask.

Table 8.22 shows some examples.

**Table 8.22. `cidr` Type Input Examples**

<code>cidr</code> Input	<code>cidr</code> Output	<code>abbrev(cidr)</code>
192.168.100.128/25	192.168.100.128/25	192.168.100.128/25
192.168/24	192.168.0.0/24	192.168.0/24
192.168/25	192.168.0.0/25	192.168.0.0/25
192.168.1	192.168.1.0/24	192.168.1/24
192.168	192.168.0.0/24	192.168.0/24
128.1	128.1.0.0/16	128.1/16
128	128.0.0.0/16	128.0/16
128.1.2	128.1.2.0/24	128.1.2/24
10.1.2	10.1.2.0/24	10.1.2/24
10.1	10.1.0.0/16	10.1/16
10	10.0.0.0/8	10/8
10.1.2.3/32	10.1.2.3/32	10.1.2.3/32
2001:4f8:3:ba::/64	2001:4f8:3:ba::/64	2001:4f8:3:ba/64
2001:4f8:3:ba: 2e0:81ff:fe22:d1f1/128	2001:4f8:3:ba: 2e0:81ff:fe22:d1f1/128	2001:4f8:3:ba: 2e0:81ff:fe22:d1f1/128
::ffff:1.2.3.0/120	::ffff:1.2.3.0/120	::ffff:1.2.3/120
::ffff:1.2.3.0/128	::ffff:1.2.3.0/128	::ffff:1.2.3.0/128

### 8.9.3. `inet` vs. `cidr`

The essential difference between `inet` and `cidr` data types is that `inet` accepts values with nonzero bits to the right of the netmask, whereas `cidr` does not. For example, `192.168.0.1/24` is valid for `inet` but not for `cidr`.

#### Tip

If you do not like the output format for `inet` or `cidr` values, try the functions `host`, `text`, and `abbrev`.

### 8.9.4. `macaddr`

The `macaddr` type stores MAC addresses, known for example from Ethernet card hardware addresses (although MAC addresses are used for other purposes as well). Input is accepted in the following formats:

```
'08:00:2b:01:02:03'  
'08-00-2b-01-02-03'  
'08002b:010203'
```

```
'08002b-010203'
'0800.2b01.0203'
'0800-2b01-0203'
'08002b010203'
```

These examples all specify the same address. Upper and lower case is accepted for the digits a through f. Output is always in the first of the forms shown.

IEEE Standard 802-2001 specifies the second form shown (with hyphens) as the canonical form for MAC addresses, and specifies the first form (with colons) as used with bit-reversed, MSB-first notation, so that 08-00-2b-01-02-03 = 10:00:D4:80:40:C0. This convention is widely ignored nowadays, and it is relevant only for obsolete network protocols (such as Token Ring). LightDB makes no provisions for bit reversal; all accepted formats use the canonical LSB order.

The remaining five input formats are not part of any standard.

## 8.9.5. macaddr8

The `macaddr8` type stores MAC addresses in EUI-64 format, known for example from Ethernet card hardware addresses (although MAC addresses are used for other purposes as well). This type can accept both 6 and 8 byte length MAC addresses and stores them in 8 byte length format. MAC addresses given in 6 byte format will be stored in 8 byte length format with the 4th and 5th bytes set to FF and FE, respectively. Note that IPv6 uses a modified EUI-64 format where the 7th bit should be set to one after the conversion from EUI-48. The function `macaddr8_set7bit` is provided to make this change. Generally speaking, any input which is comprised of pairs of hex digits (on byte boundaries), optionally separated consistently by one of ':', '-', or '.', is accepted. The number of hex digits must be either 16 (8 bytes) or 12 (6 bytes). Leading and trailing whitespace is ignored. The following are examples of input formats that are accepted:

```
'08:00:2b:01:02:03:04:05'
'08-00-2b-01-02-03-04-05'
'08002b:0102030405'
'08002b-0102030405'
'0800.2b01.0203.0405'
'0800-2b01-0203-0405'
'08002b01:02030405'
'08002b0102030405'
```

These examples all specify the same address. Upper and lower case is accepted for the digits a through f. Output is always in the first of the forms shown.

The last six input formats shown above are not part of any standard.

To convert a traditional 48 bit MAC address in EUI-48 format to modified EUI-64 format to be included as the host portion of an IPv6 address, use `macaddr8_set7bit` as shown:

```
SELECT macaddr8_set7bit('08:00:2b:01:02:03');

      macaddr8_set7bit
-----
0a:00:2b:ff:fe:01:02:03
(1 row)
```

## 8.10. Bit String Types

Bit strings are strings of 1's and 0's. They can be used to store or visualize bit masks. There are two SQL bit types: `bit(n)` and `bit_varying(n)`, where  $n$  is a positive integer.

`bit` type data must match the length  $n$  exactly; it is an error to attempt to store shorter or longer bit strings. `bit varying` data is of variable length up to the maximum length  $n$ ; longer strings will be rejected. Writing `bit` without a length is equivalent to `bit(1)`, while `bit varying` without a length specification means unlimited length.

### Note

If one explicitly casts a bit-string value to `bit( $n$ )`, it will be truncated or zero-padded on the right to be exactly  $n$  bits, without raising an error. Similarly, if one explicitly casts a bit-string value to `bit varying( $n$ )`, it will be truncated on the right if it is more than  $n$  bits.

Refer to Section 4.1.2.6 for information about the syntax of bit string constants. Bit-logical operators and string manipulation functions are available; see Section 9.6.

### Example 8.3. Using the Bit String Types

```
CREATE TABLE test (a BIT(3), b BIT VARYING(5));
INSERT INTO test VALUES (B'101', B'00');
INSERT INTO test VALUES (B'10', B'101');

ERROR: bit string length 2 does not match type bit(3)

INSERT INTO test VALUES (B'10'::bit(3), B'101');
SELECT * FROM test;
```

a	b
101	00
100	101

A bit string value requires 1 byte for each group of 8 bits, plus 5 or 8 bytes overhead depending on the length of the string (but long values may be compressed or moved out-of-line, as explained in Section 8.3 for character strings).

## 8.11. Text Search Types

LightDB provides two data types that are designed to support full text search, which is the activity of searching through a collection of natural-language *documents* to locate those that best match a *query*. The `tsvector` type represents a document in a form optimized for text search; the `tsquery` type similarly represents a text query. Chapter 12 provides a detailed explanation of this facility, and Section 9.13 summarizes the related functions and operators.

### 8.11.1. tsvector

A `tsvector` value is a sorted list of distinct *lexemes*, which are words that have been *normalized* to merge different variants of the same word (see Chapter 12 for details). Sorting and duplicate-elimination are done automatically during input, as shown in this example:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector;
          tsvector
-----
'a' 'and' 'ate' 'cat' 'fat' 'mat' 'on' 'rat' 'sat'
```

To represent lexemes containing whitespace or punctuation, surround them with quotes:

```
SELECT $$the lexeme '    ' contains spaces$$::tsvector;
           tsvector
-----
'    ' 'contains' 'lexeme' 'spaces' 'the'
```

(We use dollar-quoted string literals in this example and the next one to avoid the confusion of having to double quote marks within the literals.) Embedded quotes and backslashes must be doubled:

```
SELECT $$the lexeme 'Joe''s' contains a quote$$::tsvector;
           tsvector
-----
'Joe''s' 'a' 'contains' 'lexeme' 'quote' 'the'
```

Optionally, integer *positions* can be attached to lexemes:

```
SELECT 'a:1 fat:2 cat:3 sat:4 on:5 a:6 mat:7 and:8 ate:9 a:10
       fat:11 rat:12'::tsvector;
           tsvector
-----
'a':1,6,10 'and':8 'ate':9 'cat':3 'fat':2,11 'mat':7 'on':5
'rat':12 'sat':4
```

A position normally indicates the source word's location in the document. Positional information can be used for *proximity ranking*. Position values can range from 1 to 16383; larger numbers are silently set to 16383. Duplicate positions for the same lexeme are discarded.

Lexemes that have positions can further be labeled with a *weight*, which can be A, B, C, or D. D is the default and hence is not shown on output:

```
SELECT 'a:1A fat:2B,4C cat:5D'::tsvector;
           tsvector
-----
'a':1A 'cat':5 'fat':2B,4C
```

Weights are typically used to reflect document structure, for example by marking title words differently from body words. Text search ranking functions can assign different priorities to the different weight markers.

It is important to understand that the `tsvector` type itself does not perform any word normalization; it assumes the words it is given are normalized appropriately for the application. For example,

```
SELECT 'The Fat Rats'::tsvector;
           tsvector
-----
'Fat' 'Rats' 'The'
```

For most English-text-searching applications the above words would be considered non-normalized, but `tsvector` doesn't care. Raw document text should usually be passed through `to_tsvector` to normalize the words appropriately for searching:

```
SELECT to_tsvector('english', 'The Fat Rats');
           to_tsvector
```

```
-----
'fat':2 'rat':3
```

Again, see Chapter 12 for more detail.

## 8.11.2. tsquery

A `tsquery` value stores lexemes that are to be searched for, and can combine them using the Boolean operators `&` (AND), `|` (OR), and `!` (NOT), as well as the phrase search operator `<->` (FOLLOWED BY). There is also a variant `<N>` of the FOLLOWED BY operator, where `N` is an integer constant that specifies the distance between the two lexemes being searched for. `<->` is equivalent to `<1>`.

Parentheses can be used to enforce grouping of these operators. In the absence of parentheses, `!` (NOT) binds most tightly, `<->` (FOLLOWED BY) next most tightly, then `&` (AND), with `|` (OR) binding the least tightly.

Here are some examples:

```
SELECT 'fat & rat'::tsquery;
      tsquery
-----
'fat' & 'rat'

SELECT 'fat & (rat | cat)'::tsquery;
      tsquery
-----
'fat' & ( 'rat' | 'cat' )

SELECT 'fat & rat & ! cat'::tsquery;
      tsquery
-----
'fat' & 'rat' & !'cat'
```

Optionally, lexemes in a `tsquery` can be labeled with one or more weight letters, which restricts them to match only `tsvector` lexemes with one of those weights:

```
SELECT 'fat:ab & cat'::tsquery;
      tsquery
-----
'fat':AB & 'cat'
```

Also, lexemes in a `tsquery` can be labeled with `*` to specify prefix matching:

```
SELECT 'super:*'::tsquery;
      tsquery
-----
'super':*
```

This query will match any word in a `tsvector` that begins with “super”.

Quoting rules for lexemes are the same as described previously for lexemes in `tsvector`; and, as with `tsvector`, any required normalization of words must be done before converting to the `tsquery` type. The `to_tsquery` function is convenient for performing such normalization:

```
SELECT to_tsquery('Fat:ab & Cats');
      to_tsquery
```

```
-----
'fat':AB & 'cat'
```

Note that `to_tsquery` will process prefixes in the same way as other words, which means this comparison returns true:

```
SELECT to_tsvector( 'postgraduate' ) @@ to_tsquery( 'postgres:*' );
?column?
-----
t
```

because `postgres` gets stemmed to `postgr`:

```
SELECT to_tsvector( 'postgraduate' ), to_tsquery( 'postgres:*' );
to_tsvector | to_tsquery
-----+-----
'postgradu':1 | 'postgr':*
```

which will match the stemmed form of `postgraduate`.

## 8.12. UUID Type

The data type `uuid` stores Universally Unique Identifiers (UUID) as defined by RFC 4122, ISO/IEC 9834-8:2005, and related standards. (Some systems refer to this data type as a globally unique identifier, or GUID, instead.) This identifier is a 128-bit quantity that is generated by an algorithm chosen to make it very unlikely that the same identifier will be generated by anyone else in the known universe using the same algorithm. Therefore, for distributed systems, these identifiers provide a better uniqueness guarantee than sequence generators, which are only unique within a single database.

A UUID is written as a sequence of lower-case hexadecimal digits, in several groups separated by hyphens, specifically a group of 8 digits followed by three groups of 4 digits followed by a group of 12 digits, for a total of 32 digits representing the 128 bits. An example of a UUID in this standard form is:

```
a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11
```

LightDB also accepts the following alternative forms for input: use of upper-case digits, the standard format surrounded by braces, omitting some or all hyphens, adding a hyphen after any group of four digits. Examples are:

```
A0EEBC99-9C0B-4EF8-BB6D-6BB9BD380A11
{a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11}
a0eebc999c0b4ef8bb6d6bb9bd380a11
a0ee-bc99-9c0b-4ef8-bb6d-6bb9-bd38-0a11
{a0eebc99-9c0b4ef8-bb6d6bb9-bd380a11}
```

Output is always in the standard form.

See Section 9.14 for how to generate a UUID in LightDB.

## 8.13. XML Type

The `xml` data type can be used to store XML data. Its advantage over storing XML data in a `text` field is that it checks the input values for well-formedness, and there are support functions to perform type-safe operations on it; see Section 9.15. Use of this data type requires the installation to have been built with `configure --with-libxml`.

The `xml` type can store well-formed “documents”, as defined by the XML standard, as well as “content” fragments, which are defined by reference to the more permissive “document node”<sup>1</sup> of the XQuery and XPath data model. Roughly, this means that content fragments can have more than one top-level element or character node. The expression `xmlvalue IS DOCUMENT` can be used to evaluate whether a particular `xml` value is a full document or only a content fragment.

Limits and compatibility notes for the `xml` data type can be found in Section D.3.

### 8.13.1. Creating XML Values

To produce a value of type `xml` from character data, use the function `xmlparse`:

```
XMLPARSE ( { DOCUMENT | CONTENT } value [WELLFORMED])
```

Examples:

```
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapter></book>')
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>')
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapter></book>' WELLFORMED)
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>' WELLFORMED)
```

While this is the only way to convert character strings into XML values according to the SQL standard, the LightDB-specific syntaxes:

```
xml '<foo>bar</foo>'
'<foo>bar</foo>'::xml
```

can also be used.

The `xml` type does not validate input values against a document type declaration (DTD), even when the input value specifies a DTD. There is also currently no built-in support for validating against other XML schema languages such as XML Schema.

The inverse operation, producing a character string value from `xml`, uses the function `xmlserialize`:

```
XMLSERIALIZE ( { DOCUMENT | CONTENT } value AS type )
```

`type` can be `character`, `character varying`, or `text` (or an alias for one of those). Again, according to the SQL standard, this is the only way to convert between type `xml` and character types, but LightDB also allows you to simply cast the value.

When a character string value is cast to or from type `xml` without going through `XMLPARSE` or `XMLSERIALIZE`, respectively, the choice of `DOCUMENT` versus `CONTENT` is determined by the “XML option” session configuration parameter, which can be set using the standard command:

```
SET XML OPTION { DOCUMENT | CONTENT };
```

or the more LightDB-like syntax

```
SET xmloption TO { DOCUMENT | CONTENT };
```

<sup>1</sup> <https://www.w3.org/TR/2010/REC-xpath-datamodel-20101214/#DocumentNode>



The default is `CONTENT`, so all forms of XML data are allowed.

Compatibility: `WELLFORMED` directive is only for oracle compatible mode.

## 8.13.2. Encoding Handling

Care must be taken when dealing with multiple character encodings on the client, server, and in the XML data passed through them. When using the text mode to pass queries to the server and query results to the client (which is the normal mode), LightDB converts all character data passed between the client and the server and vice versa to the character encoding of the respective end; see Section 21.3. This includes string representations of XML values, such as in the above examples. This would ordinarily mean that encoding declarations contained in XML data can become invalid as the character data is converted to other encodings while traveling between client and server, because the embedded encoding declaration is not changed. To cope with this behavior, encoding declarations contained in character strings presented for input to the `xml` type are *ignored*, and content is assumed to be in the current server encoding. Consequently, for correct processing, character strings of XML data must be sent from the client in the current client encoding. It is the responsibility of the client to either convert documents to the current client encoding before sending them to the server, or to adjust the client encoding appropriately. On output, values of type `xml` will not have an encoding declaration, and clients should assume all data is in the current client encoding.

When using binary mode to pass query parameters to the server and query results back to the client, no encoding conversion is performed, so the situation is different. In this case, an encoding declaration in the XML data will be observed, and if it is absent, the data will be assumed to be in UTF-8 (as required by the XML standard; note that LightDB does not support UTF-16). On output, data will have an encoding declaration specifying the client encoding, unless the client encoding is UTF-8, in which case it will be omitted.

Needless to say, processing XML data with LightDB will be less error-prone and more efficient if the XML data encoding, client encoding, and server encoding are the same. Since XML data is internally processed in UTF-8, computations will be most efficient if the server encoding is also UTF-8.

### Caution

Some XML-related functions may not work at all on non-ASCII data when the server encoding is not UTF-8. This is known to be an issue for `xmltable()` and `xpath()` in particular.

## 8.13.3. Accessing XML Values

The `xml` data type is unusual in that it does not provide any comparison operators. This is because there is no well-defined and universally useful comparison algorithm for XML data. One consequence of this is that you cannot retrieve rows by comparing an `xml` column against a search value. XML values should therefore typically be accompanied by a separate key field such as an ID. An alternative solution for comparing XML values is to convert them to character strings first, but note that character string comparison has little to do with a useful XML comparison method.

Since there are no comparison operators for the `xml` data type, it is not possible to create an index directly on a column of this type. If speedy searches in XML data are desired, possible workarounds include casting the expression to a character string type and indexing that, or indexing an XPath expression. Of course, the actual query would have to be adjusted to search by the indexed expression.

The text-search functionality in LightDB can also be used to speed up full-document searches of XML data. The necessary preprocessing support is, however, not yet available in the LightDB distribution.

## 8.14. JSON Types

JSON data types are for storing JSON (JavaScript Object Notation) data, as specified in RFC 7159<sup>2</sup>. Such data can also be stored as `text`, but the JSON data types have the advantage of enforcing that each stored value is valid according to the JSON rules. There are also assorted JSON-specific functions and operators available for data stored in these data types; see Section 9.16.

LightDB offers two types for storing JSON data: `json` and `jsonb`. To implement efficient query mechanisms for these data types, LightDB also provides the `jsonpath` data type described in Section 8.14.5.

The `json` and `jsonb` data types accept *almost* identical sets of values as input. The major practical difference is one of efficiency. The `json` data type stores an exact copy of the input text, which processing functions must reparse on each execution; while `jsonb` data is stored in a decomposed binary format that makes it slightly slower to input due to added conversion overhead, but significantly faster to process, since no reparsing is needed. `jsonb` also supports indexing, which can be a significant advantage.

Because the `json` type stores an exact copy of the input text, it will preserve semantically-insignificant white space between tokens, as well as the order of keys within JSON objects. Also, if a JSON object within the value contains the same key more than once, all the key/value pairs are kept. (The processing functions consider the last value as the operative one.) By contrast, `jsonb` does not preserve white space, does not preserve the order of object keys, and does not keep duplicate object keys. If duplicate keys are specified in the input, only the last value is kept.

In general, most applications should prefer to store JSON data as `jsonb`, unless there are quite specialized needs, such as legacy assumptions about ordering of object keys.

RFC 7159 specifies that JSON strings should be encoded in UTF8. It is therefore not possible for the JSON types to conform rigidly to the JSON specification unless the database encoding is UTF8. Attempts to directly include characters that cannot be represented in the database encoding will fail; conversely, characters that can be represented in the database encoding but not in UTF8 will be allowed.

RFC 7159 permits JSON strings to contain Unicode escape sequences denoted by `\uXXXX`. In the input function for the `json` type, Unicode escapes are allowed regardless of the database encoding, and are checked only for syntactic correctness (that is, that four hex digits follow `\u`). However, the input function for `jsonb` is stricter: it disallows Unicode escapes for characters that cannot be represented in the database encoding. The `jsonb` type also rejects `\u0000` (because that cannot be represented in LightDB's `text` type), and it insists that any use of Unicode surrogate pairs to designate characters outside the Unicode Basic Multilingual Plane be correct. Valid Unicode escapes are converted to the equivalent single character for storage; this includes folding surrogate pairs into a single character.

### Note

Many of the JSON processing functions described in Section 9.16 will convert Unicode escapes to regular characters, and will therefore throw the same types of errors just described even if their input is of type `json` not `jsonb`. The fact that the `json` input function does not make these checks may be considered a historical artifact, although it does allow for simple storage (without processing) of JSON Unicode escapes in a database encoding that does not support the represented characters.

When converting textual JSON input into `jsonb`, the primitive types described by RFC 7159 are effectively mapped onto native LightDB types, as shown in Table 8.23. Therefore, there are some minor additional constraints on what constitutes valid `jsonb` data that do not apply to the `json` type, nor to JSON in the abstract, corresponding to limits on what can be represented by the underlying data type. Notably, `jsonb` will reject numbers that are outside the range of the LightDB `numeric`

---

<sup>2</sup> <https://tools.ietf.org/html/rfc7159>

data type, while `json` will not. Such implementation-defined restrictions are permitted by RFC 7159. However, in practice such problems are far more likely to occur in other implementations, as it is common to represent JSON's number primitive type as IEEE 754 double precision floating point (which RFC 7159 explicitly anticipates and allows for). When using JSON as an interchange format with such systems, the danger of losing numeric precision compared to data originally stored by LightDB should be considered.

Conversely, as noted in the table there are some minor restrictions on the input format of JSON primitive types that do not apply to the corresponding LightDB types.

**Table 8.23. JSON Primitive Types and Corresponding LightDB Types**

JSON primitive type	LightDB type	Notes
<code>string</code>	<code>text</code>	<code>\u0000</code> is disallowed, as are Unicode escapes representing characters not available in the database encoding
<code>number</code>	<code>numeric</code>	NaN and infinity values are disallowed
<code>boolean</code>	<code>boolean</code>	Only lowercase <code>true</code> and <code>false</code> spellings are accepted
<code>null</code>	(none)	SQL NULL is a different concept

## 8.14.1. JSON Input and Output Syntax

The input/output syntax for the JSON data types is as specified in RFC 7159.

The following are all valid `json` (or `jsonb`) expressions:

```
-- Simple scalar/primitive value
-- Primitive values can be numbers, quoted strings, true, false, or
-- null
SELECT '5'::json;

-- Array of zero or more elements (elements need not be of same
-- type)
SELECT '[1, 2, "foo", null]'::json;

-- Object containing pairs of keys and values
-- Note that object keys must always be quoted strings
SELECT '{"bar": "baz", "balance": 7.77, "active": false}'::json;

-- Arrays and objects can be nested arbitrarily
SELECT '{"foo": [true, "bar"], "tags": {"a": 1, "b": null}}'::json;
```

As previously stated, when a JSON value is input and then printed without any additional processing, `json` outputs the same text that was input, while `jsonb` does not preserve semantically-insignificant details such as whitespace. For example, note the differences here:

```
SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::json;
           json
-----
{"bar": "baz", "balance": 7.77, "active":false}
(1 row)

SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::jsonb;
           jsonb
```

```
-----
{"bar": "baz", "active": false, "balance": 7.77}
(1 row)
```

One semantically-insignificant detail worth noting is that in `jsonb`, numbers will be printed according to the behavior of the underlying `numeric` type. In practice this means that numbers entered with `E` notation will be printed without it, for example:

```
SELECT '{"reading": 1.230e-5}'::json, '{"reading":
1.230e-5}'::jsonb;
      json          |          jsonb
-----+-----
{"reading": 1.230e-5} | {"reading": 0.00001230}
(1 row)
```

However, `jsonb` will preserve trailing fractional zeroes, as seen in this example, even though those are semantically insignificant for purposes such as equality checks.

For the list of built-in functions and operators available for constructing and processing JSON values, see Section 9.16.

## 8.14.2. Designing JSON Documents

Representing data as JSON can be considerably more flexible than the traditional relational data model, which is compelling in environments where requirements are fluid. It is quite possible for both approaches to co-exist and complement each other within the same application. However, even for applications where maximal flexibility is desired, it is still recommended that JSON documents have a somewhat fixed structure. The structure is typically unenforced (though enforcing some business rules declaratively is possible), but having a predictable structure makes it easier to write queries that usefully summarize a set of “documents” (datums) in a table.

JSON data is subject to the same concurrency-control considerations as any other data type when stored in a table. Although storing large documents is practicable, keep in mind that any update acquires a row-level lock on the whole row. Consider limiting JSON documents to a manageable size in order to decrease lock contention among updating transactions. Ideally, JSON documents should each represent an atomic datum that business rules dictate cannot reasonably be further subdivided into smaller datums that could be modified independently.

## 8.14.3. `jsonb` Containment and Existence

Testing *containment* is an important capability of `jsonb`. There is no parallel set of facilities for the `json` type. Containment tests whether one `jsonb` document has contained within it another one. These examples return true except as noted:

```
-- Simple scalar/primitive values contain only the identical value:
SELECT '"foo"'::jsonb @> '"foo"'::jsonb;

-- The array on the right side is contained within the one on the
left:
SELECT '[1, 2, 3]'::jsonb @> '[1, 3]'::jsonb;

-- Order of array elements is not significant, so this is also
true:
SELECT '[1, 2, 3]'::jsonb @> '[3, 1]'::jsonb;

-- Duplicate array elements don't matter either:
```

```

SELECT '[1, 2, 3]':::jsonb @> '[1, 2, 2]':::jsonb;

-- The object with a single pair on the right side is contained
-- within the object on the left side:
SELECT '{"product": "LightDB", "version": 9.4, "jsonb":
  true}':::jsonb @> '{"version": 9.4}':::jsonb;

-- The array on the right side is not considered contained within
  the
-- array on the left, even though a similar array is nested within
  it:
SELECT '[1, 2, [1, 3]]':::jsonb @> '[1, 3]':::jsonb; -- yields false

-- But with a layer of nesting, it is contained:
SELECT '[1, 2, [1, 3]]':::jsonb @> '[[1, 3]]':::jsonb;

-- Similarly, containment is not reported here:
SELECT '{"foo": {"bar": "baz"}}':::jsonb @> '{"bar": "baz"}':::jsonb;
  -- yields false

-- A top-level key and an empty object is contained:
SELECT '{"foo": {"bar": "baz"}}':::jsonb @> '{"foo": {}}':::jsonb;

```

The general principle is that the contained object must match the containing object as to structure and data contents, possibly after discarding some non-matching array elements or object key/value pairs from the containing object. But remember that the order of array elements is not significant when doing a containment match, and duplicate array elements are effectively considered only once.

As a special exception to the general principle that the structures must match, an array may contain a primitive value:

```

-- This array contains the primitive string value:
SELECT '["foo", "bar"]':::jsonb @> '"bar"':::jsonb;

-- This exception is not reciprocal -- non-containment is reported
  here:
SELECT '"bar"':::jsonb @> '["bar"]':::jsonb; -- yields false

```

jsonb also has an *existence* operator, which is a variation on the theme of containment: it tests whether a string (given as a text value) appears as an object key or array element at the top level of the jsonb value. These examples return true except as noted:

```

-- String exists as array element:
SELECT '["foo", "bar", "baz"]':::jsonb ? 'bar';

-- String exists as object key:
SELECT '{"foo": "bar"}':::jsonb ? 'foo';

-- Object values are not considered:
SELECT '{"foo": "bar"}':::jsonb ? 'bar'; -- yields false

-- As with containment, existence must match at the top level:
SELECT '{"foo": {"bar": "baz"}}':::jsonb ? 'bar'; -- yields false

-- A string is considered to exist if it matches a primitive JSON
  string:
SELECT '"foo"':::jsonb ? 'foo';

```

JSON objects are better suited than arrays for testing containment or existence when there are many keys or elements involved, because unlike arrays they are internally optimized for searching, and do not need to be searched linearly.

### Tip

Because JSON containment is nested, an appropriate query can skip explicit selection of sub-objects. As an example, suppose that we have a `doc` column containing objects at the top level, with most objects containing `tags` fields that contain arrays of sub-objects. This query finds entries in which sub-objects containing both `"term": "paris"` and `"term": "food"` appear, while ignoring any such keys outside the `tags` array:

```
SELECT doc->'site_name' FROM websites
WHERE doc @> '{"tags": [{"term": "paris"},
{"term": "food"}]}' ;
```

One could accomplish the same thing with, say,

```
SELECT doc->'site_name' FROM websites
WHERE doc->'tags' @> '[{"term": "paris"},
{"term": "food"}]';
```

but that approach is less flexible, and often less efficient as well.

On the other hand, the JSON existence operator is not nested: it will only look for the specified key or array element at top level of the JSON value.

The various containment and existence operators, along with all other JSON operators and functions are documented in Section 9.16.

## 8.14.4. jsonb Indexing

GIN indexes can be used to efficiently search for keys or key/value pairs occurring within a large number of `jsonb` documents (datums). Two GIN “operator classes” are provided, offering different performance and flexibility trade-offs.

The default GIN operator class for `jsonb` supports queries with the key-exists operators `?`, `?|` and `?&`, the containment operator `@>`, and the `jsonpath` match operators `@?` and `@@`. (For details of the semantics that these operators implement, see Table 9.46.) An example of creating an index with this operator class is:

```
CREATE INDEX idxgin ON api USING GIN (jdoc);
```

The non-default GIN operator class `jsonb_path_ops` does not support the key-exists operators, but it does support `@>`, `@?` and `@@`. An example of creating an index with this operator class is:

```
CREATE INDEX idxginp ON api USING GIN (jdoc jsonb_path_ops);
```

Consider the example of a table that stores JSON documents retrieved from a third-party web service, with a documented schema definition. A typical document is:

```
{
```

```

    "guid": "9c36adc1-7fb5-4d5b-83b4-90356a46061a",
    "name": "Angela Barton",
    "is_active": true,
    "company": "MagnaFone",
    "address": "178 Howard Place, Gulf, Washington, 702",
    "registered": "2009-11-07T08:53:22 +08:00",
    "latitude": 19.793713,
    "longitude": 86.513373,
    "tags": [
      "enim",
      "aliquip",
      "qui"
    ]
  }
}

```

We store these documents in a table named `api`, in a `jsonb` column named `jdoc`. If a GIN index is created on this column, queries like the following can make use of the index:

```

-- Find documents in which the key "company" has value "MagnaFone"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @>
  '{"company": "MagnaFone"}';

```

However, the index could not be used for queries like the following, because though the operator `?` is indexable, it is not applied directly to the indexed column `jdoc`:

```

-- Find documents in which the key "tags" contains key or array
  element "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc -> 'tags' ?
  'qui';

```

Still, with appropriate use of expression indexes, the above query can use an index. If querying for particular items within the `"tags"` key is common, defining an index like this may be worthwhile:

```

CREATE INDEX idxgintags ON api USING GIN ((jdoc -> 'tags'));

```

Now, the `WHERE` clause `jdoc -> 'tags' ? 'qui'` will be recognized as an application of the indexable operator `?` to the indexed expression `jdoc -> 'tags'`. (More information on expression indexes can be found in Section 11.7.)

Another approach to querying is to exploit containment, for example:

```

-- Find documents in which the key "tags" contains array element
  "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"tags":
  ["qui"]}';

```

A simple GIN index on the `jdoc` column can support this query. But note that such an index will store copies of every key and value in the `jdoc` column, whereas the expression index of the previous example stores only data found under the `tags` key. While the simple-index approach is far more flexible (since it supports queries about any key), targeted expression indexes are likely to be smaller and faster to search than a simple index.

GIN indexes also support the `@?` and `@@` operators, which perform `jsonpath` matching. Examples are

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @?
 '$.tags[*] ? (@ == "qui")';
```

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @@ '$.tags[*]
 == "qui"';
```

For these operators, a GIN index extracts clauses of the form *accessors\_chain = constant* out of the `jsonpath` pattern, and does the index search based on the keys and values mentioned in these clauses. The accessors chain may include `.key`, `[*]`, and `[index]` accessors. The `jsonb_ops` operator class also supports `.*` and `.**` accessors, but the `jsonb_path_ops` operator class does not.

Although the `jsonb_path_ops` operator class supports only queries with the `@>`, `@?` and `@@` operators, it has notable performance advantages over the default operator class `jsonb_ops`. A `jsonb_path_ops` index is usually much smaller than a `jsonb_ops` index over the same data, and the specificity of searches is better, particularly when queries contain keys that appear frequently in the data. Therefore search operations typically perform better than with the default operator class.

The technical difference between a `jsonb_ops` and a `jsonb_path_ops` GIN index is that the former creates independent index items for each key and value in the data, while the latter creates index items only for each value in the data.<sup>3</sup> Basically, each `jsonb_path_ops` index item is a hash of the value and the key(s) leading to it; for example to index `{ "foo": { "bar": "baz" } }`, a single index item would be created incorporating all three of `foo`, `bar`, and `baz` into the hash value. Thus a containment query looking for this structure would result in an extremely specific index search; but there is no way at all to find out whether `foo` appears as a key. On the other hand, a `jsonb_ops` index would create three index items representing `foo`, `bar`, and `baz` separately; then to do the containment query, it would look for rows containing all three of these items. While GIN indexes can perform such an AND search fairly efficiently, it will still be less specific and slower than the equivalent `jsonb_path_ops` search, especially if there are a very large number of rows containing any single one of the three index items.

A disadvantage of the `jsonb_path_ops` approach is that it produces no index entries for JSON structures not containing any values, such as `{ "a": {} }`. If a search for documents containing such a structure is requested, it will require a full-index scan, which is quite slow. `jsonb_path_ops` is therefore ill-suited for applications that often perform such searches.

`jsonb` also supports `btree` and `hash` indexes. These are usually useful only if it's important to check equality of complete JSON documents. The `btree` ordering for `jsonb` datums is seldom of great interest, but for completeness it is:

*Object > Array > Boolean > Number > String > Null*

*Object with n pairs > object with n - 1 pairs*

*Array with n elements > array with n - 1 elements*

Objects with equal numbers of pairs are compared in the order:

*key-1, value-1, key-2 ...*

Note that object keys are compared in their storage order; in particular, since shorter keys are stored before longer keys, this can lead to results that might be unintuitive, such as:

```
{ "aa": 1, "c": 1 } > {"b": 1, "d": 1 }
```

<sup>3</sup> For this purpose, the term “value” includes array elements, though JSON terminology sometimes considers array elements distinct from values within objects.



Similarly, arrays with equal numbers of elements are compared in the order:

*element-1, element-2 ...*

Primitive JSON values are compared using the same comparison rules as for the underlying LightDB data type. Strings are compared using the default database collation.

## 8.14.5. jsonpath Type

The `jsonpath` type implements support for the SQL/JSON path language in LightDB to efficiently query JSON data. It provides a binary representation of the parsed SQL/JSON path expression that specifies the items to be retrieved by the path engine from the JSON data for further processing with the SQL/JSON query functions.

The semantics of SQL/JSON path predicates and operators generally follow SQL. At the same time, to provide a natural way of working with JSON data, SQL/JSON path syntax uses some JavaScript conventions:

- Dot ( `.` ) is used for member access.
- Square brackets ( `[ ]` ) are used for array access.
- SQL/JSON arrays are 0-relative, unlike regular SQL arrays that start from 1.

An SQL/JSON path expression is typically written in an SQL query as an SQL character string literal, so it must be enclosed in single quotes, and any single quotes desired within the value must be doubled (see Section 4.1.2.1). Some forms of path expressions require string literals within them. These embedded string literals follow JavaScript/ECMAScript conventions: they must be surrounded by double quotes, and backslash escapes may be used within them to represent otherwise-hard-to-type characters. In particular, the way to write a double quote within an embedded string literal is `\`, and to write a backslash itself, you must write `\\`. Other special backslash sequences include those recognized in JSON strings: `\b`, `\f`, `\n`, `\r`, `\t`, `\v` for various ASCII control characters, and `\uNNNN` for a Unicode character identified by its 4-hex-digit code point. The backslash syntax also includes two cases not allowed by JSON: `\xNN` for a character code written with only two hex digits, and `\u{N. . . }` for a character code written with 1 to 6 hex digits.

A path expression consists of a sequence of path elements, which can be any of the following:

- Path literals of JSON primitive types: Unicode text, numeric, true, false, or null.
- Path variables listed in Table 8.24.
- Accessor operators listed in Table 8.25.
- `jsonpath` operators and methods listed in Section 9.16.2.2.
- Parentheses, which can be used to provide filter expressions or define the order of path evaluation.

For details on using `jsonpath` expressions with SQL/JSON query functions, see Section 9.16.2.

**Table 8.24. jsonpath Variables**

Variable	Description
<code>\$</code>	A variable representing the JSON value being queried (the <i>context item</i> ).
<code>\$varname</code>	A named variable. Its value can be set by the parameter <i>vars</i> of several JSON processing functions; see Table 9.48 for details.
<code>@</code>	A variable representing the result of path evaluation in filter expressions.

**Table 8.25. jsonpath Accessors**

Accessor Operator	Description
<i>.key</i> <i>."\$varname"</i>	Member accessor that returns an object member with the specified key. If the key name matches some named variable starting with \$ or does not meet the JavaScript rules for an identifier, it must be enclosed in double quotes to make it a string literal.
<i>.*</i>	Wildcard member accessor that returns the values of all members located at the top level of the current object.
<i>.**</i>	Recursive wildcard member accessor that processes all levels of the JSON hierarchy of the current object and returns all the member values, regardless of their nesting level. This is a LightDB extension of the SQL/JSON standard.
<i>**{level}</i> <i>**{start_level to end_level}</i>	Like <i>**</i> , but selects only the specified levels of the JSON hierarchy. Nesting levels are specified as integers. Level zero corresponds to the current object. To access the lowest nesting level, you can use the <i>last</i> keyword. This is a LightDB extension of the SQL/JSON standard.
<i>[subscript, ...]</i>	Array element accessor. <i>subscript</i> can be given in two forms: <i>index</i> or <i>start_index to end_index</i> . The first form returns a single array element by its index. The second form returns an array slice by the range of indexes, including the elements that correspond to the provided <i>start_index</i> and <i>end_index</i> .  The specified <i>index</i> can be an integer, as well as an expression returning a single numeric value, which is automatically cast to integer. Index zero corresponds to the first array element. You can also use the <i>last</i> keyword to denote the last array element, which is useful for handling arrays of unknown length.
<i>[*]</i>	Wildcard array element accessor that returns all array elements.

## 8.15. Arrays

LightDB allows columns of a table to be defined as variable-length multidimensional arrays. Arrays of any built-in or user-defined base type, enum type, composite type, range type, or domain can be created.

### 8.15.1. Declaration of Array Types

To illustrate the use of array types, we create this table:

```
CREATE TABLE sal_emp (
    name          text,
    pay_by_quarter integer[],
    schedule      text[][]
);
```

As shown, an array data type is named by appending square brackets ([ ]) to the data type name of the array elements. The above command will create a table named `sal_emp` with a column of type `text` (`name`), a one-dimensional array of type `integer` (`pay_by_quarter`), which represents the employee's salary by quarter, and a two-dimensional array of `text` (`schedule`), which represents the employee's weekly schedule.

The syntax for `CREATE TABLE` allows the exact size of arrays to be specified, for example:

```
CREATE TABLE tictactoe (
    squares integer[3][3]
);
```

However, the current implementation ignores any supplied array size limits, i.e., the behavior is the same as for arrays of unspecified length.

The current implementation does not enforce the declared number of dimensions either. Arrays of a particular element type are all considered to be of the same type, regardless of size or number of dimensions. So, declaring the array size or number of dimensions in `CREATE TABLE` is simply documentation; it does not affect run-time behavior.

An alternative syntax, which conforms to the SQL standard by using the keyword `ARRAY`, can be used for one-dimensional arrays. `pay_by_quarter` could have been defined as:

```
pay_by_quarter integer ARRAY[4],
```

Or, if no array size is to be specified:

```
pay_by_quarter integer ARRAY,
```

As before, however, LightDB does not enforce the size restriction in any case.

## 8.15.2. Array Value Input

To write an array value as a literal constant, enclose the element values within curly braces and separate them by commas. (If you know C, this is not unlike the C syntax for initializing structures.) You can put double quotes around any element value, and must do so if it contains commas or curly braces. (More details appear below.) Thus, the general format of an array constant is the following:

```
'{ val1 delim val2 delim ... }'
```

where *delim* is the delimiter character for the type, as recorded in its `pg_type` entry. Among the standard data types provided in the LightDB distribution, all use a comma (`,`), except for type `box` which uses a semicolon (`;`). Each *val* is either a constant of the array element type, or a subarray. An example of an array constant is:

```
'{{1,2,3},{4,5,6},{7,8,9}}'
```

This constant is a two-dimensional, 3-by-3 array consisting of three subarrays of integers.

To set an element of an array constant to `NULL`, write `NULL` for the element value. (Any upper- or lower-case variant of `NULL` will do.) If you want an actual string value “`NULL`”, you must put double quotes around it.

(These kinds of array constants are actually only a special case of the generic type constants discussed in Section 4.1.2.8. The constant is initially treated as a string and passed to the array input conversion routine. An explicit type specification might be necessary.)

Now we can show some `INSERT` statements:

```
INSERT INTO sal_emp
VALUES ('Bill',
       '{10000, 10000, 10000, 10000}');
```

```
'{{"meeting", "lunch"}, {"training", "presentation"}}');
```

```
INSERT INTO sal_emp
VALUES ('Carol',
       '{20000, 25000, 25000, 25000}',
       '{{"breakfast", "consulting"}, {"meeting", "lunch"}}');
```

The result of the previous two inserts looks like this:

```
SELECT * FROM sal_emp;
name | pay_by_quarter | schedule
-----+-----
Bill | {10000,10000,10000,10000} | {{meeting,lunch},
{training,presentation}}
Carol | {20000,25000,25000,25000} | {{breakfast,consulting},
{meeting,lunch}}
(2 rows)
```

Multidimensional arrays must have matching extents for each dimension. A mismatch causes an error, for example:

```
INSERT INTO sal_emp
VALUES ('Bill',
       '{10000, 10000, 10000, 10000}',
       '{{"meeting", "lunch"}, {"meeting"}}');
```

ERROR: multidimensional arrays must have array expressions with matching dimensions

The ARRAY constructor syntax can also be used:

```
INSERT INTO sal_emp
VALUES ('Bill',
       ARRAY[10000, 10000, 10000, 10000],
       ARRAY[['meeting', 'lunch'], ['training', 'presentation']]);

INSERT INTO sal_emp
VALUES ('Carol',
       ARRAY[20000, 25000, 25000, 25000],
       ARRAY[['breakfast', 'consulting'], ['meeting', 'lunch']]);
```

Notice that the array elements are ordinary SQL constants or expressions; for instance, string literals are single quoted, instead of double quoted as they would be in an array literal. The ARRAY constructor syntax is discussed in more detail in Section 4.2.12.

### 8.15.3. Accessing Arrays

Now, we can run some queries on the table. First, we show how to access a single element of an array. This query retrieves the names of the employees whose pay changed in the second quarter:

```
SELECT name FROM sal_emp WHERE pay_by_quarter[1] <>
pay_by_quarter[2];

name
-----
Carol
```

(1 row)

The array subscript numbers are written within square brackets. By default LightDB uses a one-based numbering convention for arrays, that is, an array of  $n$  elements starts with `array[1]` and ends with `array[n]`.

This query retrieves the third quarter pay of all employees:

```
SELECT pay_by_quarter[3] FROM sal_emp;
```

```
pay_by_quarter
-----
           10000
           25000
```

(2 rows)

We can also access arbitrary rectangular slices of an array, or subarrays. An array slice is denoted by writing *lower-bound:upper-bound* for one or more array dimensions. For example, this query retrieves the first item on Bill's schedule for the first two days of the week:

```
SELECT schedule[1:2][1:1] FROM sal_emp WHERE name = 'Bill';
```

```
schedule
-----
{{meeting},{training}}
```

(1 row)

If any dimension is written as a slice, i.e., contains a colon, then all dimensions are treated as slices. Any dimension that has only a single number (no colon) is treated as being from 1 to the number specified. For example, `[2]` is treated as `[1:2]`, as in this example:

```
SELECT schedule[1:2][2] FROM sal_emp WHERE name = 'Bill';
```

```
schedule
-----
{{meeting,lunch},{training,presentation}}
```

(1 row)

To avoid confusion with the non-slice case, it's best to use slice syntax for all dimensions, e.g., `[1:2][1:1]`, not `[2][1:1]`.

It is possible to omit the *lower-bound* and/or *upper-bound* of a slice specifier; the missing bound is replaced by the lower or upper limit of the array's subscripts. For example:

```
SELECT schedule[:2][2:] FROM sal_emp WHERE name = 'Bill';
```

```
schedule
-----
{{lunch},{presentation}}
```

(1 row)

```
SELECT schedule[:][1:1] FROM sal_emp WHERE name = 'Bill';
```

```
schedule
-----
{{meeting},{training}}
```

(1 row)

An array subscript expression will return null if either the array itself or any of the subscript expressions are null. Also, null is returned if a subscript is outside the array bounds (this case does not raise an error). For example, if `schedule` currently has the dimensions `[1:3][1:2]` then referencing `schedule[3][3]` yields NULL. Similarly, an array reference with the wrong number of subscripts yields a null rather than an error.

An array slice expression likewise yields null if the array itself or any of the subscript expressions are null. However, in other cases such as selecting an array slice that is completely outside the current array bounds, a slice expression yields an empty (zero-dimensional) array instead of null. (This does not match non-slice behavior and is done for historical reasons.) If the requested slice partially overlaps the array bounds, then it is silently reduced to just the overlapping region instead of returning null.

The current dimensions of any array value can be retrieved with the `array_dims` function:

```
SELECT array_dims(schedule) FROM sal_emp WHERE name = 'Carol';
```

```
array_dims
-----
 [1:2][1:2]
(1 row)
```

`array_dims` produces a text result, which is convenient for people to read but perhaps inconvenient for programs. Dimensions can also be retrieved with `array_upper` and `array_lower`, which return the upper and lower bound of a specified array dimension, respectively:

```
SELECT array_upper(schedule, 1) FROM sal_emp WHERE name = 'Carol';
```

```
array_upper
-----
                2
(1 row)
```

`array_length` will return the length of a specified array dimension:

```
SELECT array_length(schedule, 1) FROM sal_emp WHERE name = 'Carol';
```

```
array_length
-----
                2
(1 row)
```

`cardinality` returns the total number of elements in an array across all dimensions. It is effectively the number of rows a call to `unnest` would yield:

```
SELECT cardinality(schedule) FROM sal_emp WHERE name = 'Carol';
```

```
cardinality
-----
                4
(1 row)
```

## 8.15.4. Modifying Arrays

An array value can be replaced completely:

```
UPDATE sal_emp SET pay_by_quarter = '{25000,25000,27000,27000}'
WHERE name = 'Carol';
```

or using the ARRAY expression syntax:

```
UPDATE sal_emp SET pay_by_quarter = ARRAY[25000,25000,27000,27000]
WHERE name = 'Carol';
```

An array can also be updated at a single element:

```
UPDATE sal_emp SET pay_by_quarter[4] = 15000
WHERE name = 'Bill';
```

or updated in a slice:

```
UPDATE sal_emp SET pay_by_quarter[1:2] = '{27000,27000}'
WHERE name = 'Carol';
```

The slice syntaxes with omitted *lower-bound* and/or *upper-bound* can be used too, but only when updating an array value that is not NULL or zero-dimensional (otherwise, there is no existing subscript limit to substitute).

A stored array value can be enlarged by assigning to elements not already present. Any positions between those previously present and the newly assigned elements will be filled with nulls. For example, if array `myarray` currently has 4 elements, it will have six elements after an update that assigns to `myarray[6]`; `myarray[5]` will contain null. Currently, enlargement in this fashion is only allowed for one-dimensional arrays, not multidimensional arrays.

Subscripted assignment allows creation of arrays that do not use one-based subscripts. For example one might assign to `myarray[-2:7]` to create an array with subscript values from -2 to 7.

New array values can also be constructed using the concatenation operator, `||`:

```
SELECT ARRAY[1,2] || ARRAY[3,4];
?column?
-----
{1,2,3,4}
(1 row)
```

```
SELECT ARRAY[5,6] || ARRAY[[1,2],[3,4]];
?column?
-----
{{5,6},{1,2},{3,4}}
(1 row)
```

The concatenation operator allows a single element to be pushed onto the beginning or end of a one-dimensional array. It also accepts two  $N$ -dimensional arrays, or an  $N$ -dimensional and an  $N+1$ -dimensional array.

When a single element is pushed onto either the beginning or end of a one-dimensional array, the result is an array with the same lower bound subscript as the array operand. For example:

```
SELECT array_dims(1 || '[0:1]={2,3}'::int[]);
array_dims
-----
```

```
[0:2]
(1 row)
```

```
SELECT array_dims(ARRAY[1,2] || 3);
 array_dims
-----
 [1:3]
(1 row)
```

When two arrays with an equal number of dimensions are concatenated, the result retains the lower bound subscript of the left-hand operand's outer dimension. The result is an array comprising every element of the left-hand operand followed by every element of the right-hand operand. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[3,4,5]);
 array_dims
-----
 [1:5]
(1 row)
```

```
SELECT array_dims(ARRAY[[1,2],[3,4]] || ARRAY[[5,6],[7,8],[9,0]]);
 array_dims
-----
 [1:5][1:2]
(1 row)
```

When an  $N$ -dimensional array is pushed onto the beginning or end of an  $N+1$ -dimensional array, the result is analogous to the element-array case above. Each  $N$ -dimensional sub-array is essentially an element of the  $N+1$ -dimensional array's outer dimension. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[[3,4],[5,6]]);
 array_dims
-----
 [1:3][1:2]
(1 row)
```

An array can also be constructed by using the functions `array_prepend`, `array_append`, or `array_cat`. The first two only support one-dimensional arrays, but `array_cat` supports multidimensional arrays. Some examples:

```
SELECT array_prepend(1, ARRAY[2,3]);
 array_prepend
-----
 {1,2,3}
(1 row)
```

```
SELECT array_append(ARRAY[1,2], 3);
 array_append
-----
 {1,2,3}
(1 row)
```

```
SELECT array_cat(ARRAY[1,2], ARRAY[3,4]);
 array_cat
-----
 {1,2,3,4}
(1 row)
```



```

SELECT array_cat(ARRAY[[1,2],[3,4]], ARRAY[5,6]);
      array_cat
-----
  {{1,2},{3,4},{5,6}}
(1 row)

```

```

SELECT array_cat(ARRAY[5,6], ARRAY[[1,2],[3,4]]);
      array_cat
-----
  {{5,6},{1,2},{3,4}}

```

In simple cases, the concatenation operator discussed above is preferred over direct use of these functions. However, because the concatenation operator is overloaded to serve all three cases, there are situations where use of one of the functions is helpful to avoid ambiguity. For example consider:

```

SELECT ARRAY[1, 2] || '{3, 4}'; -- the untyped literal is taken as
      an array
      ?column?
-----
  {1,2,3,4}

```

```

SELECT ARRAY[1, 2] || '7'; -- so is this one
ERROR:  malformed array literal: "7"

```

```

SELECT ARRAY[1, 2] || NULL; -- so is an undecorated
      NULL
      ?column?
-----
  {1,2}
(1 row)

```

```

SELECT array_append(ARRAY[1, 2], NULL); -- this might have been
      meant
      array_append
-----
  {1,2,NULL}

```

In the examples above, the parser sees an integer array on one side of the concatenation operator, and a constant of undetermined type on the other. The heuristic it uses to resolve the constant's type is to assume it's of the same type as the operator's other input — in this case, integer array. So the concatenation operator is presumed to represent `array_cat`, not `array_append`. When that's the wrong choice, it could be fixed by casting the constant to the array's element type; but explicit use of `array_append` might be a preferable solution.

## 8.15.5. Searching in Arrays

To search for a value in an array, each value must be checked. This can be done manually, if you know the size of the array. For example:

```

SELECT * FROM sal_emp WHERE pay_by_quarter[1] = 10000 OR
      pay_by_quarter[2] = 10000 OR
      pay_by_quarter[3] = 10000 OR
      pay_by_quarter[4] = 10000;

```

However, this quickly becomes tedious for large arrays, and is not helpful if the size of the array is unknown. An alternative method is described in Section 9.24. The above query could be replaced by:

```
SELECT * FROM sal_emp WHERE 10000 = ANY (pay_by_quarter);
```

In addition, you can find rows where the array has all values equal to 10000 with:

```
SELECT * FROM sal_emp WHERE 10000 = ALL (pay_by_quarter);
```

Alternatively, the `generate_subscripts` function can be used. For example:

```
SELECT * FROM
  (SELECT pay_by_quarter,
    generate_subscripts(pay_by_quarter, 1) AS s
   FROM sal_emp) AS foo
WHERE pay_by_quarter[s] = 10000;
```

This function is described in Table 9.63.

You can also search an array using the `&&` operator, which checks whether the left operand overlaps with the right operand. For instance:

```
SELECT * FROM sal_emp WHERE pay_by_quarter && ARRAY[10000];
```

This and other array operators are further described in Section 9.19. It can be accelerated by an appropriate index, as described in Section 11.2.

You can also search for specific values in an array using the `array_position` and `array_positions` functions. The former returns the subscript of the first occurrence of a value in an array; the latter returns an array with the subscripts of all occurrences of the value in the array. For example:

```
SELECT
  array_position(ARRAY['sun','mon','tue','wed','thu','fri','sat'],
  'mon');
array_position
-----
                2
(1 row)
```

```
SELECT array_positions(ARRAY[1, 4, 3, 1, 3, 4, 2, 1], 1);
array_positions
-----
{1,4,8}
(1 row)
```

### Tip

Arrays are not sets; searching for specific array elements can be a sign of database misdesign. Consider using a separate table with a row for each item that would be an array element. This will be easier to search, and is likely to scale better for a large number of elements.

## 8.15.6. Array Input and Output Syntax

The external text representation of an array value consists of items that are interpreted according to the I/O conversion rules for the array's element type, plus decoration that indicates the array structure. The decoration consists of curly braces (`{` and `}`) around the array value plus delimiter characters between adjacent items. The delimiter character is usually a comma (`,`) but can be something else: it is determined by the `typedelim` setting for the array's element type. Among the standard data types provided in the LightDB distribution, all use a comma, except for type `box`, which uses a semicolon (`;`). In a multidimensional array, each dimension (row, plane, cube, etc.) gets its own level of curly braces, and delimiters must be written between adjacent curly-braced entities of the same level.

The array output routine will put double quotes around element values if they are empty strings, contain curly braces, delimiter characters, double quotes, backslashes, or white space, or match the word `NULL`. Double quotes and backslashes embedded in element values will be backslash-escaped. For numeric data types it is safe to assume that double quotes will never appear, but for textual data types one should be prepared to cope with either the presence or absence of quotes.

By default, the lower bound index value of an array's dimensions is set to one. To represent arrays with other lower bounds, the array subscript ranges can be specified explicitly before writing the array contents. This decoration consists of square brackets (`[ ]`) around each array dimension's lower and upper bounds, with a colon (`:`) delimiter character in between. The array dimension decoration is followed by an equal sign (`=`). For example:

```
SELECT f1[1][-2][3] AS e1, f1[1][-1][5] AS e2
FROM (SELECT '[1:1][-2:-1][3:5]={{{1,2,3},{4,5,6}}}'::int[] AS f1)
AS ss;
```

```
e1 | e2
----+----
 1 | 6
(1 row)
```

The array output routine will include explicit dimensions in its result only when there are one or more lower bounds different from one.

If the value written for an element is `NULL` (in any case variant), the element is taken to be `NULL`. The presence of any quotes or backslashes disables this and allows the literal string value “`NULL`” to be entered. Also, for backward compatibility with pre-8.2 versions of LightDB, the `array_nulls` configuration parameter can be turned `off` to suppress recognition of `NULL` as a `NULL`.

As shown previously, when writing an array value you can use double quotes around any individual array element. You *must* do so if the element value would otherwise confuse the array-value parser. For example, elements containing curly braces, commas (or the data type's delimiter character), double quotes, backslashes, or leading or trailing whitespace must be double-quoted. Empty strings and strings matching the word `NULL` must be quoted, too. To put a double quote or backslash in a quoted array element value, precede it with a backslash. Alternatively, you can avoid quotes and use backslash-escaping to protect all data characters that would otherwise be taken as array syntax.

You can add whitespace before a left brace or after a right brace. You can also add whitespace before or after any individual item string. In all of these cases the whitespace will be ignored. However, whitespace within double-quoted elements, or surrounded on both sides by non-whitespace characters of an element, is not ignored.

### Tip

The `ARRAY` constructor syntax (see Section 4.2.12) is often easier to work with than the array-literal syntax when writing array values in SQL commands. In `ARRAY`, individual element values are written the same way they would be written when not members of an array.

## 8.16. Composite Types

A *composite type* represents the structure of a row or record; it is essentially just a list of field names and their data types. LightDB allows composite types to be used in many of the same ways that simple types can be used. For example, a column of a table can be declared to be of a composite type.

### 8.16.1. Declaration of Composite Types

Here are two simple examples of defining composite types:

```
CREATE TYPE complex AS (  
    r        double precision,  
    i        double precision  
);
```

```
CREATE TYPE inventory_item AS (  
    name            text,  
    supplier_id    integer,  
    price           numeric  
);
```

The syntax is comparable to `CREATE TABLE`, except that only field names and types can be specified; no constraints (such as `NOT NULL`) can presently be included. Note that the `AS` keyword is essential; without it, the system will think a different kind of `CREATE TYPE` command is meant, and you will get odd syntax errors.

Having defined the types, we can use them to create tables:

```
CREATE TABLE on_hand (  
    item        inventory_item,  
    count       integer  
);
```

```
INSERT INTO on_hand VALUES (ROW('fuzzy dice', 42, 1.99), 1000);
```

or functions:

```
CREATE FUNCTION price_extension(inventory_item, integer) RETURNS  
    numeric  
AS 'SELECT $1.price * $2' LANGUAGE SQL;
```

```
SELECT price_extension(item, 10) FROM on_hand;
```

Whenever you create a table, a composite type is also automatically created, with the same name as the table, to represent the table's row type. For example, had we said:

```
CREATE TABLE inventory_item (  
    name            text,  
    supplier_id    integer REFERENCES suppliers,  
    price           numeric CHECK (price > 0)  
);
```

then the same `inventory_item` composite type shown above would come into being as a byproduct, and could be used just as above. Note however an important restriction of the current implementation: since no constraints are associated with a composite type, the constraints shown in

the table definition *do not apply* to values of the composite type outside the table. (To work around this, create a domain over the composite type, and apply the desired constraints as CHECK constraints of the domain.)

## 8.16.2. Constructing Composite Values

To write a composite value as a literal constant, enclose the field values within parentheses and separate them by commas. You can put double quotes around any field value, and must do so if it contains commas or parentheses. (More details appear below.) Thus, the general format of a composite constant is the following:

```
'( val1 , val2 , ... )'
```

An example is:

```
'("fuzzy dice",42,1.99)'
```

which would be a valid value of the `inventory_item` type defined above. To make a field be NULL, write no characters at all in its position in the list. For example, this constant specifies a NULL third field:

```
'("fuzzy dice",42,)'
```

If you want an empty string rather than NULL, write double quotes:

```
'( "",42, )'
```

Here the first field is a non-NULL empty string, the third is NULL.

(These constants are actually only a special case of the generic type constants discussed in Section 4.1.2.8. The constant is initially treated as a string and passed to the composite-type input conversion routine. An explicit type specification might be necessary to tell which type to convert the constant to.)

The ROW expression syntax can also be used to construct composite values. In most cases this is considerably simpler to use than the string-literal syntax since you don't have to worry about multiple layers of quoting. We already used this method above:

```
ROW('fuzzy dice', 42, 1.99)  
ROW('', 42, NULL)
```

The ROW keyword is actually optional as long as you have more than one field in the expression, so these can be simplified to:

```
('fuzzy dice', 42, 1.99)  
( '', 42, NULL)
```

The ROW expression syntax is discussed in more detail in Section 4.2.13.

## 8.16.3. Accessing Composite Types

To access a field of a composite column, one writes a dot and the field name, much like selecting a field from a table name. In fact, it's so much like selecting from a table name that you often have to use parentheses to keep from confusing the parser. For example, you might try to select some subfields from our `on_hand` example table with something like:

```
SELECT item.name FROM on_hand WHERE item.price > 9.99;
```

This will not work since the name `item` is taken to be a table name, not a column name of `on_hand`, per SQL syntax rules. You must write it like this:

```
SELECT (item).name FROM on_hand WHERE (item).price > 9.99;
```

or if you need to use the table name as well (for instance in a multitable query), like this:

```
SELECT (on_hand.item).name FROM on_hand WHERE (on_hand.item).price > 9.99;
```

Now the parenthesized object is correctly interpreted as a reference to the `item` column, and then the subfield can be selected from it.

Similar syntactic issues apply whenever you select a field from a composite value. For instance, to select just one field from the result of a function that returns a composite value, you'd need to write something like:

```
SELECT (my_func(...)).field FROM ...
```

Without the extra parentheses, this will generate a syntax error.

The special field name `*` means “all fields”, as further explained in Section 8.16.5.

## 8.16.4. Modifying Composite Types

Here are some examples of the proper syntax for inserting and updating composite columns. First, inserting or updating a whole column:

```
INSERT INTO mytab (complex_col) VALUES((1.1,2.2));
```

```
UPDATE mytab SET complex_col = ROW(1.1,2.2) WHERE ...;
```

The first example omits `ROW`, the second uses it; we could have done it either way.

We can update an individual subfield of a composite column:

```
UPDATE mytab SET complex_col.r = (complex_col).r + 1 WHERE ...;
```

Notice here that we don't need to (and indeed cannot) put parentheses around the column name appearing just after `SET`, but we do need parentheses when referencing the same column in the expression to the right of the equal sign.

And we can specify subfields as targets for `INSERT`, too:

```
INSERT INTO mytab (complex_col.r, complex_col.i) VALUES(1.1, 2.2);
```

Had we not supplied values for all the subfields of the column, the remaining subfields would have been filled with null values.

## 8.16.5. Using Composite Types in Queries

There are various special syntax rules and behaviors associated with composite types in queries. These rules provide useful shortcuts, but can be confusing if you don't know the logic behind them.

In LightDB, a reference to a table name (or alias) in a query is effectively a reference to the composite value of the table's current row. For example, if we had a table `inventory_item` as shown above, we could write:

```
SELECT c FROM inventory_item c;
```

This query produces a single composite-valued column, so we might get output like:

```

          c
-----
 ("fuzzy dice",42,1.99)
 (1 row)

```

Note however that simple names are matched to column names before table names, so this example works only because there is no column named `c` in the query's tables.

The ordinary qualified-column-name syntax `table_name.column_name` can be understood as applying field selection to the composite value of the table's current row. (For efficiency reasons, it's not actually implemented that way.)

When we write

```
SELECT c.* FROM inventory_item c;
```

then, according to the SQL standard, we should get the contents of the table expanded into separate columns:

```

   name      | supplier_id | price
-----+-----+-----
 fuzzy dice |           42 |  1.99
 (1 row)

```

as if the query were

```
SELECT c.name, c.supplier_id, c.price FROM inventory_item c;
```

LightDB will apply this expansion behavior to any composite-valued expression, although as shown above, you need to write parentheses around the value that `.*` is applied to whenever it's not a simple table name. For example, if `myfunc()` is a function returning a composite type with columns `a`, `b`, and `c`, then these two queries have the same result:

```
SELECT (myfunc(x)).* FROM some_table;
SELECT (myfunc(x)).a, (myfunc(x)).b, (myfunc(x)).c FROM some_table;
```

### Tip

LightDB handles column expansion by actually transforming the first form into the second. So, in this example, `myfunc()` would get invoked three times per row with either syntax. If it's an expensive function you may wish to avoid that, which you can do with a query like:

```
SELECT m.* FROM some_table, LATERAL myfunc(x) AS m;
```

Placing the function in a LATERAL FROM item keeps it from being invoked more than once per row. `m.*` is still expanded into `m.a`, `m.b`, `m.c`, but now those variables are just references to the output of the FROM item. (The LATERAL keyword is optional here, but we show it to clarify that the function is getting `x` from `some_table`.)

The `composite_value.*` syntax results in column expansion of this kind when it appears at the top level of a SELECT output list, a RETURNING list in INSERT/UPDATE/DELETE, a VALUES clause, or a row constructor. In all other contexts (including when nested inside one of those constructs), attaching `.*` to a composite value does not change the value, since it means “all columns” and so the same composite value is produced again. For example, if `somefunc()` accepts a composite-valued argument, these queries are the same:

```
SELECT somefunc(c.*) FROM inventory_item c;
SELECT somefunc(c) FROM inventory_item c;
```

In both cases, the current row of `inventory_item` is passed to the function as a single composite-valued argument. Even though `.*` does nothing in such cases, using it is good style, since it makes clear that a composite value is intended. In particular, the parser will consider `c` in `c.*` to refer to a table name or alias, not to a column name, so that there is no ambiguity; whereas without `.*`, it is not clear whether `c` means a table name or a column name, and in fact the column-name interpretation will be preferred if there is a column named `c`.

Another example demonstrating these concepts is that all these queries mean the same thing:

```
SELECT * FROM inventory_item c ORDER BY c;
SELECT * FROM inventory_item c ORDER BY c.*;
SELECT * FROM inventory_item c ORDER BY ROW(c.*);
```

All of these ORDER BY clauses specify the row's composite value, resulting in sorting the rows according to the rules described in Section 9.24.6. However, if `inventory_item` contained a column named `c`, the first case would be different from the others, as it would mean to sort by that column only. Given the column names previously shown, these queries are also equivalent to those above:

```
SELECT * FROM inventory_item c ORDER BY ROW(c.name, c.supplier_id,
c.price);
SELECT * FROM inventory_item c ORDER BY (c.name, c.supplier_id,
c.price);
```

(The last case uses a row constructor with the key word ROW omitted.)

Another special syntactical behavior associated with composite values is that we can use *functional notation* for extracting a field of a composite value. The simple way to explain this is that the notations `field(table)` and `table.field` are interchangeable. For example, these queries are equivalent:

```
SELECT c.name FROM inventory_item c WHERE c.price > 1000;
SELECT name(c) FROM inventory_item c WHERE price(c) > 1000;
```

Moreover, if we have a function that accepts a single argument of a composite type, we can call it with either notation. These queries are all equivalent:

```
SELECT somefunc(c) FROM inventory_item c;
SELECT somefunc(c.*) FROM inventory_item c;
```



```
SELECT c.somefunc FROM inventory_item c;
```

This equivalence between functional notation and field notation makes it possible to use functions on composite types to implement “computed fields”. An application using the last query above wouldn't need to be directly aware that `somefunc` isn't a real column of the table.

### Tip

Because of this behavior, it's unwise to give a function that takes a single composite-type argument the same name as any of the fields of that composite type. If there is ambiguity, the field-name interpretation will be chosen if field-name syntax is used, while the function will be chosen if function-call syntax is used. However, LightDB versions before 11 always chose the field-name interpretation, unless the syntax of the call required it to be a function call. One way to force the function interpretation in older versions is to schema-qualify the function name, that is, write `schema.func(compositevalue)`.

## 8.16.6. Composite Type Input and Output Syntax

The external text representation of a composite value consists of items that are interpreted according to the I/O conversion rules for the individual field types, plus decoration that indicates the composite structure. The decoration consists of parentheses ( ( and ) ) around the whole value, plus commas ( , ) between adjacent items. Whitespace outside the parentheses is ignored, but within the parentheses it is considered part of the field value, and might or might not be significant depending on the input conversion rules for the field data type. For example, in:

```
' ( 42 ) '
```

the whitespace will be ignored if the field type is integer, but not if it is text.

As shown previously, when writing a composite value you can write double quotes around any individual field value. You *must* do so if the field value would otherwise confuse the composite-value parser. In particular, fields containing parentheses, commas, double quotes, or backslashes must be double-quoted. To put a double quote or backslash in a quoted composite field value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted field value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as composite syntax.

A completely empty field value (no characters at all between the commas or parentheses) represents a NULL. To write a value that is an empty string rather than NULL, write " ".

The composite output routine will put double quotes around field values if they are empty strings or contain parentheses, commas, double quotes, backslashes, or white space. (Doing so for white space is not essential, but aids legibility.) Double quotes and backslashes embedded in field values will be doubled.

### Note

Remember that what you write in an SQL command will first be interpreted as a string literal, and then as a composite. This doubles the number of backslashes you need (assuming escape string syntax is used). For example, to insert a `text` field containing a double quote and a backslash in a composite value, you'd need to write:

```
INSERT ... VALUES ('(\"\"\\\"')');
```

The string-literal processor removes one level of backslashes, so that what arrives at the composite-value parser looks like (`"\""`). In turn, the string fed to the `text` data type's input routine becomes `"\"`. (If we were working with a data type whose input routine also treated backslashes specially, `bytea` for example, we might need as many as eight backslashes in the command to get one backslash into the stored composite field.) Dollar quoting (see Section 4.1.2.4) can be used to avoid the need to double backslashes.

### Tip

The `ROW` constructor syntax is usually easier to work with than the composite-literal syntax when writing composite values in SQL commands. In `ROW`, individual field values are written the same way they would be written when not members of a composite.

## 8.17. Range Types

Range types are data types representing a range of values of some element type (called the range's *subtype*). For instance, ranges of `timestamp` might be used to represent the ranges of time that a meeting room is reserved. In this case the data type is `tsrange` (short for “timestamp range”), and `timestamp` is the subtype. The subtype must have a total order so that it is well-defined whether element values are within, before, or after a range of values.

Range types are useful because they represent many element values in a single range value, and because concepts such as overlapping ranges can be expressed clearly. The use of time and date ranges for scheduling purposes is the clearest example; but price ranges, measurement ranges from an instrument, and so forth can also be useful.

### 8.17.1. Built-in Range Types

LightDB comes with the following built-in range types:

- `int4range` — Range of integer
- `int8range` — Range of bigint
- `numrange` — Range of numeric
- `tsrange` — Range of timestamp without time zone
- `tstzrange` — Range of timestamp with time zone
- `daterange` — Range of date

In addition, you can define your own range types; see `CREATE TYPE` for more information.

### 8.17.2. Examples

```
CREATE TABLE reservation (room int, during tsrange);
INSERT INTO reservation VALUES
  (1108, '[2010-01-01 14:30, 2010-01-01 15:30)');
```

```

-- Containment
SELECT int4range(10, 20) @> 3;

-- Overlaps
SELECT numrange(11.1, 22.2) && numrange(20.0, 30.0);

-- Extract the upper bound
SELECT upper(int8range(15, 25));

-- Compute the intersection
SELECT int4range(10, 20) * int4range(15, 25);

-- Is the range empty?
SELECT isempty(numrange(1, 5));

```

See Table 9.54 and Table 9.55 for complete lists of operators and functions on range types.

### 8.17.3. Inclusive and Exclusive Bounds

Every non-empty range has two bounds, the lower bound and the upper bound. All points between these values are included in the range. An inclusive bound means that the boundary point itself is included in the range as well, while an exclusive bound means that the boundary point is not included in the range.

In the text form of a range, an inclusive lower bound is represented by “[” while an exclusive lower bound is represented by “(”. Likewise, an inclusive upper bound is represented by “]”, while an exclusive upper bound is represented by “)”. (See Section 8.17.5 for more details.)

The functions `lower_inc` and `upper_inc` test the inclusivity of the lower and upper bounds of a range value, respectively.

### 8.17.4. Infinite (Unbounded) Ranges

The lower bound of a range can be omitted, meaning that all values less than the upper bound are included in the range, e.g., `( , 3]`. Likewise, if the upper bound of the range is omitted, then all values greater than the lower bound are included in the range. If both lower and upper bounds are omitted, all values of the element type are considered to be in the range. Specifying a missing bound as inclusive is automatically converted to exclusive, e.g., `[ , ]` is converted to `( , )`. You can think of these missing values as  $\pm$ -infinity, but they are special range type values and are considered to be beyond any range element type's  $\pm$ -infinity values.

Element types that have the notion of “infinity” can use them as explicit bound values. For example, with timestamp ranges, `[today, infinity)` excludes the special timestamp value `infinity`, while `[today, infinity]` include it, as does `[today, )` and `[today, ]`.

The functions `lower_inf` and `upper_inf` test for infinite lower and upper bounds of a range, respectively.

### 8.17.5. Range Input/Output

The input for a range value must follow one of the following patterns:

```

( lower-bound , upper-bound )
( lower-bound , upper-bound ]
[ lower-bound , upper-bound )
[ lower-bound , upper-bound ]

```

`empty`

The parentheses or brackets indicate whether the lower and upper bounds are exclusive or inclusive, as described previously. Notice that the final pattern is `empty`, which represents an empty range (a range that contains no points).

The *lower-bound* may be either a string that is valid input for the subtype, or `empty` to indicate no lower bound. Likewise, *upper-bound* may be either a string that is valid input for the subtype, or `empty` to indicate no upper bound.

Each bound value can be quoted using " (double quote) characters. This is necessary if the bound value contains parentheses, brackets, commas, double quotes, or backslashes, since these characters would otherwise be taken as part of the range syntax. To put a double quote or backslash in a quoted bound value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted bound value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as range syntax. Also, to write a bound value that is an empty string, write "", since writing nothing means an infinite bound.

Whitespace is allowed before and after the range value, but any whitespace between the parentheses or brackets is taken as part of the lower or upper bound value. (Depending on the element type, it might or might not be significant.)

### Note

These rules are very similar to those for writing field values in composite-type literals. See Section 8.16.6 for additional commentary.

Examples:

```
-- includes 3, does not include 7, and does include all points in
  between
SELECT '[3,7)::int4range;

-- does not include either 3 or 7, but includes all points in
  between
SELECT '(3,7)::int4range;

-- includes only the single point 4
SELECT '[4,4)::int4range;

-- includes no points (and will be normalized to 'empty')
SELECT '[4,4)::int4range;
```

## 8.17.6. Constructing Ranges

Each range type has a constructor function with the same name as the range type. Using the constructor function is frequently more convenient than writing a range literal constant, since it avoids the need for extra quoting of the bound values. The constructor function accepts two or three arguments. The two-argument form constructs a range in standard form (lower bound inclusive, upper bound exclusive), while the three-argument form constructs a range with bounds of the form specified by the third argument. The third argument must be one of the strings "()", "(]", "[)", or "[ ]". For example:

```
-- The full form is: lower bound, upper bound, and text argument
  indicating
```

```
-- inclusivity/exclusivity of bounds.
SELECT numrange(1.0, 14.0, '()');

-- If the third argument is omitted, '[' is assumed.
SELECT numrange(1.0, 14.0);

-- Although '[' is specified here, on display the value will be
   converted to
-- canonical form, since int8range is a discrete range type (see
   below).
SELECT int8range(1, 14, '[');

-- Using NULL for either bound causes the range to be unbounded on
   that side.
SELECT numrange(NULL, 2.2);
```

## 8.17.7. Discrete Range Types

A discrete range is one whose element type has a well-defined “step”, such as `integer` or `date`. In these types two elements can be said to be adjacent, when there are no valid values between them. This contrasts with continuous ranges, where it's always (or almost always) possible to identify other element values between two given values. For example, a range over the `numeric` type is continuous, as is a range over `timestamp`. (Even though `timestamp` has limited precision, and so could theoretically be treated as discrete, it's better to consider it continuous since the step size is normally not of interest.)

Another way to think about a discrete range type is that there is a clear idea of a “next” or “previous” value for each element value. Knowing that, it is possible to convert between inclusive and exclusive representations of a range's bounds, by choosing the next or previous element value instead of the one originally given. For example, in an integer range type `[ 4 , 8 ]` and `( 3 , 9 )` denote the same set of values; but this would not be so for a range over `numeric`.

A discrete range type should have a *canonicalization* function that is aware of the desired step size for the element type. The canonicalization function is charged with converting equivalent values of the range type to have identical representations, in particular consistently inclusive or exclusive bounds. If a canonicalization function is not specified, then ranges with different formatting will always be treated as unequal, even though they might represent the same set of values in reality.

The built-in range types `int4range`, `int8range`, and `daterange` all use a canonical form that includes the lower bound and excludes the upper bound; that is, `[ )`. User-defined range types can use other conventions, however.

## 8.17.8. Defining New Range Types

Users can define their own range types. The most common reason to do this is to use ranges over subtypes not provided among the built-in range types. For example, to define a new range type of subtype `float8`:

```
CREATE TYPE floatrange AS RANGE (
    subtype = float8,
    subtype_diff = float8mi
);

SELECT '[1.234, 5.678]':floatrange;
```

Because `float8` has no meaningful “step”, we do not define a canonicalization function in this example.

Defining your own range type also allows you to specify a different subtype B-tree operator class or collation to use, so as to change the sort ordering that determines which values fall into a given range.

If the subtype is considered to have discrete rather than continuous values, the `CREATE TYPE` command should specify a `canonical` function. The canonicalization function takes an input range value, and must return an equivalent range value that may have different bounds and formatting. The canonical output for two ranges that represent the same set of values, for example the integer ranges `[1, 7]` and `[1, 8)`, must be identical. It doesn't matter which representation you choose to be the canonical one, so long as two equivalent values with different formattings are always mapped to the same value with the same formatting. In addition to adjusting the inclusive/exclusive bounds format, a canonicalization function might round off boundary values, in case the desired step size is larger than what the subtype is capable of storing. For instance, a range type over `timestamp` could be defined to have a step size of an hour, in which case the canonicalization function would need to round off bounds that weren't a multiple of an hour, or perhaps throw an error instead.

In addition, any range type that is meant to be used with GiST indexes should define a subtype difference, or `subtype_diff`, function. (The index will still work without `subtype_diff`, but it is likely to be considerably less efficient than if a difference function is provided.) The subtype difference function takes two input values of the subtype, and returns their difference (i.e.,  $X$  minus  $Y$ ) represented as a `float8` value. In our example above, the function `float8mi` that underlies the regular `float8` minus operator can be used; but for any other subtype, some type conversion would be necessary. Some creative thought about how to represent differences as numbers might be needed, too. To the greatest extent possible, the `subtype_diff` function should agree with the sort ordering implied by the selected operator class and collation; that is, its result should be positive whenever its first argument is greater than its second according to the sort ordering.

A less-oversimplified example of a `subtype_diff` function is:

```
CREATE FUNCTION time_subtype_diff(x time, y time) RETURNS float8 AS
'SELECT EXTRACT(EPOCH FROM (x - y))' LANGUAGE sql STRICT IMMUTABLE;

CREATE TYPE timerange AS RANGE (
    subtype = time,
    subtype_diff = time_subtype_diff
);

SELECT '[11:10, 23:00]':timerange;
```

See `CREATE TYPE` for more information about creating range types.

## 8.17.9. Indexing

GiST indexes can be created for table columns of range types. For instance, to create a GiST index:

```
CREATE INDEX reservation_idx ON reservation USING GIST (during);
```

A GiST index can accelerate queries involving these range operators: `=`, `&&`, `<@`, `@>`, `<<`, `>>`, `-|-`, `&<`, and `&>` (see Table 9.54 for more information).

In addition, B-tree and hash indexes can be created for table columns of range types. For these index types, basically the only useful range operation is equality. There is a B-tree sort ordering defined for range values, with corresponding `<` and `>` operators, but the ordering is rather arbitrary and not usually useful in the real world. Range types' B-tree and hash support is primarily meant to allow sorting and hashing internally in queries, rather than creation of actual indexes.

## 8.17.10. Constraints on Ranges

While UNIQUE is a natural constraint for scalar values, it is usually unsuitable for range types. Instead, an exclusion constraint is often more appropriate (see CREATE TABLE ... CONSTRAINT ... EXCLUDE). Exclusion constraints allow the specification of constraints such as “non-overlapping” on a range type. For example:

```
CREATE TABLE reservation (
    during tsrange,
    EXCLUDE USING GIST (during WITH &&)
);
```

That constraint will prevent any overlapping values from existing in the table at the same time:

```
INSERT INTO reservation VALUES
    ('[2010-01-01 11:30, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO reservation VALUES
    ('[2010-01-01 14:45, 2010-01-01 15:45)');
ERROR:  conflicting key value violates exclusion constraint
"reservation_during_excl"
DETAIL:  Key (during)=(["2010-01-01 14:45:00", "2010-01-01
15:45:00"]) conflicts
with existing key (during)=(["2010-01-01 11:30:00", "2010-01-01
15:00:00"]).
```

You can use the `btree_gist` extension to define exclusion constraints on plain scalar data types, which can then be combined with range exclusions for maximum flexibility. For example, after `btree_gist` is installed, the following constraint will reject overlapping ranges only if the meeting room numbers are equal:

```
CREATE EXTENSION btree_gist;
CREATE TABLE room_reservation (
    room text,
    during tsrange,
    EXCLUDE USING GIST (room WITH =, during WITH &&)
);

INSERT INTO room_reservation VALUES
    ('123A', '[2010-01-01 14:00, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO room_reservation VALUES
    ('123A', '[2010-01-01 14:30, 2010-01-01 15:30)');
ERROR:  conflicting key value violates exclusion constraint
"room_reservation_room_during_excl"
DETAIL:  Key (room, during)=(123A, ["2010-01-01
14:30:00", "2010-01-01 15:30:00"]) conflicts
with existing key (room, during)=(123A, ["2010-01-01
14:00:00", "2010-01-01 15:00:00"]).

INSERT INTO room_reservation VALUES
    ('123B', '[2010-01-01 14:30, 2010-01-01 15:30)');
INSERT 0 1
```

## 8.18. Domain Types

A *domain* is a user-defined data type that is based on another *underlying type*. Optionally, it can have constraints that restrict its valid values to a subset of what the underlying type would allow. Otherwise it behaves like the underlying type — for example, any operator or function that can be applied to the underlying type will work on the domain type. The underlying type can be any built-in or user-defined base type, enum type, array type, composite type, range type, or another domain.

For example, we could create a domain over integers that accepts only positive integers:

```
CREATE DOMAIN posint AS integer CHECK (VALUE > 0);
CREATE TABLE mytable (id posint);
INSERT INTO mytable VALUES(1);    -- works
INSERT INTO mytable VALUES(-1);  -- fails
```

When an operator or function of the underlying type is applied to a domain value, the domain is automatically down-cast to the underlying type. Thus, for example, the result of `mytable.id - 1` is considered to be of type `integer` not `posint`. We could write `(mytable.id - 1)::posint` to cast the result back to `posint`, causing the domain's constraints to be rechecked. In this case, that would result in an error if the expression had been applied to an `id` value of 1. Assigning a value of the underlying type to a field or variable of the domain type is allowed without writing an explicit cast, but the domain's constraints will be checked.

For additional information see `CREATE DOMAIN`.

## 8.19. Object Identifier Types

Object identifiers (OIDs) are used internally by LightDB as primary keys for various system tables. Type `oid` represents an object identifier. There are also several alias types for `oid` named *regsomething*. Table 8.26 shows an overview.

The `oid` type is currently implemented as an unsigned four-byte integer. Therefore, it is not large enough to provide database-wide uniqueness in large databases, or even in large individual tables.

The `oid` type itself has few operations beyond comparison. It can be cast to `integer`, however, and then manipulated using the standard integer operators. (Beware of possible signed-versus-unsigned confusion if you do this.)

The OID alias types have no operations of their own except for specialized input and output routines. These routines are able to accept and display symbolic names for system objects, rather than the raw numeric value that type `oid` would use. The alias types allow simplified lookup of OID values for objects. For example, to examine the `pg_attribute` rows related to a table `mytable`, one could write:

```
SELECT * FROM pg_attribute WHERE attrelid = 'mytable'::regclass;
```

rather than:

```
SELECT * FROM pg_attribute
  WHERE attrelid = (SELECT oid FROM pg_class WHERE relname =
    'mytable');
```

While that doesn't look all that bad by itself, it's still oversimplified. A far more complicated subselect would be needed to select the right OID if there are multiple tables named `mytable` in different schemas. The `regclass` input converter handles the table lookup according to the schema path setting, and so it does the “right thing” automatically. Similarly, casting a table's OID to `regclass` is handy for symbolic display of a numeric OID.



**Table 8.26. Object Identifier Types**

Name	References	Description	Value Example
oid	any	numeric object identifier	564182
regclass	pg_class	relation name	pg_type
regcollation	pg_collation	collation name	"POSIX"
regconfig	pg_ts_config	text search configuration	english
regdictionary	pg_ts_dict	text search dictionary	simple
regnamespace	pg_namespace	namespace name	pg_catalog
regoper	pg_operator	operator name	+
regoperator	pg_operator	operator with argument types	*(integer, integer) or -(NONE, integer)
regproc	pg_proc	function name	sum
regprocedure	pg_proc	function with argument types	sum(int4)
regrole	pg_authid	role name	smithee
regtype	pg_type	data type name	integer

All of the OID alias types for objects grouped by namespace accept schema-qualified names, and will display schema-qualified names on output if the object would not be found in the current search path without being qualified. The `regproc` and `regoper` alias types will only accept input names that are unique (not overloaded), so they are of limited use; for most uses `regprocedure` or `regoperator` are more appropriate. For `regoperator`, unary operators are identified by writing `NONE` for the unused operand.

An additional property of most of the OID alias types is the creation of dependencies. If a constant of one of these types appears in a stored expression (such as a column default expression or view), it creates a dependency on the referenced object. For example, if a column has a default expression `nextval('my_seq'::regclass)`, LightDB understands that the default expression depends on the sequence `my_seq`; the system will not let the sequence be dropped without first removing the default expression. `regrole` is the only exception for the property. Constants of this type are not allowed in such expressions.

### Note

The OID alias types do not completely follow transaction isolation rules. The planner also treats them as simple constants, which may result in sub-optimal planning.

Another identifier type used by the system is `xid`, or transaction (abbreviated `xact`) identifier. This is the data type of the system columns `xmin` and `xmax`. Transaction identifiers are 32-bit quantities. In some contexts, a 64-bit variant `xid8` is used. Unlike `xid` values, `xid8` values increase strictly monotonically and cannot be reused in the lifetime of a database cluster.

A third identifier type used by the system is `cid`, or command identifier. This is the data type of the system columns `cmin` and `cmax`. Command identifiers are also 32-bit quantities.

A final identifier type used by the system is `tid`, or tuple identifier (row identifier). This is the data type of the system column `ctid`. A tuple ID is a pair (block number, tuple index within block) that identifies the physical location of the row within its table.

(The system columns are further explained in Section 5.5.)

## 8.20. pg\_lsn Type

The `pg_lsn` data type can be used to store LSN (Log Sequence Number) data which is a pointer to a location in the WAL. This type is a representation of `XLogRecPtr` and an internal system type of LightDB.

Internally, an LSN is a 64-bit integer, representing a byte position in the write-ahead log stream. It is printed as two hexadecimal numbers of up to 8 digits each, separated by a slash; for example, `16/B374D848`. The `pg_lsn` type supports the standard comparison operators, like `=` and `>`. Two LSNs can be subtracted using the `-` operator; the result is the number of bytes separating those write-ahead log locations.

## 8.21. Pseudo-Types

The LightDB type system contains a number of special-purpose entries that are collectively called *pseudo-types*. A pseudo-type cannot be used as a column data type, but it can be used to declare a function's argument or result type. Each of the available pseudo-types is useful in situations where a function's behavior does not correspond to simply taking or returning a value of a specific SQL data type. Table 8.27 lists the existing pseudo-types.

**Table 8.27. Pseudo-Types**

Name	Description
<code>any</code>	Indicates that a function accepts any input data type.
<code>anyelement</code>	Indicates that a function accepts any data type (see Section 36.2.5).
<code>anyarray</code>	Indicates that a function accepts any array data type (see Section 36.2.5).
<code>anynonarray</code>	Indicates that a function accepts any non-array data type (see Section 36.2.5).
<code>anyenum</code>	Indicates that a function accepts any enum data type (see Section 36.2.5 and Section 8.7).
<code>anyrange</code>	Indicates that a function accepts any range data type (see Section 36.2.5 and Section 8.17).
<code>anycompatible</code>	Indicates that a function accepts any data type, with automatic promotion of multiple arguments to a common data type (see Section 36.2.5).
<code>anycompatiblearray</code>	Indicates that a function accepts any array data type, with automatic promotion of multiple arguments to a common data type (see Section 36.2.5).
<code>anycompatiblenonarray</code>	Indicates that a function accepts any non-array data type, with automatic promotion of multiple arguments to a common data type (see Section 36.2.5).
<code>anycompatiblerange</code>	Indicates that a function accepts any range data type, with automatic promotion of multiple arguments to a common data type (see Section 36.2.5 and Section 8.17).
<code>cstring</code>	Indicates that a function accepts or returns a null-terminated C string.
<code>internal</code>	Indicates that a function accepts or returns a server-internal data type.

Name	Description
<code>language_handler</code>	A procedural language call handler is declared to return <code>language_handler</code> .
<code>fdw_handler</code>	A foreign-data wrapper handler is declared to return <code>fdw_handler</code> .
<code>table_am_handler</code>	A table access method handler is declared to return <code>table_am_handler</code> .
<code>index_am_handler</code>	An index access method handler is declared to return <code>index_am_handler</code> .
<code>tsm_handler</code>	A tablesample method handler is declared to return <code>tsm_handler</code> .
<code>record</code>	Identifies a function taking or returning an unspecified row type.
<code>trigger</code>	A trigger function is declared to return <code>trigger</code> .
<code>event_trigger</code>	An event trigger function is declared to return <code>event_trigger</code> .
<code>pg_ddl_command</code>	Identifies a representation of DDL commands that is available to event triggers.
<code>void</code>	Indicates that a function returns no value.
<code>unknown</code>	Identifies a not-yet-resolved type, e.g., of an undecorated string literal.

Functions coded in C (whether built-in or dynamically loaded) can be declared to accept or return any of these pseudo-types. It is up to the function author to ensure that the function will behave safely when a pseudo-type is used as an argument type.

Functions coded in procedural languages can use pseudo-types only as allowed by their implementation languages. At present most procedural languages forbid use of a pseudo-type as an argument type, and allow only `void` and `record` as a result type (plus `trigger` or `event_trigger` when the function is used as a trigger or event trigger). Some also support polymorphic functions using the polymorphic pseudo-types, which are shown above and discussed in detail in Section 36.2.5.

The `internal` pseudo-type is used to declare functions that are meant only to be called internally by the database system, and not by direct invocation in an SQL query. If a function has at least one `internal`-type argument then it cannot be called from SQL. To preserve the type safety of this restriction it is important to follow this coding rule: do not create any function that is declared to return `internal` unless it has at least one `internal` argument.

---

# Chapter 9. Functions and Operators

LightDB provides a large number of functions and operators for the built-in data types. This chapter describes most of them, although additional special-purpose functions appear in relevant sections of the manual. Users can also define their own functions and operators, as described in Part V. The `Itsql` commands `\df` and `\do` can be used to list all available functions and operators, respectively.

The notation used throughout this chapter to describe the argument and result data types of a function or operator is like this:

```
repeat ( text , integer ) → text
```

which says that the function `repeat` takes one text and one integer argument and returns a result of type text. The right arrow is also used to indicate the result of an example, thus:

```
repeat( 'Pg' , 4 ) → PgPgPgPg
```

If you are concerned about portability then note that most of the functions and operators described in this chapter, with the exception of the most trivial arithmetic and comparison operators and some explicitly marked functions, are not specified by the SQL standard. Some of this extended functionality is present in other SQL database management systems, and in many cases this functionality is compatible and consistent between the various implementations.

## 9.1. Logical Operators

The usual logical operators are available:

```
boolean AND boolean → boolean
```

```
boolean OR boolean → boolean
```

```
NOT boolean → boolean
```

SQL uses a three-valued logic system with true, false, and null, which represents “unknown”. Observe the following truth tables:

<b>a</b>	<b>b</b>	<b>a AND b</b>	<b>a OR b</b>
TRUE	TRUE	TRUE	TRUE
TRUE	FALSE	FALSE	TRUE
TRUE	NULL	NULL	TRUE
FALSE	FALSE	FALSE	FALSE
FALSE	NULL	FALSE	NULL
NULL	NULL	NULL	NULL

<b>a</b>	<b>NOT a</b>
TRUE	FALSE
FALSE	TRUE
NULL	NULL

The operators `AND` and `OR` are commutative, that is, you can switch the left and right operands without affecting the result. (However, it is not guaranteed that the left operand is evaluated before the right operand. See Section 4.2.15 for more information about the order of evaluation of subexpressions.)

## 9.2. Comparison Functions and Operators

The usual comparison operators are available, as shown in Table 9.1.

**Table 9.1. Comparison Operators**

Operator	Description
<i>datatype</i> < <i>datatype</i> → boolean	Less than
<i>datatype</i> > <i>datatype</i> → boolean	Greater than
<i>datatype</i> <= <i>datatype</i> → boolean	Less than or equal to
<i>datatype</i> >= <i>datatype</i> → boolean	Greater than or equal to
<i>datatype</i> = <i>datatype</i> → boolean	Equal
<i>datatype</i> <> <i>datatype</i> → boolean	Not equal
<i>datatype</i> != <i>datatype</i> → boolean	Not equal

### Note

<> is the standard SQL notation for “not equal”. != is an alias, which is converted to <> at a very early stage of parsing. Hence, it is not possible to implement != and <> operators that do different things.

These comparison operators are available for all built-in data types that have a natural ordering, including numeric, string, and date/time types. In addition, arrays, composite types, and ranges can be compared if their component data types are comparable.

It is usually possible to compare values of related data types as well; for example `integer > bigint` will work. Some cases of this sort are implemented directly by “cross-type” comparison operators, but if no such operator is available, the parser will coerce the less-general type to the more-general type and apply the latter's comparison operator.

As shown above, all comparison operators are binary operators that return values of type `boolean`. Thus, expressions like `1 < 2 < 3` are not valid (because there is no < operator to compare a Boolean value with 3). Use the `BETWEEN` predicates shown below to perform range tests.

There are also some comparison predicates, as shown in Table 9.2. These behave much like operators, but have special syntax mandated by the SQL standard.

**Table 9.2. Comparison Predicates**

Predicate	Description	Example(s)
<i>datatype</i> BETWEEN <i>datatype</i> AND <i>datatype</i> → boolean	Between (inclusive of the range endpoints).	<code>2 BETWEEN 1 AND 3 → t</code> <code>2 BETWEEN 3 AND 1 → f</code>
<i>datatype</i> NOT BETWEEN <i>datatype</i> AND <i>datatype</i> → boolean	Not between (the negation of BETWEEN).	<code>2 NOT BETWEEN 1 AND 3 → f</code>

<b>Predicate</b>	<b>Description</b>	<b>Example(s)</b>
<i>datatype</i> BETWEEN SYMMETRIC <i>datatype</i> AND <i>datatype</i> → boolean	Between, after sorting the two endpoint values.	2 BETWEEN SYMMETRIC 3 AND 1 → t
<i>datatype</i> NOT BETWEEN SYMMETRIC <i>datatype</i> AND <i>datatype</i> → boolean	Not between, after sorting the two endpoint values.	2 NOT BETWEEN SYMMETRIC 3 AND 1 → f
<i>datatype</i> IS DISTINCT FROM <i>datatype</i> → boolean	Not equal, treating null as a comparable value.	1 IS DISTINCT FROM NULL → t (rather than NULL) NULL IS DISTINCT FROM NULL → f (rather than NULL)
<i>datatype</i> IS NOT DISTINCT FROM <i>datatype</i> → boolean	Equal, treating null as a comparable value.	1 IS NOT DISTINCT FROM NULL → f (rather than NULL) NULL IS NOT DISTINCT FROM NULL → t (rather than NULL)
<i>datatype</i> IS NULL → boolean	Test whether value is null.	1.5 IS NULL → f
<i>datatype</i> IS NOT NULL → boolean	Test whether value is not null.	'null' IS NOT NULL → t
<i>datatype</i> ISNULL → boolean	Test whether value is null (nonstandard syntax).	
<i>datatype</i> NOTNULL → boolean	Test whether value is not null (nonstandard syntax).	
boolean IS TRUE → boolean	Test whether boolean expression yields true.	true IS TRUE → t NULL::boolean IS TRUE → f (rather than NULL)
boolean IS NOT TRUE → boolean	Test whether boolean expression yields false or unknown.	true IS NOT TRUE → f NULL::boolean IS NOT TRUE → t (rather than NULL)
boolean IS FALSE → boolean	Test whether boolean expression yields false.	true IS FALSE → f NULL::boolean IS FALSE → f (rather than NULL)
boolean IS NOT FALSE → boolean	Test whether boolean expression yields true or unknown.	true IS NOT FALSE → t NULL::boolean IS NOT FALSE → t (rather than NULL)

<b>Predicate</b>	<b>Description</b>	<b>Example(s)</b>
	boolean IS UNKNOWN → boolean Test whether boolean expression yields unknown.	true IS UNKNOWN → f NULL::boolean IS UNKNOWN → t (rather than NULL)
	boolean IS NOT UNKNOWN → boolean Test whether boolean expression yields true or false.	true IS NOT UNKNOWN → t NULL::boolean IS NOT UNKNOWN → f (rather than NULL)

The BETWEEN predicate simplifies range tests:

`a BETWEEN x AND y`

is equivalent to

`a >= x AND a <= y`

Notice that BETWEEN treats the endpoint values as included in the range. BETWEEN SYMMETRIC is like BETWEEN except there is no requirement that the argument to the left of AND be less than or equal to the argument on the right. If it is not, those two arguments are automatically swapped, so that a nonempty range is always implied.

The various variants of BETWEEN are implemented in terms of the ordinary comparison operators, and therefore will work for any data type(s) that can be compared.

### Note

The use of AND in the BETWEEN syntax creates an ambiguity with the use of AND as a logical operator. To resolve this, only a limited set of expression types are allowed as the second argument of a BETWEEN clause. If you need to write a more complex sub-expression in BETWEEN, write parentheses around the sub-expression.

Ordinary comparison operators yield null (signifying “unknown”), not true or false, when either input is null. For example, `7 = NULL` yields null, as does `7 <> NULL`. When this behavior is not suitable, use the IS [ NOT ] DISTINCT FROM predicates:

`a IS DISTINCT FROM b`

`a IS NOT DISTINCT FROM b`

For non-null inputs, IS DISTINCT FROM is the same as the <> operator. However, if both inputs are null it returns false, and if only one input is null it returns true. Similarly, IS NOT DISTINCT FROM is identical to = for non-null inputs, but it returns true when both inputs are null, and false when only one input is null. Thus, these predicates effectively act as though null were a normal data value, rather than “unknown”.

To check whether a value is or is not null, use the predicates:

`expression IS NULL`

`expression IS NOT NULL`

or the equivalent, but nonstandard, predicates:

```
expression ISNULL
expression NOTNULL
```

Do not write `expression = NULL` because NULL is not “equal to” NULL. (The null value represents an unknown value, and it is not known whether two unknown values are equal.)

**Tip**

Some applications might expect that `expression = NULL` returns true if `expression` evaluates to the null value. It is highly recommended that these applications be modified to comply with the SQL standard. However, if that cannot be done the `transform_null_equals` configuration variable is available. If it is enabled, LightDB will convert `x = NULL` clauses to `x IS NULL`.

If the `expression` is row-valued, then `IS NULL` is true when the row expression itself is null or when all the row's fields are null, while `IS NOT NULL` is true when the row expression itself is non-null and all the row's fields are non-null. Because of this behavior, `IS NULL` and `IS NOT NULL` do not always return inverse results for row-valued expressions; in particular, a row-valued expression that contains both null and non-null fields will return false for both tests. In some cases, it may be preferable to write `row IS DISTINCT FROM NULL` or `row IS NOT DISTINCT FROM NULL`, which will simply check whether the overall row value is null without any additional tests on the row fields.

Boolean values can also be tested using the predicates

```
boolean_expression IS TRUE
boolean_expression IS NOT TRUE
boolean_expression IS FALSE
boolean_expression IS NOT FALSE
boolean_expression IS UNKNOWN
boolean_expression IS NOT UNKNOWN
```

These will always return true or false, never a null value, even when the operand is null. A null input is treated as the logical value “unknown”. Notice that `IS UNKNOWN` and `IS NOT UNKNOWN` are effectively the same as `IS NULL` and `IS NOT NULL`, respectively, except that the input expression must be of Boolean type.

Some comparison-related functions are also available, as shown in Table 9.3.

**Table 9.3. Comparison Functions**

Function	Description	Example(s)
<code>num_nonnulls ( VARIADIC "any" )</code>	→ integer	Returns the number of non-null arguments. <code>num_nonnulls(1, NULL, 2) → 2</code>
<code>num_nulls ( VARIADIC "any" )</code>	→ integer	Returns the number of null arguments. <code>num_nulls(1, NULL, 2) → 1</code>



## 9.3. Mathematical Functions and Operators

Mathematical operators are provided for many LightDB types. For types without standard mathematical conventions (e.g., date/time types) we describe the actual behavior in subsequent sections.

Table 9.4 shows the mathematical operators that are available for the standard numeric types. Unless otherwise noted, operators shown as accepting *numeric\_type* are available for all the types `smallint`, `integer`, `bigint`, `numeric`, `real`, and `double precision`. Operators shown as accepting *integral\_type* are available for the types `smallint`, `integer`, and `bigint`. Except where noted, each form of an operator returns the same data type as its argument(s). Calls involving multiple argument data types, such as `integer + numeric`, are resolved by using the type appearing later in these lists.

**Table 9.4. Mathematical Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<i>numeric_type</i> + <i>numeric_type</i> → <i>numeric_type</i>	Addition	2 + 3 → 5
+ <i>numeric_type</i> → <i>numeric_type</i>	Unary plus (no operation)	+ 3.5 → 3.5
<i>numeric_type</i> - <i>numeric_type</i> → <i>numeric_type</i>	Subtraction	2 - 3 → -1
- <i>numeric_type</i> → <i>numeric_type</i>	Negation	- (-4) → 4
<i>numeric_type</i> * <i>numeric_type</i> → <i>numeric_type</i>	Multiplication	2 * 3 → 6
<i>numeric_type</i> / <i>numeric_type</i> → <i>numeric_type</i>	Division (for integral types, division truncates the result towards zero)	5.0 / 2 → 2.5000000000000000 5 / 2 → 2 (-5) / 2 → -2
<i>numeric_type</i> % <i>numeric_type</i> → <i>numeric_type</i>	Modulo (remainder); available for <code>smallint</code> , <code>integer</code> , <code>bigint</code> , and <code>numeric</code>	5 % 4 → 1
<code>numeric</code> ^ <code>numeric</code> → <code>numeric</code> <code>double precision</code> ^ <code>double precision</code> → <code>double precision</code>	Exponentiation	2 ^ 3 → 8 Unlike typical mathematical practice, multiple uses of ^ will associate left to right by default:

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
		$2 \wedge 3 \wedge 3 \rightarrow 512$ $2 \wedge (3 \wedge 3) \rightarrow 134217728$
	/ double precision $\rightarrow$ double precision Square root   / 25.0 $\rightarrow$ 5	
	/ double precision $\rightarrow$ double precision Cube root    / 64.0 $\rightarrow$ 4	
	bigint ! $\rightarrow$ numeric Factorial (deprecated, use factorial() instead) 5 ! $\rightarrow$ 120	
	!! bigint $\rightarrow$ numeric Factorial as a prefix operator (deprecated, use factorial() instead) !! 5 $\rightarrow$ 120	
	@ numeric_type $\rightarrow$ numeric_type Absolute value @ -5.0 $\rightarrow$ 5	
	integral_type & integral_type $\rightarrow$ integral_type Bitwise AND 91 & 15 $\rightarrow$ 11	
	integral_type   integral_type $\rightarrow$ integral_type Bitwise OR 32   3 $\rightarrow$ 35	
	integral_type # integral_type $\rightarrow$ integral_type Bitwise exclusive OR 17 # 5 $\rightarrow$ 20	
	~ integral_type $\rightarrow$ integral_type Bitwise NOT ~1 $\rightarrow$ -2	
	integral_type << integer $\rightarrow$ integral_type Bitwise shift left 1 << 4 $\rightarrow$ 16	
	integral_type >> integer $\rightarrow$ integral_type Bitwise shift right 8 >> 2 $\rightarrow$ 2	

Table 9.5 shows the available mathematical functions. Many of these functions are provided in multiple forms with different argument types. Except where noted, any given form of a function returns the same data type as its argument(s); cross-type cases are resolved in the same way as explained above for operators. The functions working with double precision data are mostly implemented on top of the host system's C library; accuracy and behavior in boundary cases can therefore vary depending on the host system.

**Table 9.5. Mathematical Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>abs( numeric_type )</code>	$\rightarrow$ <code>numeric_type</code> Absolute value	<code>abs(-17.4) → 17.4</code>
<code>cbrt( double precision )</code>	$\rightarrow$ <code>double precision</code> Cube root	<code>cbrt(64.0) → 4</code>
<code>ceil( numeric )</code>	$\rightarrow$ <code>numeric</code>	
<code>ceil( double precision )</code>	$\rightarrow$ <code>double precision</code> Nearest integer greater than or equal to argument	<code>ceil(42.2) → 43</code> <code>ceil(-42.8) → -42</code>
<code>ceiling( numeric )</code>	$\rightarrow$ <code>numeric</code>	
<code>ceiling( double precision )</code>	$\rightarrow$ <code>double precision</code> Nearest integer greater than or equal to argument (same as <code>ceil</code> )	<code>ceiling(95.3) → 96</code>
<code>degrees( double precision )</code>	$\rightarrow$ <code>double precision</code> Converts radians to degrees	<code>degrees(0.5) → 28.64788975654116</code>
<code>div( y numeric, x numeric )</code>	$\rightarrow$ <code>numeric</code> Integer quotient of $y/x$ (truncates towards zero)	<code>div(9,4) → 2</code>
<code>exp( numeric )</code>	$\rightarrow$ <code>numeric</code>	
<code>exp( double precision )</code>	$\rightarrow$ <code>double precision</code> Exponential (e raised to the given power)	<code>exp(1.0) → 2.7182818284590452</code>
<code>factorial( bigint )</code>	$\rightarrow$ <code>numeric</code> Factorial	<code>factorial(5) → 120</code>
<code>floor( numeric )</code>	$\rightarrow$ <code>numeric</code>	
<code>floor( double precision )</code>	$\rightarrow$ <code>double precision</code> Nearest integer less than or equal to argument	<code>floor(42.8) → 42</code> <code>floor(-42.8) → -43</code>
<code>gcd( numeric_type, numeric_type )</code>	$\rightarrow$ <code>numeric_type</code> Greatest common divisor (the largest positive number that divides both inputs with no remainder); returns 0 if both inputs are zero; available for <code>integer</code> , <code>bigint</code> , and <code>numeric</code>	<code>gcd(1071, 462) → 21</code>
<code>lcm( numeric_type, numeric_type )</code>	$\rightarrow$ <code>numeric_type</code>	

<b>Function</b>	<b>Description</b> <b>Example(s)</b>
	Least common multiple (the smallest strictly positive number that is an integral multiple of both inputs); returns 0 if either input is zero; available for <code>integer</code> , <code>bigint</code> , and <code>numeric</code> <code>lcm(1071, 462) → 23562</code>
	<code>ln(numeric) → numeric</code> <code>ln(double precision) → double precision</code> Natural logarithm <code>ln(2.0) → 0.6931471805599453</code>
	<code>log(numeric) → numeric</code> <code>log(double precision) → double precision</code> Base 10 logarithm <code>log(100) → 2</code>
	<code>log10(numeric) → numeric</code> <code>log10(double precision) → double precision</code> Base 10 logarithm (same as <code>log</code> ) <code>log10(1000) → 3</code>
	<code>log(b numeric, x numeric) → numeric</code> Logarithm of <code>x</code> to base <code>b</code> <code>log(2.0, 64.0) → 6.0000000000</code>
	<code>min_scale(numeric) → integer</code> Minimum scale (number of fractional decimal digits) needed to represent the supplied value precisely <code>min_scale(8.4100) → 2</code>
	<code>mod(y numeric_type, x numeric_type) → numeric_type</code> Remainder of <code>y/x</code> ; available for <code>smallint</code> , <code>integer</code> , <code>bigint</code> , and <code>numeric</code> <code>mod(9, 4) → 1</code>
	<code>pi() → double precision</code> Approximate value of $\pi$ <code>pi() → 3.141592653589793</code>
	<code>power(a numeric, b numeric) → numeric</code> <code>power(a double precision, b double precision) → double precision</code> <code>a</code> raised to the power of <code>b</code> <code>power(9, 3) → 729</code>
	<code>radians(double precision) → double precision</code> Converts degrees to radians <code>radians(45.0) → 0.7853981633974483</code>
	<code>round(numeric) → numeric</code> <code>round(double precision) → double precision</code> Rounds to nearest integer. For <code>numeric</code> , ties are broken by rounding away from zero. For <code>double precision</code> , the tie-breaking behavior is platform dependent, but “round to nearest even” is the most common rule.

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
		<code>round(42.4) → 42</code>
	<code>round(v numeric, s integer) → numeric</code> Rounds <i>v</i> to <i>s</i> decimal places. Ties are broken by rounding away from zero.	<code>round(42.4382, 2) → 42.44</code>
	<code>scale(numeric) → integer</code> Scale of the argument (the number of decimal digits in the fractional part)	<code>scale(8.4100) → 4</code>
	<code>sign(numeric) → numeric</code> <code>sign(double precision) → double precision</code> Sign of the argument (-1, 0, or +1)	<code>sign(-8.4) → -1</code>
	<code>sqrt(numeric) → numeric</code> <code>sqrt(double precision) → double precision</code> Square root	<code>sqrt(2) → 1.4142135623730951</code>
	<code>trim_scale(numeric) → numeric</code> Reduces the value's scale (number of fractional decimal digits) by removing trailing zeroes	<code>trim_scale(8.4100) → 8.41</code>
	<code>trunc(numeric) → numeric</code> <code>trunc(double precision) → double precision</code> Truncates to integer (towards zero)	<code>trunc(42.8) → 42</code> <code>trunc(-42.8) → -42</code>
	<code>trunc(v numeric, s integer) → numeric</code> Truncates <i>v</i> to <i>s</i> decimal places	<code>trunc(42.4382, 2) → 42.43</code>
	<code>width_bucket(operand numeric, low numeric, high numeric, count integer) → integer</code> <code>width_bucket(operand double precision, low double precision, high double precision, count integer) → integer</code> Returns the number of the bucket in which <i>operand</i> falls in a histogram having <i>count</i> equal-width buckets spanning the range <i>low</i> to <i>high</i> . Returns 0 or <i>count</i> +1 for an input outside that range.	<code>width_bucket(5.35, 0.024, 10.06, 5) → 3</code>
	<code>width_bucket(operand anyelement, thresholds anyarray) → integer</code> Returns the number of the bucket in which <i>operand</i> falls given an array listing the lower bounds of the buckets. Returns 0 for an input less than the first lower bound. <i>operand</i> and the array elements can be of any type having standard comparison operators. The <i>thresholds</i> array <i>must be sorted</i> , smallest first, or unexpected results will be obtained.	<code>width_bucket(now(), array['yesterday', 'today', 'tomorrow']::timestampz[]) → 2</code>

Table 9.6 shows functions for generating random numbers.

**Table 9.6. Random Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>random()</code>	→ double precision Returns a random value in the range $0.0 \leq x < 1.0$	<code>random()</code> → 0.897124072839091
<code>setseed(double precision)</code>	→ void Sets the seed for subsequent <code>random()</code> calls; argument must be between -1.0 and 1.0, inclusive	<code>setseed(0.12345)</code>

The `random()` function uses a simple linear congruential algorithm. It is fast but not suitable for cryptographic applications; see the `lcrypto` module for a more secure alternative. If `setseed()` is called, the series of results of subsequent `random()` calls in the current session can be repeated by re-issuing `setseed()` with the same argument. Without any prior `setseed()` call in the same session, the first `random()` call obtains a seed from a platform-dependent source of random bits.

Table 9.7 shows the available trigonometric functions. Each of these functions comes in two variants, one that measures angles in radians and one that measures angles in degrees.

**Table 9.7. Trigonometric Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>acos(double precision)</code>	→ double precision Inverse cosine, result in radians	<code>acos(1)</code> → 0
<code>acosd(double precision)</code>	→ double precision Inverse cosine, result in degrees	<code>acosd(0.5)</code> → 60
<code>asin(double precision)</code>	→ double precision Inverse sine, result in radians	<code>asin(1)</code> → 1.5707963267948966
<code>asind(double precision)</code>	→ double precision Inverse sine, result in degrees	<code>asind(0.5)</code> → 30
<code>atan(double precision)</code>	→ double precision Inverse tangent, result in radians	<code>atan(1)</code> → 0.7853981633974483
<code>atand(double precision)</code>	→ double precision Inverse tangent, result in degrees	<code>atand(1)</code> → 45
<code>atan2(y double precision, x double precision)</code>	→ double precision Inverse tangent of $y/x$ , result in radians	<code>atan2(1, 0)</code> → 1.5707963267948966

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>atan2d(y double precision, x double precision)</code>	→ double precision Inverse tangent of y/x, result in degrees	<code>atan2d(1, 0) → 90</code>
<code>cos(double precision)</code>	→ double precision Cosine, argument in radians	<code>cos(0) → 1</code>
<code>cosd(double precision)</code>	→ double precision Cosine, argument in degrees	<code>cosd(60) → 0.5</code>
<code>cot(double precision)</code>	→ double precision Cotangent, argument in radians	<code>cot(0.5) → 1.830487721712452</code>
<code>cotd(double precision)</code>	→ double precision Cotangent, argument in degrees	<code>cotd(45) → 1</code>
<code>sin(double precision)</code>	→ double precision Sine, argument in radians	<code>sin(1) → 0.8414709848078965</code>
<code>sind(double precision)</code>	→ double precision Sine, argument in degrees	<code>sind(30) → 0.5</code>
<code>tan(double precision)</code>	→ double precision Tangent, argument in radians	<code>tan(1) → 1.5574077246549023</code>
<code>tand(double precision)</code>	→ double precision Tangent, argument in degrees	<code>tand(45) → 1</code>

**Note**

Another way to work with angles measured in degrees is to use the unit transformation functions `radians()` and `degrees()` shown earlier. However, using the degree-based trigonometric functions is preferred, as that way avoids round-off error for special cases such as `sind(30)`.

Table 9.8 shows the available hyperbolic functions.

**Table 9.8. Hyperbolic Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>sinh(double precision)</code>	→ double precision	

Function	Description	Example(s)
	Hyperbolic sine	<code>sinh(1) → 1.1752011936438014</code>
	<code>cosh(double precision) → double precision</code> Hyperbolic cosine	<code>cosh(0) → 1</code>
	<code>tanh(double precision) → double precision</code> Hyperbolic tangent	<code>tanh(1) → 0.7615941559557649</code>
	<code>asinh(double precision) → double precision</code> Inverse hyperbolic sine	<code>asinh(1) → 0.881373587019543</code>
	<code>acosh(double precision) → double precision</code> Inverse hyperbolic cosine	<code>acosh(1) → 0</code>
	<code>atanh(double precision) → double precision</code> Inverse hyperbolic tangent	<code>atanh(0.5) → 0.5493061443340548</code>

## 9.4. String Functions and Operators

This section describes functions and operators for examining and manipulating string values. Strings in this context include values of the types `character`, `character varying`, and `text`. Except where noted, these functions and operators are declared to accept and return type `text`. They will interchangeably accept `character varying` arguments. Values of type `character` will be converted to `text` before the function or operator is applied, resulting in stripping any trailing spaces in the `character` value.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9.9. LightDB also provides versions of these functions that use the regular function invocation syntax (see Table 9.10).

### Note

Before LightDB 8.3, these functions would silently accept values of several non-string data types as well, due to the presence of implicit coercions from those data types to `text`. Those coercions have been removed because they frequently caused surprising behaviors. However, the string concatenation operator (`||`) still accepts non-string input, so long as at least one input is of a string type, as shown in Table 9.9. For other cases, insert an explicit coercion to `text` if you need to duplicate the previous behavior.

**Table 9.9. SQL String Functions and Operators**

Function/Operator	Description	Example(s)
		<code>text    text → text</code>



Function/Operator	Description	Example(s)
	Concatenates the two strings.	'Light'    'DB' → LightDB
text    anynonarray → text anynonarray    text → text	Converts the non-string input to text, then concatenates the two strings. (The non-string input cannot be of an array type, because that would create ambiguity with the array    operators. If you want to concatenate an array's text equivalent, cast it to text explicitly.)	'Value: '    42 → Value: 42
expr1    expr2 → text	The following data types can be used in expr1 and expr2: smallint, integer, bigint, real, double precision, numeric, time, time with time zone, timestamp, timestamp with time zone, date.	1    42 → 142
text IS [NOT] [form] NORMALIZED → boolean	Checks whether the string is in the specified Unicode normalization form. The optional form key word specifies the form: NFC (the default), NFD, NFKC, or NFKD. This expression can only be used when the server encoding is UTF8. Note that checking for normalization using this expression is often faster than normalizing possibly already normalized strings.	U&'\0061\0308bc' IS NFD NORMALIZED → t
bit_length(text) → integer	Returns number of bits in the string (8 times the octet_length).	bit_length('jose') → 32
char_length(text) → integer character_length(text) → integer	Returns number of characters in the string.	char_length('josé') → 4
lower(text) → text	Converts the string to all lower case, according to the rules of the database's locale.	lower('TOM') → tom
normalize(text [, form]) → text	Converts the string to the specified Unicode normalization form. The optional form key word specifies the form: NFC (the default), NFD, NFKC, or NFKD. This function can only be used when the server encoding is UTF8.	normalize(U&'\0061\0308bc', NFC) → U&'\00E4bc'
octet_length(text) → integer	Returns number of bytes in the string.	octet_length('josé') → 5 (if server encoding is UTF8)
octet_length(character) → integer	Returns number of bytes in the string. Since this version of the function accepts type character directly, it will not strip trailing spaces.	octet_length('abc ' :: character(4)) → 4

Function/Operator Description Example(s)
<p><code>overlay ( string text PLACING newsubstring text FROM start integer [ FOR count integer ] ) → text</code>  Replaces the substring of <i>string</i> that starts at the <i>start</i>'th character and extends for <i>count</i> characters with <i>newsubstring</i>. If <i>count</i> is omitted, it defaults to the length of <i>newsubstring</i>.</p> <p><code>overlay('Txxxxas' placing 'hom' from 2 for 4) → Thomas</code></p>
<p><code>position ( substring text IN string text ) → integer</code>  Returns first starting index of the specified <i>substring</i> within <i>string</i>, or zero if it's not present.</p> <p><code>position('om' in 'Thomas') → 3</code></p>
<p><code>substring ( string text [ FROM start integer ] [ FOR count integer ] ) → text</code>  Extracts the substring of <i>string</i> starting at the <i>start</i>'th character if that is specified, and stopping after <i>count</i> characters if that is specified. Provide at least one of <i>start</i> and <i>count</i>.</p> <p><code>substring('Thomas' from 2 for 3) → hom</code>  <code>substring('Thomas' from 3) → omas</code>  <code>substring('Thomas' for 2) → Th</code></p>
<p><code>substring ( string text FROM pattern text ) → text</code>  Extracts the first substring matching POSIX regular expression; see Section 9.7.3.</p> <p><code>substring('Thomas' from '...\$') → mas</code></p>
<p><code>substring ( string text FROM pattern text FOR escape text ) → text</code>  Extracts the first substring matching SQL regular expression; see Section 9.7.2.</p> <p><code>substring('Thomas' from '%#o_a#_' for '#') → oma</code></p>
<p><code>trim ( [ LEADING   TRAILING   BOTH ] [ characters text ] FROM string text ) → text</code>  Removes the longest string containing only characters in <i>characters</i> (a space by default) from the start, end, or both ends (BOTH is the default) of <i>string</i>.</p> <p><code>trim(both 'xyz' from 'yxTomxx') → Tom</code></p>
<p><code>trim ( [ LEADING   TRAILING   BOTH ] [ FROM ] string text [ , characters text ] ) → text</code>  This is a non-standard syntax for <code>trim()</code>.</p> <p><code>trim(both from 'yxTomxx', 'xyz') → Tom</code></p>
<p><code>upper ( text ) → text</code>  Converts the string to all upper case, according to the rules of the database's locale.</p> <p><code>upper('tom') → TOM</code></p>

Additional string manipulation functions are available and are listed in Table 9.10. Some of them are used internally to implement the SQL-standard string functions listed in Table 9.9.

**Table 9.10. Other String Functions**

Function	Description	Example(s)
<code>ascii ( text )</code>	→ integer Returns the numeric code of the first character of the argument. In UTF8 encoding, returns the Unicode code point of the character. In other multibyte encodings, the argument must be an ASCII character.	<code>ascii ( 'x' )</code> → 120
<code>btrim ( string text [, characters text ] )</code>	→ text Removes the longest string containing only characters in <i>characters</i> (a space by default) from the start and end of <i>string</i> .	<code>btrim ( 'xyxtrimyyx', 'xyz' )</code> → trim
<code>chr ( integer )</code>	→ text Returns the character with the given code. In UTF8 encoding the argument is treated as a Unicode code point. In other multibyte encodings the argument must designate an ASCII character. Lightdb 23.3 introduced a new database level GUC parameter <code>lightdb_ascii_zero_store_value</code> . In Oracle or Mysql compatible mode, if <code>lightdb_ascii_zero_store_value</code> is set to a non-zero ASCII value, <code>chr ( 0 )</code> return a character of ASCII value <code>lightdb_ascii_zero_store_value</code> , in other case (including compatible mode not in Oracle and not in Mysql) <code>chr ( 0 )</code> is disallowed because text data types cannot store that character. For more information about GUC <code>lightdb_ascii_zero_store_value</code> , See <code>lightdb_ascii_zero_store_value</code>	<code>chr ( 65 )</code> → A  <code>chr ( 0 )</code> → \x14 (If compatible mode is Oracle or Mysql, and <code>lightdb_ascii_zero_store_value</code> is set to 20)
<code>concat ( val1 "any" [, val2 "any" [, ...]] )</code>	→ text Concatenates the text representations of all the arguments. NULL arguments are ignored.	<code>concat ( 'abcde', 2, NULL, 22 )</code> → abcde222
<code>concat_ws ( sep text, val1 "any" [, val2 "any" [, ...]] )</code>	→ text Concatenates all but the first argument, with separators. The first argument is used as the separator string, and should not be NULL. Other NULL arguments are ignored.	<code>concat_ws ( ', ', 'abcde', 2, NULL, 22 )</code> → abcde,2,22
<code>format ( formatstr text [, formatarg "any" [, ...]] )</code>	→ text Formats arguments according to a format string; see Section 9.4.1. This function is similar to the C function <code>sprintf</code> .	<code>format ( 'Hello %s, %1\$s', 'World' )</code> → Hello World, World
<code>initcap ( text )</code>	→ text Converts the first letter of each word to upper case and the rest to lower case. Words are sequences of alphanumeric characters separated by non-alphanumeric characters.	<code>initcap ( 'hi THOMAS' )</code> → Hi Thomas
<code>left ( string text, n integer )</code>	→ text Returns first <i>n</i> characters in the string, or when <i>n</i> is negative, returns all but last $ n $ characters.	<code>left ( 'abcde', 2 )</code> → ab
<code>length ( text )</code>	→ integer	

Function
<p><b>Description</b> <b>Example(s)</b></p> <p>Returns the number of characters in the string.</p> <pre>length('jose') → 4</pre>
<p><code>lpad(string text, length integer [, fill text]) → text</code>  Extends the <i>string</i> to length <i>length</i> by prepending the characters <i>fill</i> (a space by default). If the <i>string</i> is already longer than <i>length</i> then it is truncated (on the right).</p> <pre>lpad('hi', 5, 'xy') → xyxhi</pre>
<p><code>ltrim(string text [, characters text]) → text</code>  Removes the longest string containing only characters in <i>characters</i> (a space by default) from the start of <i>string</i>.</p> <pre>ltrim('zzytest', 'xyz') → test</pre>
<p><code>md5(text) → text</code>  Computes the MD5 hash of the argument, with the result written in hexadecimal.</p> <pre>md5('abc') → 900150983cd24fb0d6963f7d28e17f72</pre>
<p><code>parse_ident(qualified_identifier text [, strict_mode boolean DEFAULT true]) → text[]</code>  Splits <i>qualified_identifier</i> into an array of identifiers, removing any quoting of individual identifiers. By default, extra characters after the last identifier are considered an error; but if the second parameter is <i>false</i>, then such extra characters are ignored. (This behavior is useful for parsing names for objects like functions.) Note that this function does not truncate over-length identifiers. If you want truncation you can cast the result to <code>name[]</code>.</p> <pre>parse_ident('"SomeSchema".someTable') → {SomeSchema, sometable}</pre>
<p><code>pg_client_encoding() → name</code>  Returns current client encoding name.</p> <pre>pg_client_encoding() → UTF8</pre>
<p><code>quote_ident(text) → text</code>  Returns the given string suitably quoted to be used as an identifier in an SQL statement string. Quotes are added only if necessary (i.e., if the string contains non-identifier characters or would be case-folded). Embedded quotes are properly doubled. See also Example 41.1.</p> <pre>quote_ident('Foo bar') → "Foo bar"</pre>
<p><code>quote_literal(text) → text</code>  Returns the given string suitably quoted to be used as a string literal in an SQL statement string. Embedded single-quotes and backslashes are properly doubled. Note that <code>quote_literal</code> returns null on null input; if the argument might be null, <code>quote_nullable</code> is often more suitable. See also Example 41.1.</p> <pre>quote_literal(E'O\'Reilly') → 'O\'Reilly'</pre>
<p><code>quote_literal(anyelement) → text</code>  Converts the given value to text and then quotes it as a literal. Embedded single-quotes and backslashes are properly doubled.</p> <pre>quote_literal(42.5) → '42.5'</pre>
<p><code>quote_nullable(text) → text</code></p>

Function	Description
<code>quote_nullable</code>	Returns the given string suitably quoted to be used as a string literal in an SQL statement string; or, if the argument is null, returns NULL. Embedded single-quotes and backslashes are properly doubled. See also Example 41.1. <code>quote_nullable(NULL) → NULL</code>
<code>quote_nullable</code>	<code>quote_nullable( anyelement ) → text</code> Converts the given value to text and then quotes it as a literal; or, if the argument is null, returns NULL. Embedded single-quotes and backslashes are properly doubled. <code>quote_nullable( 42.5 ) → '42.5'</code>
<code>regexp_match</code>	<code>regexp_match( string text, pattern text [, flags text ] ) → text [ ]</code> Returns captured substrings resulting from the first match of a POSIX regular expression to the <i>string</i> ; see Section 9.7.3. <code>regexp_match( 'foobarbequebaz', '(bar)(beque)' ) → {bar,beque}</code>
<code>regexp_matches</code>	<code>regexp_matches( string text, pattern text [, flags text ] ) → set of text [ ]</code> Returns captured substrings resulting from the first match of a POSIX regular expression to the <i>string</i> , or multiple matches if the <i>g</i> flag is used; see Section 9.7.3. <code>regexp_matches( 'foobarbequebaz', 'ba.', 'g' ) →</code>  <code>{bar}</code> <code>{baz}</code>
<code>regexp_replace</code>	<code>regexp_replace( string text, pattern text, replacement text [, flags text ] ) → text</code> Replaces substrings resulting from the first match of a POSIX regular expression, or multiple substring matches if the <i>g</i> flag is used; see Section 9.7.3. <code>regexp_replace( 'Thomas', '[mN]a.', 'M' ) → ThM</code>
<code>regexp_split_to_array</code>	<code>regexp_split_to_array( string text, pattern text [, flags text ] ) → text [ ]</code> Splits <i>string</i> using a POSIX regular expression as the delimiter; see Section 9.7.3. <code>regexp_split_to_array( 'hello world', '\s+' ) → {hello,world}</code>
<code>regexp_split_to_table</code>	<code>regexp_split_to_table( string text, pattern text [, flags text ] ) → set of text</code> Splits <i>string</i> using a POSIX regular expression as the delimiter; see Section 9.7.3. <code>regexp_split_to_table( 'hello world', '\s+' ) →</code>  <code>hello</code> <code>world</code>
<code>repeat</code>	<code>repeat( string text, number integer ) → text</code> Repeats <i>string</i> the specified <i>number</i> of times. <code>repeat( 'Pg', 4 ) → PgPgPgPg</code>
<code>replace</code>	<code>replace( string text, from text, to text ) → text</code> Replaces all occurrences in <i>string</i> of substring <i>from</i> with substring <i>to</i> . <code>replace( 'abcdefabcdef', 'cd', 'XX' ) → abXXefabXXef</code>
<code>reverse</code>	<code>reverse( text ) → text</code>

Function	Description	Example(s)
	Reverses the order of the characters in the string.	<code>reverse('abcde') → edcba</code>
	<code>right(string text, n integer) → text</code> Returns last <i>n</i> characters in the string, or when <i>n</i> is negative, returns all but first $ n $ characters.	<code>right('abcde', 2) → de</code>
	<code>rpad(string text, length integer [, fill text]) → text</code> Extends the <i>string</i> to length <i>length</i> by appending the characters <i>fill</i> (a space by default). If the <i>string</i> is already longer than <i>length</i> then it is truncated.	<code>rpad('hi', 5, 'xy') → hixyx</code>
	<code>rtrim(string text [, characters text]) → text</code> Removes the longest string containing only characters in <i>characters</i> (a space by default) from the end of <i>string</i> .	<code>rtrim('testxxxz', 'xyz') → test</code>
	<code>split_part(string text, delimiter text, n integer) → text</code> Splits <i>string</i> at occurrences of <i>delimiter</i> and returns the <i>n</i> 'th field (counting from one).	<code>split_part('abc~@~def~@~ghi', '~@~', 2) → def</code>
	<code>strpos(string text, substring text) → integer</code> Returns first starting index of the specified <i>substring</i> within <i>string</i> , or zero if it's not present. (Same as <code>position(substring in string)</code> , but note the reversed argument order.)	<code>strpos('high', 'ig') → 2</code>
	<code>substr(string text, start integer [, count integer]) → text</code> Extracts the substring of <i>string</i> starting at the <i>start</i> 'th character, and extending for <i>count</i> characters if that is specified. (Same as <code>substring(string from start for count)</code> .)	<code>substr('alphabet', 3) → phabet</code> <code>substr('alphabet', 3, 2) → ph</code>
	<code>starts_with(string text, prefix text) → boolean</code> Returns true if <i>string</i> starts with <i>prefix</i> .	<code>starts_with('alphabet', 'alph') → t</code>
	<code>to_ascii(string text) → text</code> <code>to_ascii(string text, encoding name) → text</code> <code>to_ascii(string text, encoding integer) → text</code> Converts <i>string</i> to ASCII from another encoding, which may be identified by name or number. If <i>encoding</i> is omitted the database encoding is assumed (which in practice is the only useful case). The conversion consists primarily of dropping accents. Conversion is only supported from LATIN1, LATIN2, LATIN9, and WIN1250 encodings. (See the unaccent module for another, more flexible solution.)	<code>to_ascii('Karél') → Karel</code>
	<code>to_hex(integer) → text</code> <code>to_hex(bigint) → text</code>	

Function
<p><b>Description</b> <b>Example(s)</b></p> <p>Converts the number to its equivalent hexadecimal representation.</p> <pre>to_hex(2147483647) → 7fffffff</pre>
<pre>translate(<i>string</i> text, <i>from</i> text, <i>to</i> text) → text</pre> <p>Replaces each character in <i>string</i> that matches a character in the <i>from</i> set with the corresponding character in the <i>to</i> set. If <i>from</i> is longer than <i>to</i>, occurrences of the extra characters in <i>from</i> are deleted.</p> <pre>translate('12345', '143', 'ax') → a2x5</pre>

The `concat`, `concat_ws` and `format` functions are variadic, so it is possible to pass the values to be concatenated or formatted as an array marked with the `VARIADIC` keyword (see Section 36.5.5). The array's elements are treated as if they were separate ordinary arguments to the function. If the variadic array argument is `NULL`, `concat` and `concat_ws` return `NULL`, but `format` treats a `NULL` as a zero-element array.

See also the aggregate function `string_agg` in Section 9.21, and the functions for converting between strings and the `bytea` type in Table 9.13.

## 9.4.1. format

The function `format` produces output formatted according to a format string, in a style similar to the C function `sprintf`.

```
format(formatstr text [, formatarg "any" [, ...] ])
```

*formatstr* is a format string that specifies how the result should be formatted. Text in the format string is copied directly to the result, except where *format specifiers* are used. Format specifiers act as placeholders in the string, defining how subsequent function arguments should be formatted and inserted into the result. Each *formatarg* argument is converted to text according to the usual output rules for its data type, and then formatted and inserted into the result string according to the format specifier(s).

Format specifiers are introduced by a `%` character and have the form

```
%[position][flags][width]type
```

where the component fields are:

*position* (optional)

A string of the form `n$` where `n` is the index of the argument to print. Index 1 means the first argument after *formatstr*. If the *position* is omitted, the default is to use the next argument in sequence.

*flags* (optional)

Additional options controlling how the format specifier's output is formatted. Currently the only supported flag is a minus sign (`-`) which will cause the format specifier's output to be left-justified. This has no effect unless the *width* field is also specified.

*width* (optional)

Specifies the *minimum* number of characters to use to display the format specifier's output. The output is padded on the left or right (depending on the `-` flag) with spaces as needed to fill the width. A too-small width does not cause truncation of the output, but is simply ignored. The width

may be specified using any of the following: a positive integer; an asterisk (\*) to use the next function argument as the width; or a string of the form \*n\$ to use the *n*th function argument as the width.

If the width comes from a function argument, that argument is consumed before the argument that is used for the format specifier's value. If the width argument is negative, the result is left aligned (as if the - flag had been specified) within a field of length `abs(width)`.

*type* (required)

The type of format conversion to use to produce the format specifier's output. The following types are supported:

- `s` formats the argument value as a simple string. A null value is treated as an empty string.
- `I` treats the argument value as an SQL identifier, double-quoting it if necessary. It is an error for the value to be null (equivalent to `quote_ident`).
- `L` quotes the argument value as an SQL literal. A null value is displayed as the string `NULL`, without quotes (equivalent to `quote_nullable`).

In addition to the format specifiers described above, the special sequence `%%` may be used to output a literal `%` character.

Here are some examples of the basic format conversions:

```
SELECT format('Hello %s', 'World');
Result: Hello World
```

```
SELECT format('Testing %s, %s, %s, %%', 'one', 'two', 'three');
Result: Testing one, two, three, %
```

```
SELECT format('INSERT INTO %I VALUES(%L)', 'Foo bar', E'O
\'Reilly');
Result: INSERT INTO "Foo bar" VALUES('O'Reilly')
```

```
SELECT format('INSERT INTO %I VALUES(%L)', 'locations', 'C:\Program
Files');
Result: INSERT INTO locations VALUES('C:\Program Files')
```

Here are examples using *width* fields and the - flag:

```
SELECT format('|%10s|', 'foo');
Result: |          foo|
```

```
SELECT format('|%-10s|', 'foo');
Result: |foo          |
```

```
SELECT format('|%*s|', 10, 'foo');
Result: |          foo|
```

```
SELECT format('|%*s|', -10, 'foo');
Result: |foo          |
```

```
SELECT format('|%-*s|', 10, 'foo');
Result: |foo          |
```

```
SELECT format('|%-*s|', -10, 'foo');
Result: |foo          |
```



These examples show use of *position* fields:

```
SELECT format('Testing %3$s, %2$s, %1$s', 'one', 'two', 'three');
Result: Testing three, two, one
```

```
SELECT format('|%*2$s|', 'foo', 10, 'bar');
Result: |          bar|
```

```
SELECT format('|%1$*2$s|', 'foo', 10, 'bar');
Result: |          foo|
```

Unlike the standard C function `sprintf`, LightDB's `format` function allows format specifiers with and without *position* fields to be mixed in the same format string. A format specifier without a *position* field always uses the next argument after the last argument consumed. In addition, the `format` function does not require all function arguments to be used in the format string. For example:

```
SELECT format('Testing %3$s, %2$s, %s', 'one', 'two', 'three');
Result: Testing three, two, three
```

The `%I` and `%L` format specifiers are particularly useful for safely constructing dynamic SQL statements. See Example 41.1.

## 9.5. Binary String Functions and Operators

This section describes functions and operators for examining and manipulating binary strings, that is values of type `bytea`. Many of these are equivalent, in purpose and syntax, to the text-string functions described in the previous section.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9.11. LightDB also provides versions of these functions that use the regular function invocation syntax (see Table 9.12).

**Table 9.11. SQL Binary String Functions and Operators**

Function/Operator Description Example(s)
<code>bytea    bytea → bytea</code> Concatenates the two binary strings. <code>'\x123456'::bytea    '\x789a00bcde'::bytea →                      \x123456789a00bcde</code>
<code>bit_length(bytea) → integer</code> Returns number of bits in the binary string (8 times the <code>octet_length</code> ). <code>bit_length('\x123456'::bytea) → 24</code>
<code>octet_length(bytea) → integer</code> Returns number of bytes in the binary string. <code>octet_length('\x123456'::bytea) → 3</code>
<code>overlay(bytes bytea PLACING newsubstring bytea FROM start integer [FOR count integer]) → bytea</code> Replaces the substring of <i>bytes</i> that starts at the <i>start</i> 'th byte and extends for <i>count</i> bytes with <i>newsubstring</i> . If <i>count</i> is omitted, it defaults to the length of <i>newsubstring</i> .

Function/Operator	Description	Example(s)
		<code>overlay('\x1234567890'::bytea placing '\002\003'::bytea from 2 for 3) → \x12020390</code>
	<code>position(substring bytea IN bytes bytea) → integer</code> Returns first starting index of the specified <i>substring</i> within <i>bytes</i> , or zero if it's not present.	<code>position('\x5678'::bytea in '\x1234567890'::bytea) → 3</code>
	<code>substring(bytes bytea [ FROM start integer ] [ FOR count integer ]) → bytea</code> Extracts the substring of <i>bytes</i> starting at the <i>start</i> 'th byte if that is specified, and stopping after <i>count</i> bytes if that is specified. Provide at least one of <i>start</i> and <i>count</i> .	<code>substring('\x1234567890'::bytea from 3 for 2) → \x5678</code>
	<code>trim([ BOTH ] bytesremoved bytea FROM bytes bytea) → bytea</code> Removes the longest string containing only bytes appearing in <i>bytesremoved</i> from the start and end of <i>bytes</i> .	<code>trim('\x9012'::bytea from '\x1234567890'::bytea) → \x345678</code>
	<code>trim([ BOTH ] [ FROM ] bytes bytea, bytesremoved bytea) → bytea</code> This is a non-standard syntax for <code>trim()</code> .	<code>trim(both from '\x1234567890'::bytea, '\x9012'::bytea) → \x345678</code>

Additional binary string manipulation functions are available and are listed in Table 9.12. Some of them are used internally to implement the SQL-standard string functions listed in Table 9.11.

**Table 9.12. Other Binary String Functions**

Function	Description	Example(s)
	<code>btrim(bytes bytea, bytesremoved bytea) → bytea</code> Removes the longest string containing only bytes appearing in <i>bytesremoved</i> from the start and end of <i>bytes</i> .	<code>btrim('\x1234567890'::bytea, '\x9012'::bytea) → \x345678</code>
	<code>get_bit(bytes bytea, n bigint) → integer</code> Extracts <i>n</i> 'th bit from binary string.	<code>get_bit('\x1234567890'::bytea, 30) → 1</code>
	<code>get_byte(bytes bytea, n integer) → integer</code> Extracts <i>n</i> 'th byte from binary string.	<code>get_byte('\x1234567890'::bytea, 4) → 144</code>
	<code>length(bytea) → integer</code> Returns the number of bytes in the binary string.	<code>length('\x1234567890'::bytea) → 5</code>
	<code>length(bytes bytea, encoding name) → integer</code> Returns the number of characters in the binary string, assuming that it is text in the given <i>encoding</i> .	

Function	Description	Example(s)
		<code>length('jose'::bytea, 'UTF8') → 4</code>
<code>md5(bytea) → text</code>	Computes the MD5 hash of the binary string, with the result written in hexadecimal.	<code>md5('Th\000omas'::bytea) → 8ab2d3c9689aaf18b4958c334c82d8b1</code>
<code>set_bit(bytes bytea, n bigint, newvalue integer) → bytea</code>	Sets <i>n</i> 'th bit in binary string to <i>newvalue</i> .	<code>set_bit('\x1234567890'::bytea, 30, 0) → \x1234563890</code>
<code>set_byte(bytes bytea, n integer, newvalue integer) → bytea</code>	Sets <i>n</i> 'th byte in binary string to <i>newvalue</i> .	<code>set_byte('\x1234567890'::bytea, 4, 64) → \x1234567840</code>
<code>sha224(bytea) → bytea</code>	Computes the SHA-224 hash of the binary string.	<code>sha224('abc'::bytea) → \x23097d223405d8228642a477bda255b32aadfce4bda0b3f7e36c9da7</code>
<code>sha256(bytea) → bytea</code>	Computes the SHA-256 hash of the binary string.	<code>sha256('abc'::bytea) → \xba7816bf8f01cfea414140de5dae2223b00361a396177a9cb410ff61f20015ad</code>
<code>sha384(bytea) → bytea</code>	Computes the SHA-384 hash of the binary string.	<code>sha384('abc'::bytea) → \xcb00753f45a35e8bb5a03d699ac65007272c32ab0eded1631a8b605a43ff5bed8086072ba1e7cc2358baeca134c825a7</code>
<code>sha512(bytea) → bytea</code>	Computes the SHA-512 hash of the binary string.	<code>sha512('abc'::bytea) → \xddaf35a193617abacc417349ae20413112e6fa4e89a97ea20a9eeee64b55d39a2192992a274fc1a836ba3c23a3feebbd454d4423643ce80e2a9ac94fa54ca49f</code>
<code>substr(bytes bytea, start integer [, count integer]) → bytea</code>	Extracts the substring of <i>bytes</i> starting at the <i>start</i> 'th byte, and extending for <i>count</i> bytes if that is specified. (Same as <code>substring(bytes from start for count)</code> .)	<code>substr('\x1234567890'::bytea, 3, 2) → \x5678</code>

Functions `get_byte` and `set_byte` number the first byte of a binary string as byte 0. Functions `get_bit` and `set_bit` number bits from the right within each byte; for example bit 0 is the least significant bit of the first byte, and bit 15 is the most significant bit of the second byte.

For historical reasons, the function `md5` returns a hex-encoded value of type `text` whereas the SHA-2 functions return type `bytea`. Use the functions `encode` and `decode` to convert between the two. For example write `encode(sha256('abc'), 'hex')` to get a hex-encoded text representation, or `decode(md5('abc'), 'hex')` to get a `bytea` value.

Functions for converting strings between different character sets (encodings), and for representing arbitrary binary data in textual form, are shown in Table 9.13. For these functions, an argument or

result of type `text` is expressed in the database's default encoding, while arguments or results of type `bytea` are in an encoding named by another argument.

**Table 9.13. Text/Binary String Conversion Functions**

Function	Description	Example(s)
<code>convert</code>	<code>( bytes bytea, src_encoding name, dest_encoding name ) → bytea</code> Converts a binary string representing text in encoding <code>src_encoding</code> to a binary string in encoding <code>dest_encoding</code> (see Section 21.3.4 for available conversions).	<code>convert('text_in_utf8', 'UTF8', 'LATIN1') →</code> <code>\x746578745f696e5f75746638</code>
<code>convert_from</code>	<code>( bytes bytea, src_encoding name ) → text</code> Converts a binary string representing text in encoding <code>src_encoding</code> to text in the database encoding (see Section 21.3.4 for available conversions).	<code>convert_from('text_in_utf8', 'UTF8') → text_in_utf8</code>
<code>convert_to</code>	<code>( string text, dest_encoding name ) → bytea</code> Converts a text string (in the database encoding) to a binary string encoded in encoding <code>dest_encoding</code> (see Section 21.3.4 for available conversions).	<code>convert_to('some_text', 'UTF8') → \x736f6d655f74657874</code>
<code>encode</code>	<code>( bytes bytea, format text ) → text</code> Encodes binary data into a textual representation; supported <code>format</code> values are: <code>base64</code> , <code>escape</code> , <code>hex</code> .	<code>encode('123\000\001', 'base64') → MTIzAAE=</code>
<code>decode</code>	<code>( string text, format text ) → bytea</code> Decodes binary data from a textual representation; supported <code>format</code> values are the same as for <code>encode</code> .	<code>decode('MTIzAAE=', 'base64') → \x3132330001</code>

The `encode` and `decode` functions support the following textual formats:

**base64**

The `base64` format is that of RFC 2045 Section 6.8<sup>1</sup>. As per the RFC, encoded lines are broken at 76 characters. However instead of the MIME CRLF end-of-line marker, only a newline is used for end-of-line. The `decode` function ignores carriage-return, newline, space, and tab characters. Otherwise, an error is raised when `decode` is supplied invalid base64 data — including when trailing padding is incorrect.

**escape**

The `escape` format converts zero bytes and bytes with the high bit set into octal escape sequences (`\nnn`), and it doubles backslashes. Other byte values are represented literally. The `decode` function will raise an error if a backslash is not followed by either a second backslash or three octal digits; it accepts other byte values unchanged.

**hex**

The `hex` format represents each 4 bits of data as one hexadecimal digit, 0 through `f`, writing the higher-order digit of each byte first. The `encode` function outputs the `a-f` hex digits in lower case. Because the smallest unit of data is 8 bits, there are always an even number of characters

<sup>1</sup> <https://tools.ietf.org/html/rfc2045#section-6.8>

returned by `encode`. The `decode` function accepts the a-f characters in either upper or lower case. An error is raised when `decode` is given invalid hex data — including when given an odd number of characters.

See also the aggregate function `string_agg` in Section 9.21 and the large object functions in Section 33.4.

## 9.6. Bit String Functions and Operators

This section describes functions and operators for examining and manipulating bit strings, that is values of the types `bit` and `bit_varying`. (While only type `bit` is mentioned in these tables, values of type `bit_varying` can be used interchangeably.) Bit strings support the usual comparison operators shown in Table 9.1, as well as the operators shown in Table 9.14.

**Table 9.14. Bit String Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<code>bit    bit → bit</code>	Concatenation	<code>B'10001'    B'011' → 10001011</code>
<code>bit &amp; bit → bit</code>	Bitwise AND (inputs must be of equal length)	<code>B'10001' &amp; B'01101' → 00001</code>
<code>bit   bit → bit</code>	Bitwise OR (inputs must be of equal length)	<code>B'10001'   B'01101' → 11101</code>
<code>bit # bit → bit</code>	Bitwise exclusive OR (inputs must be of equal length)	<code>B'10001' # B'01101' → 11100</code>
<code>~ bit → bit</code>	Bitwise NOT	<code>~ B'10001' → 01110</code>
<code>bit &lt;&lt; integer → bit</code>	Bitwise shift left (string length is preserved)	<code>B'10001' &lt;&lt; 3 → 01000</code>
<code>bit &gt;&gt; integer → bit</code>	Bitwise shift right (string length is preserved)	<code>B'10001' &gt;&gt; 2 → 00100</code>

Some of the functions available for binary strings are also available for bit strings, as shown in Table 9.15.

**Table 9.15. Bit String Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>bit_length(bit) → integer</code>		

Function	Description	Example(s)
	Returns number of bits in the bit string.	<code>bit_length(B'10111') → 5</code>
	<code>length(bit) → integer</code> Returns number of bits in the bit string.	<code>length(B'10111') → 5</code>
	<code>octet_length(bit) → integer</code> Returns number of bytes in the bit string.	<code>octet_length(B'101111011') → 2</code>
	<code>overlay(bits bit PLACING newsubstring bit FROM start integer [ FOR count integer ]) → bit</code> Replaces the substring of <i>bits</i> that starts at the <i>start</i> 'th bit and extends for <i>count</i> bits with <i>newsubstring</i> . If <i>count</i> is omitted, it defaults to the length of <i>newsubstring</i> .	<code>overlay(B'01010101010101010' placing B'11111' from 2 for 3) → 01111101010101010</code>
	<code>position(substring bit IN bits bit) → integer</code> Returns first starting index of the specified <i>substring</i> within <i>bits</i> , or zero if it's not present.	<code>position(B'010' in B'000001101011') → 8</code>
	<code>substring(bits bit [ FROM start integer ] [ FOR count integer ]) → bit</code> Extracts the substring of <i>bits</i> starting at the <i>start</i> 'th bit if that is specified, and stopping after <i>count</i> bits if that is specified. Provide at least one of <i>start</i> and <i>count</i> .	<code>substring(B'110010111111' from 3 for 2) → 00</code>
	<code>get_bit(bits bit, n integer) → integer</code> Extracts <i>n</i> 'th bit from bit string; the first (leftmost) bit is bit 0.	<code>get_bit(B'101010101010101010', 6) → 1</code>
	<code>set_bit(bits bit, n integer, newvalue integer) → bit</code> Sets <i>n</i> 'th bit in bit string to <i>newvalue</i> ; the first (leftmost) bit is bit 0.	<code>set_bit(B'101010101010101010', 6, 0) → 101010001010101010</code>

In addition, it is possible to cast integral values to and from type `bit`. Casting an integer to `bit(n)` copies the rightmost *n* bits. Casting an integer to a bit string width wider than the integer itself will sign-extend on the left. Some examples:

```

44::bit(10)           0000101100
44::bit(3)           100
cast(-44 as bit(12)) 111111010100
'1110'::bit(4)::integer 14

```

Note that casting to just “bit” means casting to `bit(1)`, and so will deliver only the least significant bit of the integer.

## 9.7. Pattern Matching

There are three separate approaches to pattern matching provided by LightDB: the traditional SQL `LIKE` operator, the more recent `SIMILAR TO` operator (added in SQL:1999), and POSIX-style

regular expressions. Aside from the basic “does this string match this pattern?” operators, functions are available to extract or replace matching substrings and to split a string at matching locations.

**Tip**

If you have pattern matching needs that go beyond this, consider writing a user-defined function in Perl or Tcl.

**Caution**

While most regular-expression searches can be executed very quickly, regular expressions can be contrived that take arbitrary amounts of time and memory to process. Be wary of accepting regular-expression search patterns from hostile sources. If you must do so, it is advisable to impose a statement timeout.

Searches using `SIMILAR TO` patterns have the same security hazards, since `SIMILAR TO` provides many of the same capabilities as POSIX-style regular expressions.

`LIKE` searches, being much simpler than the other two options, are safer to use with possibly-hostile pattern sources.

The pattern matching operators of all three kinds do not support nondeterministic collations. If required, apply a different collation to the expression to work around this limitation.

## 9.7.1. LIKE

```
string LIKE pattern [ESCAPE escape-character]  
string NOT LIKE pattern [ESCAPE escape-character]
```

The `LIKE` expression returns true if the *string* matches the supplied *pattern*. (As expected, the `NOT LIKE` expression returns false if `LIKE` returns true, and vice versa. An equivalent expression is `NOT (string LIKE pattern)`.)

If *pattern* does not contain percent signs or underscores, then the pattern only represents the string itself; in that case `LIKE` acts like the equals operator. An underscore (`_`) in *pattern* stands for (matches) any single character; a percent sign (`%`) matches any sequence of zero or more characters.

Some examples:

```
'abc' LIKE 'abc'      true  
'abc' LIKE 'a%'      true  
'abc' LIKE '_b_'     true  
'abc' LIKE 'c'       false
```

`LIKE` pattern matching always covers the entire string. Therefore, if it's desired to match a sequence anywhere within a string, the pattern must start and end with a percent sign.

To match a literal underscore or percent sign without matching other characters, the respective character in *pattern* must be preceded by the escape character. The default escape character is the backslash but a different one can be selected by using the `ESCAPE` clause. To match the escape character itself, write two escape characters.

**Note**

If you have `standard_conforming_strings` turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

It's also possible to select no escape character by writing `ESCAPE ''`. This effectively disables the escape mechanism, which makes it impossible to turn off the special meaning of underscore and percent signs in the pattern.

According to the SQL standard, omitting `ESCAPE` means there is no escape character (rather than defaulting to a backslash), and a zero-length `ESCAPE` value is disallowed. LightDB's behavior in this regard is therefore slightly nonstandard.

The key word `ILIKE` can be used instead of `LIKE` to make the match case-insensitive according to the active locale. This is not in the SQL standard but is a LightDB extension.

The operator `~~` is equivalent to `LIKE`, and `~~*` corresponds to `ILIKE`. There are also `!~~` and `!~~*` operators that represent `NOT LIKE` and `NOT ILIKE`, respectively. All of these operators are LightDB-specific. You may see these operator names in `EXPLAIN` output and similar places, since the parser actually translates `LIKE` et al. to these operators.

The phrases `LIKE`, `ILIKE`, `NOT LIKE`, and `NOT ILIKE` are generally treated as operators in LightDB syntax; for example they can be used in *expression operator ANY (subquery)* constructs, although an `ESCAPE` clause cannot be included there. In some obscure cases it may be necessary to use the underlying operator names instead.

Also see the prefix operator `^@` and corresponding `starts_with` function, which are useful in cases where simply matching the beginning of a string is needed.

## 9.7.2. SIMILAR TO Regular Expressions

```
string SIMILAR TO pattern [ESCAPE escape-character]
string NOT SIMILAR TO pattern [ESCAPE escape-character]
```

The `SIMILAR TO` operator returns true or false depending on whether its pattern matches the given string. It is similar to `LIKE`, except that it interprets the pattern using the SQL standard's definition of a regular expression. SQL regular expressions are a curious cross between `LIKE` notation and common (POSIX) regular expression notation.

Like `LIKE`, the `SIMILAR TO` operator succeeds only if its pattern matches the entire string; this is unlike common regular expression behavior where the pattern can match any part of the string. Also like `LIKE`, `SIMILAR TO` uses `_` and `%` as wildcard characters denoting any single character and any string, respectively (these are comparable to `.` and `.*` in POSIX regular expressions).

In addition to these facilities borrowed from `LIKE`, `SIMILAR TO` supports these pattern-matching metacharacters borrowed from POSIX regular expressions:

- `|` denotes alternation (either of two alternatives).
- `*` denotes repetition of the previous item zero or more times.
- `+` denotes repetition of the previous item one or more times.
- `?` denotes repetition of the previous item zero or one time.
- `{m}` denotes repetition of the previous item exactly *m* times.
- `{m, }` denotes repetition of the previous item *m* or more times.



- $\{m, n\}$  denotes repetition of the previous item at least  $m$  and not more than  $n$  times.
- Parentheses ( ) can be used to group items into a single logical item.
- A bracket expression [ . . . ] specifies a character class, just as in POSIX regular expressions.

Notice that the period (.) is not a metacharacter for `SIMILAR TO`.

As with `LIKE`, a backslash disables the special meaning of any of these metacharacters. A different escape character can be specified with `ESCAPE`, or the escape capability can be disabled by writing `ESCAPE ''`.

According to the SQL standard, omitting `ESCAPE` means there is no escape character (rather than defaulting to a backslash), and a zero-length `ESCAPE` value is disallowed. LightDB's behavior in this regard is therefore slightly nonstandard.

Another nonstandard extension is that following the escape character with a letter or digit provides access to the escape sequences defined for POSIX regular expressions; see Table 9.20, Table 9.21, and Table 9.22 below.

Some examples:

```
'abc' SIMILAR TO 'abc'           true
'abc' SIMILAR TO 'a'             false
'abc' SIMILAR TO '%(b|d)%'      true
'abc' SIMILAR TO '(b|c)%'       false
'-abc-' SIMILAR TO '%\mabc\M%'  true
'xabcy' SIMILAR TO '%\mabc\M%'  false
```

The `substring` function with three parameters provides extraction of a substring that matches an SQL regular expression pattern. The function can be written according to SQL99 syntax:

```
substring(string from pattern for escape-character)
```

or as a plain three-argument function:

```
substring(string, pattern, escape-character)
```

As with `SIMILAR TO`, the specified pattern must match the entire data string, or else the function fails and returns null. To indicate the part of the pattern for which the matching data sub-string is of interest, the pattern should contain two occurrences of the escape character followed by a double quote ("). The text matching the portion of the pattern between these separators is returned when the match is successful.

The escape-double-quote separators actually divide `substring`'s pattern into three independent regular expressions; for example, a vertical bar (|) in any of the three sections affects only that section. Also, the first and third of these regular expressions are defined to match the smallest possible amount of text, not the largest, when there is any ambiguity about how much of the data string matches which pattern. (In POSIX parlance, the first and third regular expressions are forced to be non-greedy.)

As an extension to the SQL standard, LightDB allows there to be just one escape-double-quote separator, in which case the third regular expression is taken as empty; or no separators, in which case the first and third regular expressions are taken as empty.

Some examples, with # " delimiting the return string:

```
substring('foobar' from '%"o_b#"' for '#')    oob
substring('foobar' from '# "o_b#"' for '#')    NULL
```

## 9.7.3. POSIX Regular Expressions

Table 9.16 lists the available operators for pattern matching using POSIX regular expressions.

**Table 9.16. Regular Expression Match Operators**

Operator	Description	Example(s)
<code>text ~ text</code>	→ boolean String matches regular expression, case sensitively	<code>'thomas' ~ 't.*ma' → t</code>
<code>text ~* text</code>	→ boolean String matches regular expression, case insensitively	<code>'thomas' ~* 'T.*ma' → t</code>
<code>text !~ text</code>	→ boolean String does not match regular expression, case sensitively	<code>'thomas' !~ 't.*max' → t</code>
<code>text !~* text</code>	→ boolean String does not match regular expression, case insensitively	<code>'thomas' !~* 'T.*ma' → f</code>

POSIX regular expressions provide a more powerful means for pattern matching than the `LIKE` and `SIMILAR TO` operators. Many Unix tools such as `egrep`, `sed`, or `awk` use a pattern matching language that is similar to the one described here.

A regular expression is a character sequence that is an abbreviated definition of a set of strings (a *regular set*). A string is said to match a regular expression if it is a member of the regular set described by the regular expression. As with `LIKE`, pattern characters match string characters exactly unless they are special characters in the regular expression language — but regular expressions use different special characters than `LIKE` does. Unlike `LIKE` patterns, a regular expression is allowed to match anywhere within a string, unless the regular expression is explicitly anchored to the beginning or end of the string.

Some examples:

```
'abcd' ~ 'bc'           true
'abcd' ~ 'a.c'         true — dot matches any character
'abcd' ~ 'a.*d'        true — * repeats the preceding pattern item
'abcd' ~ '(b|x)'       true — | means OR, parentheses group
'abcd' ~ '^a'          true — ^ anchors to start of string
'abcd' ~ '^(b|c)'      false — would match except for anchoring
```

The POSIX pattern language is described in much greater detail below.

The `substring` function with two parameters, `substring(string from pattern)`, provides extraction of a substring that matches a POSIX regular expression pattern. It returns null if there is no match, otherwise the first portion of the text that matched the pattern. But if the pattern contains any parentheses, the portion of the text that matched the first parenthesized subexpression (the one whose left parenthesis comes first) is returned. You can put parentheses around the whole expression if you want to use parentheses within it without triggering this exception. If you need parentheses in the pattern before the subexpression you want to extract, see the non-capturing parentheses described below.

Some examples:

```
substring('foobar' from 'o.b')      oob
substring('foobar' from 'o(.)b')    o
```

The `regexp_replace` function provides substitution of new text for substrings that match POSIX regular expression patterns. It has the syntax `regexp_replace(source, pattern, replacement [, flags ])`. The *source* string is returned unchanged if there is no match to the *pattern*. If there is a match, the *source* string is returned with the *replacement* string substituted for the matching substring. The *replacement* string can contain `\n`, where *n* is 1 through 9, to indicate that the source substring matching the *n*'th parenthesized subexpression of the pattern should be inserted, and it can contain `&` to indicate that the substring matching the entire pattern should be inserted. Write `\\` if you need to put a literal backslash in the replacement text. The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Flag `i` specifies case-insensitive matching, while flag `g` specifies replacement of each matching substring rather than only the first one. Supported flags (though not `g`) are described in Table 9.24.

Some examples:

```
regexp_replace('foobarbaz', 'b..', 'X')
                                fooXbaz
regexp_replace('foobarbaz', 'b..', 'X', 'g')
                                fooXX
regexp_replace('foobarbaz', 'b(..)', 'X\lY', 'g')
                                fooXarYXazY
```

The `regexp_match` function returns a text array of captured substring(s) resulting from the first match of a POSIX regular expression pattern to a string. It has the syntax `regexp_match(string, pattern [, flags ])`. If there is no match, the result is NULL. If a match is found, and the *pattern* contains no parenthesized subexpressions, then the result is a single-element text array containing the substring matching the whole pattern. If a match is found, and the *pattern* contains parenthesized subexpressions, then the result is a text array whose *n*'th element is the substring matching the *n*'th parenthesized subexpression of the *pattern* (not counting “non-capturing” parentheses; see below for details). The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Supported flags are described in Table 9.24.

Some examples:

```
SELECT regexp_match('foobarbequebaz', 'bar.*que');
 regexp_match
-----
 {barbeque}
(1 row)

SELECT regexp_match('foobarbequebaz', '(bar)(beque)');
 regexp_match
-----
 {bar,beque}
(1 row)
```

In the common case where you just want the whole matching substring or NULL for no match, write something like

```
SELECT (regexp_match('foobarbequebaz', 'bar.*que'))[1];
 regexp_match
```

```
-----
barbeque
(1 row)
```

The `regexp_matches` function returns a set of text arrays of captured substring(s) resulting from matching a POSIX regular expression pattern to a string. It has the same syntax as `regexp_match`. This function returns no rows if there is no match, one row if there is a match and the `g` flag is not given, or *N* rows if there are *N* matches and the `g` flag is given. Each returned row is a text array containing the whole matched substring or the substrings matching parenthesized subexpressions of the *pattern*, just as described above for `regexp_match`. `regexp_matches` accepts all the flags shown in Table 9.24, plus the `g` flag which commands it to return all matches, not just the first one.

Some examples:

```
SELECT regexp_matches('foo', 'not there');
 regexp_matches
-----
(0 rows)
```

```
SELECT regexp_matches('foobarbequebazilbarfbonk', '(b[^b]+)
(b[^b]+)', 'g');
 regexp_matches
-----
{bar,beque}
{bazil,barf}
(2 rows)
```

### Tip

In most cases `regexp_matches()` should be used with the `g` flag, since if you only want the first match, it's easier and more efficient to use `regexp_match()`. However, `regexp_match()` only exists in LightDB version 10 and up. When working in older versions, a common trick is to place a `regexp_matches()` call in a sub-select, for example:

```
SELECT col1, (SELECT regexp_matches(col2, '(bar)
(beque)')) FROM tab;
```

This produces a text array if there's a match, or `NULL` if not, the same as `regexp_match()` would do. Without the sub-select, this query would produce no output at all for table rows without a match, which is typically not the desired behavior.

The `regexp_split_to_table` function splits a string using a POSIX regular expression pattern as a delimiter. It has the syntax `regexp_split_to_table(string, pattern [, flags ])`. If there is no match to the *pattern*, the function returns the *string*. If there is at least one match, for each match it returns the text from the end of the last match (or the beginning of the string) to the beginning of the match. When there are no more matches, it returns the text from the end of the last match to the end of the string. The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. `regexp_split_to_table` supports the flags described in Table 9.24.

The `regexp_split_to_array` function behaves the same as `regexp_split_to_table`, except that `regexp_split_to_array` returns its result as an array of text. It has the syntax `regexp_split_to_array(string, pattern [, flags ])`. The parameters are the same as for `regexp_split_to_table`.

Some examples:

```
SELECT foo FROM regexp_split_to_table('the quick brown fox jumps
over the lazy dog', '\s+') AS foo;
foo
```

-----

```
the
quick
brown
fox
jumps
over
the
lazy
dog
(9 rows)
```

```
SELECT regexp_split_to_array('the quick brown fox jumps over the
lazy dog', '\s+');
          regexp_split_to_array
```

-----

```
{the,quick,brown,fox,jumps,over,the,lazy,dog}
(1 row)
```

```
SELECT foo FROM regexp_split_to_table('the quick brown fox', '\s*')
AS foo;
foo
```

-----

```
t
h
e
q
u
i
c
k
b
r
o
w
n
f
o
x
(16 rows)
```

As the last example demonstrates, the regexp split functions ignore zero-length matches that occur at the start or end of the string or immediately after a previous match. This is contrary to the strict definition of regexp matching that is implemented by `regexp_match` and `regexp_matches`, but is usually the most convenient behavior in practice. Other software systems such as Perl use similar definitions.

### 9.7.3.1. Regular Expression Details

LightDB's regular expressions are implemented using a software package written by Henry Spencer. Much of the description of regular expressions below is copied verbatim from his manual.

Regular expressions (REs), as defined in POSIX 1003.2, come in two forms: *extended* REs or EREs (roughly those of `egrep`), and *basic* REs or BREs (roughly those of `ed`). LightDB supports both forms, and also implements some extensions that are not in the POSIX standard, but have become widely used due to their availability in programming languages such as Perl and Tcl. REs using these non-POSIX extensions are called *advanced* REs or AREs in this documentation. AREs are almost an exact superset of EREs, but BREs have several notational incompatibilities (as well as being much more limited). We first describe the ARE and ERE forms, noting features that apply only to AREs, and then describe how BREs differ.

**Note**

LightDB always initially presumes that a regular expression follows the ARE rules. However, the more limited ERE or BRE rules can be chosen by prepending an *embedded option* to the RE pattern, as described in Section 9.7.3.4. This can be useful for compatibility with applications that expect exactly the POSIX 1003.2 rules.

A regular expression is defined as one or more *branches*, separated by `|`. It matches anything that matches one of the branches.

A branch is zero or more *quantified atoms* or *constraints*, concatenated. It matches a match for the first, followed by a match for the second, etc; an empty branch matches the empty string.

A quantified atom is an *atom* possibly followed by a single *quantifier*. Without a quantifier, it matches a match for the atom. With a quantifier, it can match some number of matches of the atom. An *atom* can be any of the possibilities shown in Table 9.17. The possible quantifiers and their meanings are shown in Table 9.18.

A *constraint* matches an empty string, but matches only when specific conditions are met. A constraint can be used where an atom could be used, except it cannot be followed by a quantifier. The simple constraints are shown in Table 9.19; some more constraints are described later.

**Table 9.17. Regular Expression Atoms**

Atom	Description
<code>( re )</code>	(where <i>re</i> is any regular expression) matches a match for <i>re</i> , with the match noted for possible reporting
<code>( ? : re )</code>	as above, but the match is not noted for reporting (a “non-capturing” set of parentheses) (AREs only)
<code>.</code>	matches any single character
<code>[ chars ]</code>	a <i>bracket expression</i> , matching any one of the <i>chars</i> (see Section 9.7.3.2 for more detail)
<code>\k</code>	(where <i>k</i> is a non-alphanumeric character) matches that character taken as an ordinary character, e.g., <code>\\</code> matches a backslash character
<code>\c</code>	where <i>c</i> is alphanumeric (possibly followed by other characters) is an <i>escape</i> , see Section 9.7.3.3 (AREs only; in EREs and BREs, this matches <i>c</i> )
<code>{</code>	when followed by a character other than a digit, matches the left-brace character <code>{</code> ; when followed by a digit, it is the beginning of a <i>bound</i> (see below)

Atom	Description
$x$	where $x$ is a single character with no other significance, matches that character

An RE cannot end with a backslash (\).

**Note**

If you have `standard_conforming_strings` turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

**Table 9.18. Regular Expression Quantifiers**

Quantifier	Matches
*	a sequence of 0 or more matches of the atom
+	a sequence of 1 or more matches of the atom
?	a sequence of 0 or 1 matches of the atom
{ $m$ }	a sequence of exactly $m$ matches of the atom
{ $m$ , }	a sequence of $m$ or more matches of the atom
{ $m$ , $n$ }	a sequence of $m$ through $n$ (inclusive) matches of the atom; $m$ cannot exceed $n$
*?	non-greedy version of *
+?	non-greedy version of +
??	non-greedy version of ?
{ $m$ }?	non-greedy version of { $m$ }
{ $m$ , }?	non-greedy version of { $m$ , }
{ $m$ , $n$ }?	non-greedy version of { $m$ , $n$ }

The forms using { . . . } are known as *bounds*. The numbers  $m$  and  $n$  within a bound are unsigned decimal integers with permissible values from 0 to 255 inclusive.

*Non-greedy* quantifiers (available in AREs only) match the same possibilities as their corresponding normal (*greedy*) counterparts, but prefer the smallest number rather than the largest number of matches. See Section 9.7.3.5 for more detail.

**Note**

A quantifier cannot immediately follow another quantifier, e.g., \*\* is invalid. A quantifier cannot begin an expression or subexpression or follow ^ or |.

**Table 9.19. Regular Expression Constraints**

Constraint	Description
^	matches at the beginning of the string
\$	matches at the end of the string
(?= <i>re</i> )	<i>positive lookahead</i> matches at any point where a substring matching <i>re</i> begins (AREs only)

Constraint	Description
(?!re)	<i>negative lookahead</i> matches at any point where no substring matching <i>re</i> begins (AREs only)
(?<=re)	<i>positive lookbehind</i> matches at any point where a substring matching <i>re</i> ends (AREs only)
(?<!re)	<i>negative lookbehind</i> matches at any point where no substring matching <i>re</i> ends (AREs only)

Lookahead and lookbehind constraints cannot contain *back references* (see Section 9.7.3.3), and all parentheses within them are considered non-capturing.

### 9.7.3.2. Bracket Expressions

A *bracket expression* is a list of characters enclosed in [ ]. It normally matches any single character from the list (but see below). If the list begins with ^, it matches any single character *not* from the rest of the list. If two characters in the list are separated by -, this is shorthand for the full range of characters between those two (inclusive) in the collating sequence, e.g., [0-9] in ASCII matches any decimal digit. It is illegal for two ranges to share an endpoint, e.g., a-c-e. Ranges are very collating-sequence-dependent, so portable programs should avoid relying on them.

To include a literal ] in the list, make it the first character (after ^, if that is used). To include a literal -, make it the first or last character, or the second endpoint of a range. To use a literal - as the first endpoint of a range, enclose it in [. and .] to make it a collating element (see below). With the exception of these characters, some combinations using [ (see next paragraphs), and escapes (AREs only), all other special characters lose their special significance within a bracket expression. In particular, \ is not special when following ERE or BRE rules, though it is special (as introducing an escape) in AREs.

Within a bracket expression, a collating element (a character, a multiple-character sequence that collates as if it were a single character, or a collating-sequence name for either) enclosed in [. and .] stands for the sequence of characters of that collating element. The sequence is treated as a single element of the bracket expression's list. This allows a bracket expression containing a multiple-character collating element to match more than one character, e.g., if the collating sequence includes a ch collating element, then the RE [[.ch.]]\*c matches the first five characters of chchcc.

#### Note

LightDB currently does not support multi-character collating elements. This information describes possible future behavior.

Within a bracket expression, a collating element enclosed in [= and =] is an *equivalence class*, standing for the sequences of characters of all collating elements equivalent to that one, including itself. (If there are no other equivalent collating elements, the treatment is as if the enclosing delimiters were [. and .].) For example, if o and ^ are the members of an equivalence class, then [[=o=]], [[=^=]], and [o^] are all synonymous. An equivalence class cannot be an endpoint of a range.

Within a bracket expression, the name of a character class enclosed in [: and :] stands for the list of all characters belonging to that class. A character class cannot be used as an endpoint of a range. The POSIX standard defines these character class names: `alnum` (letters and numeric digits), `alpha` (letters), `blank` (space and tab), `cntrl` (control characters), `digit` (numeric digits), `graph` (printable characters except space), `lower` (lower-case letters), `print` (printable characters including space), `punct` (punctuation), `space` (any white space), `upper` (upper-case letters), and `xdigit` (hexadecimal digits). The behavior of these standard character classes is generally consistent across platforms for characters in the 7-bit ASCII set. Whether a given non-ASCII character is considered to belong to one of these classes depends on the *collation* that is used for the regular-



expression function or operator (see Section 21.2), or by default on the database's `LC_CTYPE` locale setting (see Section 21.1). The classification of non-ASCII characters can vary across platforms even in similarly-named locales. (But the `C` locale never considers any non-ASCII characters to belong to any of these classes.) In addition to these standard character classes, LightDB defines the `ascii` character class, which contains exactly the 7-bit ASCII set.

There are two special cases of bracket expressions: the bracket expressions `[[:<:]]` and `[[:>:]]` are constraints, matching empty strings at the beginning and end of a word respectively. A word is defined as a sequence of word characters that is neither preceded nor followed by word characters. A word character is an `alnum` character (as defined by the POSIX character class described above) or an underscore. This is an extension, compatible with but not specified by POSIX 1003.2, and should be used with caution in software intended to be portable to other systems. The constraint escapes described below are usually preferable; they are no more standard, but are easier to type.

### 9.7.3.3. Regular Expression Escapes

*Escapes* are special sequences beginning with `\` followed by an alphanumeric character. Escapes come in several varieties: character entry, class shorthands, constraint escapes, and back references. A `\` followed by an alphanumeric character but not constituting a valid escape is illegal in AREs. In EREs, there are no escapes: outside a bracket expression, a `\` followed by an alphanumeric character merely stands for that character as an ordinary character, and inside a bracket expression, `\` is an ordinary character. (The latter is the one actual incompatibility between EREs and AREs.)

*Character-entry escapes* exist to make it easier to specify non-printing and other inconvenient characters in REs. They are shown in Table 9.20.

*Class-shorthand escapes* provide shorthands for certain commonly-used character classes. They are shown in Table 9.21.

A *constraint escape* is a constraint, matching the empty string if specific conditions are met, written as an escape. They are shown in Table 9.22.

A *back reference* (`\n`) matches the same string matched by the previous parenthesized subexpression specified by the number *n* (see Table 9.23). For example, `([bc])\1` matches `bb` or `cc` but not `bc` or `cb`. The subexpression must entirely precede the back reference in the RE. Subexpressions are numbered in the order of their leading parentheses. Non-capturing parentheses do not define subexpressions.

**Table 9.20. Regular Expression Character-Entry Escapes**

Escape	Description
<code>\a</code>	alert (bell) character, as in C
<code>\b</code>	backspace, as in C
<code>\B</code>	synonym for backslash ( <code>\</code> ) to help reduce the need for backslash doubling
<code>\cX</code>	(where <i>X</i> is any character) the character whose low-order 5 bits are the same as those of <i>X</i> , and whose other bits are all zero
<code>\e</code>	the character whose collating-sequence name is <code>ESC</code> , or failing that, the character with octal value <code>033</code>
<code>\f</code>	form feed, as in C
<code>\n</code>	newline, as in C
<code>\r</code>	carriage return, as in C
<code>\t</code>	horizontal tab, as in C

Escape	Description
<code>\uvwxyz</code>	(where <i>wxyz</i> is exactly four hexadecimal digits) the character whose hexadecimal value is <code>0xwxyz</code>
<code>\Ustuvwxyz</code>	(where <i>stuvwxyz</i> is exactly eight hexadecimal digits) the character whose hexadecimal value is <code>0x.stuvwxyz</code>
<code>\v</code>	vertical tab, as in C
<code>\xhhh</code>	(where <i>hhh</i> is any sequence of hexadecimal digits) the character whose hexadecimal value is <code>0xhhh</code> (a single character no matter how many hexadecimal digits are used)
<code>\0</code>	the character whose value is 0 (the null byte)
<code>\xy</code>	(where <i>xy</i> is exactly two octal digits, and is not a <i>back reference</i> ) the character whose octal value is <code>0xy</code>
<code>\xyz</code>	(where <i>xyz</i> is exactly three octal digits, and is not a <i>back reference</i> ) the character whose octal value is <code>0xyz</code>

Hexadecimal digits are 0-9, a-f, and A-F. Octal digits are 0-7.

Numeric character-entry escapes specifying values outside the ASCII range (0–127) have meanings dependent on the database encoding. When the encoding is UTF-8, escape values are equivalent to Unicode code points, for example `\u1234` means the character U+1234. For other multibyte encodings, character-entry escapes usually just specify the concatenation of the byte values for the character. If the escape value does not correspond to any legal character in the database encoding, no error will be raised, but it will never match any data.

The character-entry escapes are always taken as ordinary characters. For example, `\135` is `]` in ASCII, but `\135` does not terminate a bracket expression.

**Table 9.21. Regular Expression Class-Shorthand Escapes**

Escape	Description
<code>\d</code>	<code>[[:digit:]]</code>
<code>\s</code>	<code>[[:space:]]</code>
<code>\w</code>	<code>[[:alnum: ]_]</code> (note underscore is included)
<code>\D</code>	<code>[^[:digit:]]</code>
<code>\S</code>	<code>[^[:space:]]</code>
<code>\W</code>	<code>[^[:alnum: ]_]</code> (note underscore is included)

Within bracket expressions, `\d`, `\s`, and `\w` lose their outer brackets, and `\D`, `\S`, and `\W` are illegal. (So, for example, `[a-c\d]` is equivalent to `[a-c[:digit:]]`. Also, `[a-c\D]`, which is equivalent to `[a-c^[[:digit:]]]`, is illegal.)

**Table 9.22. Regular Expression Constraint Escapes**

Escape	Description
<code>\A</code>	matches only at the beginning of the string (see Section 9.7.3.5 for how this differs from <code>^</code> )
<code>\m</code>	matches only at the beginning of a word

Escape	Description
\M	matches only at the end of a word
\Y	matches only at the beginning or end of a word
\y	matches only at a point that is not the beginning or end of a word
\Z	matches only at the end of the string (see Section 9.7.3.5 for how this differs from \$)

A word is defined as in the specification of [[:<:]] and [[:>:]] above. Constraint escapes are illegal within bracket expressions.

**Table 9.23. Regular Expression Back References**

Escape	Description
\m	(where <i>m</i> is a nonzero digit) a back reference to the <i>m</i> 'th subexpression
\mnn	(where <i>m</i> is a nonzero digit, and <i>nn</i> is some more digits, and the decimal value <i>mnn</i> is not greater than the number of closing capturing parentheses seen so far) a back reference to the <i>mnn</i> 'th subexpression

**Note**

There is an inherent ambiguity between octal character-entry escapes and back references, which is resolved by the following heuristics, as hinted at above. A leading zero always indicates an octal escape. A single non-zero digit, not followed by another digit, is always taken as a back reference. A multi-digit sequence not starting with a zero is taken as a back reference if it comes after a suitable subexpression (i.e., the number is in the legal range for a back reference), and otherwise is taken as octal.

### 9.7.3.4. Regular Expression Metasyntax

In addition to the main syntax described above, there are some special forms and miscellaneous syntactic facilities available.

An RE can begin with one of two special *director* prefixes. If an RE begins with `***:`, the rest of the RE is taken as an ARE. (This normally has no effect in LightDB, since REs are assumed to be AREs; but it does have an effect if ERE or BRE mode had been specified by the *flags* parameter to a regex function.) If an RE begins with `***=`, the rest of the RE is taken to be a literal string, with all characters considered ordinary characters.

An ARE can begin with *embedded options*: a sequence `(?xyz)` (where *xyz* is one or more alphabetic characters) specifies options affecting the rest of the RE. These options override any previously determined options — in particular, they can override the case-sensitivity behavior implied by a regex operator, or the *flags* parameter to a regex function. The available option letters are shown in Table 9.24. Note that these same option letters are used in the *flags* parameters of regex functions.

**Table 9.24. ARE Embedded-Option Letters**

Option	Description
b	rest of RE is a BRE

Option	Description
c	case-sensitive matching (overrides operator type)
e	rest of RE is an ERE
i	case-insensitive matching (see Section 9.7.3.5) (overrides operator type)
m	historical synonym for n
n	newline-sensitive matching (see Section 9.7.3.5)
p	partial newline-sensitive matching (see Section 9.7.3.5)
q	rest of RE is a literal (“quoted”) string, all ordinary characters
s	non-newline-sensitive matching (default)
t	tight syntax (default; see below)
w	inverse partial newline-sensitive (“weird”) matching (see Section 9.7.3.5)
x	expanded syntax (see below)

Embedded options take effect at the ) terminating the sequence. They can appear only at the start of an ARE (after the \*\*\* : director if any).

In addition to the usual (*tight*) RE syntax, in which all characters are significant, there is an *expanded* syntax, available by specifying the embedded x option. In the expanded syntax, white-space characters in the RE are ignored, as are all characters between a # and the following newline (or the end of the RE). This permits paragraphing and commenting a complex RE. There are three exceptions to that basic rule:

- a white-space character or # preceded by \ is retained
- white space or # within a bracket expression is retained
- white space and comments cannot appear within multi-character symbols, such as ( ? :

For this purpose, white-space characters are blank, tab, newline, and any character that belongs to the *space* character class.

Finally, in an ARE, outside bracket expressions, the sequence (?#*ttt*) (where *ttt* is any text not containing a ) is a comment, completely ignored. Again, this is not allowed between the characters of multi-character symbols, like ( ? : . Such comments are more a historical artifact than a useful facility, and their use is deprecated; use the expanded syntax instead.

*None* of these metasyntax extensions is available if an initial \*\*\* = director has specified that the user's input be treated as a literal string rather than as an RE.

### 9.7.3.5. Regular Expression Matching Rules

In the event that an RE could match more than one substring of a given string, the RE matches the one starting earliest in the string. If the RE could match more than one substring starting at that point, either the longest possible match or the shortest possible match will be taken, depending on whether the RE is *greedy* or *non-greedy*.

Whether an RE is greedy or not is determined by the following rules:

- Most atoms, and all constraints, have no greediness attribute (because they cannot match variable amounts of text anyway).

- Adding parentheses around an RE does not change its greediness.
- A quantified atom with a fixed-repetition quantifier ( $\{m\}$  or  $\{m\}?$ ) has the same greediness (possibly none) as the atom itself.
- A quantified atom with other normal quantifiers (including  $\{m, n\}$  with  $m$  equal to  $n$ ) is greedy (prefers longest match).
- A quantified atom with a non-greedy quantifier (including  $\{m, n\}?$  with  $m$  equal to  $n$ ) is non-greedy (prefers shortest match).
- A branch — that is, an RE that has no top-level `|` operator — has the same greediness as the first quantified atom in it that has a greediness attribute.
- An RE consisting of two or more branches connected by the `|` operator is always greedy.

The above rules associate greediness attributes not only with individual quantified atoms, but with branches and entire REs that contain quantified atoms. What that means is that the matching is done in such a way that the branch, or whole RE, matches the longest or shortest possible substring *as a whole*. Once the length of the entire match is determined, the part of it that matches any particular subexpression is determined on the basis of the greediness attribute of that subexpression, with subexpressions starting earlier in the RE taking priority over ones starting later.

An example of what this means:

```
SELECT SUBSTRING('XY1234Z', 'Y*([0-9]{1,3})');
Result: 123
SELECT SUBSTRING('XY1234Z', 'Y*?([0-9]{1,3})');
Result: 1
```

In the first case, the RE as a whole is greedy because `Y*` is greedy. It can match beginning at the `Y`, and it matches the longest possible string starting there, i.e., `Y123`. The output is the parenthesized part of that, or `123`. In the second case, the RE as a whole is non-greedy because `Y*?` is non-greedy. It can match beginning at the `Y`, and it matches the shortest possible string starting there, i.e., `Y1`. The subexpression `[0-9]{1,3}` is greedy but it cannot change the decision as to the overall match length; so it is forced to match just `1`.

In short, when an RE contains both greedy and non-greedy subexpressions, the total match length is either as long as possible or as short as possible, according to the attribute assigned to the whole RE. The attributes assigned to the subexpressions only affect how much of that match they are allowed to “eat” relative to each other.

The quantifiers  $\{1, 1\}$  and  $\{1, 1\}?$  can be used to force greediness or non-greediness, respectively, on a subexpression or a whole RE. This is useful when you need the whole RE to have a greediness attribute different from what's deduced from its elements. As an example, suppose that we are trying to separate a string containing some digits into the digits and the parts before and after them. We might try to do that like this:

```
SELECT regexp_match('abc01234xyz', '(.*)(\d+)(.*)');
Result: {abc0123,4,xyz}
```

That didn't work: the first `.*` is greedy so it “eats” as much as it can, leaving the `\d+` to match at the last possible place, the last digit. We might try to fix that by making it non-greedy:

```
SELECT regexp_match('abc01234xyz', '(.*?)(\d+)(.*)');
Result: {abc,0,""}
```

That didn't work either, because now the RE as a whole is non-greedy and so it ends the overall match as soon as possible. We can get what we want by forcing the RE as a whole to be greedy:

```
SELECT regexp_match('abc01234xyz', '(?: .*?)(\d+)(.*){1,1}');
Result: {abc,01234,xyz}
```

Controlling the RE's overall greediness separately from its components' greediness allows great flexibility in handling variable-length patterns.

When deciding what is a longer or shorter match, match lengths are measured in characters, not collating elements. An empty string is considered longer than no match at all. For example: `bb*` matches the three middle characters of `abbbc`; `(week|wee)(night|knights)` matches all ten characters of `weeknights`; when `(.)*.*` is matched against `abc` the parenthesized subexpression matches all three characters; and when `(a*)*` is matched against `bc` both the whole RE and the parenthesized subexpression match an empty string.

If case-independent matching is specified, the effect is much as if all case distinctions had vanished from the alphabet. When an alphabetic that exists in multiple cases appears as an ordinary character outside a bracket expression, it is effectively transformed into a bracket expression containing both cases, e.g., `x` becomes `[xX]`. When it appears inside a bracket expression, all case counterparts of it are added to the bracket expression, e.g., `[x]` becomes `[xX]` and `[^x]` becomes `[^xX]`.

If newline-sensitive matching is specified, `.` and bracket expressions using `^` will never match the newline character (so that matches will never cross newlines unless the RE explicitly arranges it) and `^` and `$` will match the empty string after and before a newline respectively, in addition to matching at beginning and end of string respectively. But the ARE escapes `\A` and `\Z` continue to match beginning or end of string *only*.

If partial newline-sensitive matching is specified, this affects `.` and bracket expressions as with newline-sensitive matching, but not `^` and `$`.

If inverse partial newline-sensitive matching is specified, this affects `^` and `$` as with newline-sensitive matching, but not `.` and bracket expressions. This isn't very useful but is provided for symmetry.

### 9.7.3.6. Limits and Compatibility

No particular limit is imposed on the length of REs in this implementation. However, programs intended to be highly portable should not employ REs longer than 256 bytes, as a POSIX-compliant implementation can refuse to accept such REs.

The only feature of AREs that is actually incompatible with POSIX EREs is that `\` does not lose its special significance inside bracket expressions. All other ARE features use syntax which is illegal or has undefined or unspecified effects in POSIX EREs; the `***` syntax of directors likewise is outside the POSIX syntax for both BREs and EREs.

Many of the ARE extensions are borrowed from Perl, but some have been changed to clean them up, and a few Perl extensions are not present. Incompatibilities of note include `\b`, `\B`, the lack of special treatment for a trailing newline, the addition of complemented bracket expressions to the things affected by newline-sensitive matching, the restrictions on parentheses and back references in lookahead/lookbehind constraints, and the longest/shortest-match (rather than first-match) matching semantics.

### 9.7.3.7. Basic Regular Expressions

BREs differ from EREs in several respects. In BREs, `|`, `+`, and `?` are ordinary characters and there is no equivalent for their functionality. The delimiters for bounds are `\{` and `\}`, with `{` and `}` by themselves ordinary characters. The parentheses for nested subexpressions are `\(` and `\)`, with `(` and `)`

) by themselves ordinary characters. `^` is an ordinary character except at the beginning of the RE or the beginning of a parenthesized subexpression, `$` is an ordinary character except at the end of the RE or the end of a parenthesized subexpression, and `*` is an ordinary character if it appears at the beginning of the RE or the beginning of a parenthesized subexpression (after a possible leading `^`). Finally, single-digit back references are available, and `\<` and `\>` are synonyms for `[[:<:]]` and `[[:>:]]` respectively; no other escapes are available in BREs.

### 9.7.3.8. Differences from XQuery (`LIKE_REGEX`)

Since SQL:2008, the SQL standard includes a `LIKE_REGEX` operator that performs pattern matching according to the XQuery regular expression standard. LightDB does not yet implement this operator, but you can get very similar behavior using the `regexp_match()` function, since XQuery regular expressions are quite close to the ARE syntax described above.

Notable differences between the existing POSIX-based regular-expression feature and XQuery regular expressions include:

- XQuery character class subtraction is not supported. An example of this feature is using the following to match only English consonants: `[a-z-[aeiou]]`.
- XQuery character class shorthands `\c`, `\C`, `\i`, and `\I` are not supported.
- XQuery character class elements using `\p{UnicodeProperty}` or the inverse `\P{UnicodeProperty}` are not supported.
- POSIX interprets character classes such as `\w` (see Table 9.21) according to the prevailing locale (which you can control by attaching a `COLLATE` clause to the operator or function). XQuery specifies these classes by reference to Unicode character properties, so equivalent behavior is obtained only with a locale that follows the Unicode rules.
- The SQL standard (not XQuery itself) attempts to cater for more variants of “newline” than POSIX does. The newline-sensitive matching options described above consider only ASCII NL (`\n`) to be a newline, but SQL would have us treat CR (`\r`), CRLF (`\r\n`) (a Windows-style newline), and some Unicode-only characters like LINE SEPARATOR (U+2028) as newlines as well. Notably, `.` and `\s` should count `\r\n` as one character not two according to SQL.
- Of the character-entry escapes described in Table 9.20, XQuery supports only `\n`, `\r`, and `\t`.
- XQuery does not support the `[ :name : ]` syntax for character classes within bracket expressions.
- XQuery does not have lookahead or lookbehind constraints, nor any of the constraint escapes described in Table 9.22.
- The metasyntax forms described in Section 9.7.3.4 do not exist in XQuery.
- The regular expression flag letters defined by XQuery are related to but not the same as the option letters for POSIX (Table 9.24). While the `i` and `q` options behave the same, others do not:
  - XQuery's `s` (allow dot to match newline) and `m` (allow `^` and `$` to match at newlines) flags provide access to the same behaviors as POSIX's `n`, `p` and `w` flags, but they do *not* match the behavior of POSIX's `s` and `m` flags. Note in particular that dot-matches-newline is the default behavior in POSIX but not XQuery.
  - XQuery's `x` (ignore whitespace in pattern) flag is noticeably different from POSIX's expanded-mode flag. POSIX's `x` flag also allows `#` to begin a comment in the pattern, and POSIX will not ignore a whitespace character after a backslash.

## 9.8. Data Type Formatting Functions

The LightDB formatting functions provide a powerful set of tools for converting various data types (date/time, integer, floating point, numeric) to formatted strings and for converting from formatted strings to specific data types. Table 9.25 lists them. These functions all follow a common calling convention: the first argument is the value to be formatted and the second argument is a template that defines the output or input format.

**Table 9.25. Formatting Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>to_char(timestamp, text) → text</code> <code>to_char(timestamp with time zone, text) → text</code>	Converts time stamp to string according to the given format.	<code>to_char(timestamp '2002-04-20 17:31:12.66', 'HH12:MI:SS') → 05:31:12</code>
<code>to_char(interval, text) → text</code>	Converts interval to string according to the given format.	<code>to_char(interval '15h 2m 12s', 'HH24:MI:SS') → 15:02:12</code>
<code>to_char(numeric_type, text) → text</code>	Converts number to string according to the given format; available for integer, bigint, numeric, real, double precision.	<code>to_char(125, '999') → 125</code> <code>to_char(125.8::real, '999D9') → 125.8</code> <code>to_char(-125.8, '999D99S') → 125.80-</code>
<code>to_date(text, text) → date</code>	Converts string to date according to the given format.	<code>to_date('05 Dec 2000', 'DD Mon YYYY') → 2000-12-05</code>
<code>to_number(text, text) → numeric</code>	Converts string to numeric according to the given format.	<code>to_number('12,454.8-', '99G999D9S') → -12454.8</code>
<code>to_timestamp(text, text) → timestamp with time zone</code>	Converts string to time stamp according to the given format. (See also <code>to_timestamp(double precision)</code> in Table 9.32.)	<code>to_timestamp('05 Dec 2000', 'DD Mon YYYY') → 2000-12-05 00:00:00-05</code>

**Tip**

`to_timestamp` and `to_date` exist to handle input formats that cannot be converted by simple casting. For most standard date/time formats, simply casting the source string to the required data type works, and is much easier. Similarly, `to_number` is unnecessary for standard numeric representations.

In a `to_char` output template string, there are certain patterns that are recognized and replaced with appropriately-formatted data based on the given value. Any text that is not a template pattern is simply copied verbatim. Similarly, in an input template string (for the other functions), template patterns identify the values to be supplied by the input data string. If there are characters in the template string



that are not template patterns, the corresponding characters in the input data string are simply skipped over (whether or not they are equal to the template string characters).

Table 9.26 shows the template patterns available for formatting date and time values.

**Table 9.26. Template Patterns for Date/Time Formatting**

<b>Pattern</b>	<b>Description</b>
HH	hour of day (01–12)
HH12	hour of day (01–12)
HH24	hour of day (00–23)
MI	minute (00–59)
SS	second (00–59)
MS	millisecond (000–999)
US	microsecond (000000–999999)
FF1	tenth of second (0–9)
FF2	hundredth of second (00–99)
FF3	millisecond (000–999)
FF4	tenth of a millisecond (0000–9999)
FF5	hundredth of a millisecond (00000–99999)
FF6	microsecond (000000–999999)
SSSS, SSSSS	seconds past midnight (0–86399)
AM, am, PM or pm	meridiem indicator (without periods)
A.M., a.m., P.M. or p.m.	meridiem indicator (with periods)
Y, YYY	year (4 or more digits) with comma
YYYY	year (4 or more digits)
YYY	last 3 digits of year
YY	last 2 digits of year
Y	last digit of year
IYYY	ISO 8601 week-numbering year (4 or more digits)
IYY	last 3 digits of ISO 8601 week-numbering year
IY	last 2 digits of ISO 8601 week-numbering year
I	last digit of ISO 8601 week-numbering year
BC, bc, AD or ad	era indicator (without periods)
B.C., b.c., A.D. or a.d.	era indicator (with periods)
MONTH	full upper case month name (blank-padded to 9 chars)
Month	full capitalized month name (blank-padded to 9 chars)
month	full lower case month name (blank-padded to 9 chars)
MON	abbreviated upper case month name (3 chars in English, localized lengths vary)
Mon	abbreviated capitalized month name (3 chars in English, localized lengths vary)

<b>Pattern</b>	<b>Description</b>
mon	abbreviated lower case month name (3 chars in English, localized lengths vary)
MM	month number (01–12)
DAY	full upper case day name (blank-padded to 9 chars)
Day	full capitalized day name (blank-padded to 9 chars)
day	full lower case day name (blank-padded to 9 chars)
DY	abbreviated upper case day name (3 chars in English, localized lengths vary)
Dy	abbreviated capitalized day name (3 chars in English, localized lengths vary)
dy	abbreviated lower case day name (3 chars in English, localized lengths vary)
DDD	day of year (001–366)
IDDD	day of ISO 8601 week-numbering year (001–371; day 1 of the year is Monday of the first ISO week)
DD	day of month (01–31)
D	day of the week, Sunday (1) to Saturday (7)
ID	ISO 8601 day of the week, Monday (1) to Sunday (7)
W	week of month (1–5) (the first week starts on the first day of the month)
WW	week number of year (1–53) (the first week starts on the first day of the year)
IW	week number of ISO 8601 week-numbering year (01–53; the first Thursday of the year is in week 1)
CC	century (2 digits) (the twenty-first century starts on 2001-01-01)
J	Julian Date (integer days since November 24, 4714 BC at local midnight; see Section B.7)
Q	quarter
RM	month in upper case Roman numerals (I–XII; I=January)
rm	month in lower case Roman numerals (i–xii; i=January)
TZ	upper case time-zone abbreviation (only supported in <code>to_char</code> )
tz	lower case time-zone abbreviation (only supported in <code>to_char</code> )
TZH	time-zone hours
TZM	time-zone minutes
OF	time-zone offset from UTC (only supported in <code>to_char</code> )

Modifiers can be applied to any template pattern to alter its behavior. For example, `FMMonth` is the `Month` pattern with the `FM` modifier. Table 9.27 shows the modifier patterns for date/time formatting.

**Table 9.27. Template Pattern Modifiers for Date/Time Formatting**

Modifier	Description	Example
FM prefix	fill mode (suppress leading zeroes and padding blanks)	FMMonth
TH suffix	upper case ordinal number suffix	DDTH, e.g., 12TH
th suffix	lower case ordinal number suffix	DDth, e.g., 12th
FX prefix	fixed format global option (see usage notes)	FX Month DD Day
TM prefix	translation mode (use localized day and month names based on <code>lc_time</code> )	TMMonth
SP suffix	spell mode (not implemented)	DDSP

Usage notes for date/time formatting:

- `FM` suppresses leading zeroes and trailing blanks that would otherwise be added to make the output of a pattern be fixed-width. In `LightDB`, `FM` modifies only the next specification, while in `Oracle` `FM` affects all subsequent specifications, and repeated `FM` modifiers toggle fill mode on and off.
  - `TM` suppresses trailing blanks whether or not `FM` is specified.
  - `to_timestamp` and `to_date` ignore letter case in the input; so for example `MON`, `Mon`, and `mon` all accept the same strings. When using the `TM` modifier, case-folding is done according to the rules of the function's input collation (see Section 21.2).
  - `to_timestamp` and `to_date` skip multiple blank spaces at the beginning of the input string and around date and time values unless the `FX` option is used. For example, `to_timestamp(' 2000 JUN', 'YYYY MON')` and `to_timestamp('2000 - JUN', 'YYYY-MON')` work, but `to_timestamp('2000 JUN', 'FXYYYY MON')` returns an error because `to_timestamp` expects only a single space. `FX` must be specified as the first item in the template.
  - A separator (a space or non-letter/non-digit character) in the template string of `to_timestamp` and `to_date` matches any single separator in the input string or is skipped, unless the `FX` option is used. For example, `to_timestamp('2000JUN', 'YYYY//MON')` and `to_timestamp('2000/JUN', 'YYYY MON')` work, but `to_timestamp('2000//JUN', 'YYYY/MON')` returns an error because the number of separators in the input string exceeds the number of separators in the template.
- If `FX` is specified, a separator in the template string matches exactly one character in the input string. But note that the input string character is not required to be the same as the separator from the template string. For example, `to_timestamp('2000/JUN', 'FXYYYY MON')` works, but `to_timestamp('2000/JUN', 'FXYYYY MON')` returns an error because the second space in the template string consumes the letter `J` from the input string.
- A `TZH` template pattern can match a signed number. Without the `FX` option, minus signs may be ambiguous, and could be interpreted as a separator. This ambiguity is resolved as follows: If the number of separators before `TZH` in the template string is less than the number of separators before the minus sign in the input string, the minus sign is interpreted as part of `TZH`. Otherwise, the minus sign is considered to be a separator between values. For example, `to_timestamp('2000 -10', 'YYYY TZH')` matches `-10` to `TZH`, but `to_timestamp('2000 -10', 'YYYY TZH')` matches `10` to `TZH`.

- Ordinary text is allowed in `to_char` templates and will be output literally. You can put a substring in double quotes to force it to be interpreted as literal text even if it contains template patterns. For example, in `"Hello Year "YYYY'`, the `YYYY` will be replaced by the year data, but the single `Y` in `Year` will not be. In `to_date`, `to_number`, and `to_timestamp`, literal text and double-quoted strings result in skipping the number of characters contained in the string; for example `"XX"` skips two input characters (whether or not they are `XX`).

### Tip

Prior to LightDB 12, it was possible to skip arbitrary text in the input string using non-letter or non-digit characters. For example, `to_timestamp('2000y6m1d', 'YYYY-MM-DD')` used to work. Now you can only use letter characters for this purpose. For example, `to_timestamp('2000y6m1d', 'YYYYtMMtDDt')` and `to_timestamp('2000y6m1d', 'YYYY"Y"MM"m"DD"d"')` skip `y`, `m`, and `d`.

- If you want to have a double quote in the output you must precede it with a backslash, for example `'\"YYYY Month\"'`. Backslashes are not otherwise special outside of double-quoted strings. Within a double-quoted string, a backslash causes the next character to be taken literally, whatever it is (but this has no special effect unless the next character is a double quote or another backslash).
- In `to_timestamp` and `to_date`, if the year format specification is less than four digits, e.g., `YYY`, and the supplied year is less than four digits, the year will be adjusted to be nearest to the year 2020, e.g., 95 becomes 1995.
- In `to_timestamp` and `to_date`, negative years are treated as signifying BC. If you write both a negative year and an explicit BC field, you get AD again. An input of year zero is treated as 1 BC.
- In `to_timestamp` and `to_date`, the `YYYY` conversion has a restriction when processing years with more than 4 digits. You must use some non-digit character or template after `YYYY`, otherwise the year is always interpreted as 4 digits. For example (with the year 20000): `to_date('200001131', 'YYYYMMDD')` will be interpreted as a 4-digit year; instead use a non-digit separator after the year, like `to_date('20000-1131', 'YYYY-MMDD')` or `to_date('20000Nov31', 'YYYYMonDD')`.
- In `to_timestamp` and `to_date`, the `CC` (century) field is accepted but ignored if there is a `YYY`, `YYYY` or `Y,YYY` field. If `CC` is used with `YY` or `Y` then the result is computed as that year in the specified century. If the century is specified but the year is not, the first year of the century is assumed.
- In `to_timestamp` and `to_date`, weekday names or numbers (`DAY`, `D`, and related field types) are accepted but are ignored for purposes of computing the result. The same is true for quarter (`Q`) fields.
- In `to_timestamp` and `to_date`, an ISO 8601 week-numbering date (as distinct from a Gregorian date) can be specified in one of two ways:
  - Year, week number, and weekday: for example `to_date('2006-42-4', 'IYYY-IW-ID')` returns the date 2006-10-19. If you omit the weekday it is assumed to be 1 (Monday).
  - Year and day of year: for example `to_date('2006-291', 'IYYY-IDDD')` also returns 2006-10-19.

Attempting to enter a date using a mixture of ISO 8601 week-numbering fields and Gregorian date fields is nonsensical, and will cause an error. In the context of an ISO 8601 week-numbering year, the concept of a “month” or “day of month” has no meaning. In the context of a Gregorian year, the ISO week has no meaning.

**Caution**

While `to_date` will reject a mixture of Gregorian and ISO week-numbering date fields, `to_char` will not, since output format specifications like `YYYY-MM-DD (IYYY-IDDD)` can be useful. But avoid writing something like `IYYY-MM-DD`; that would yield surprising results near the start of the year. (See Section 9.9.1 for more information.)

- In `to_timestamp`, millisecond (MS) or microsecond (US) fields are used as the seconds digits after the decimal point. For example `to_timestamp('12.3', 'SS.MS')` is not 3 milliseconds, but 300, because the conversion treats it as 12 + 0.3 seconds. So, for the format `SS.MS`, the input values `12.3`, `12.30`, and `12.300` specify the same number of milliseconds. To get three milliseconds, one must write `12.003`, which the conversion treats as 12 + 0.003 = 12.003 seconds.

Here is a more complex example: `to_timestamp('15:12:02.020.001230', 'HH24:MI:SS.MS.US')` is 15 hours, 12 minutes, and 2 seconds + 20 milliseconds + 1230 microseconds = 2.021230 seconds.

- `to_char(..., 'ID')`'s day of the week numbering matches the `extract(isodow from ...)` function, but `to_char(..., 'D')`'s does not match `extract(dow from ...)`'s day numbering.
- `to_char(interval)` formats HH and HH12 as shown on a 12-hour clock, for example zero hours and 36 hours both output as 12, while HH24 outputs the full hour value, which can exceed 23 in an interval value.

Table 9.28 shows the template patterns available for formatting numeric values.

**Table 9.28. Template Patterns for Numeric Formatting**

Pattern	Description
9	digit position (can be dropped if insignificant)
0	digit position (will not be dropped, even if insignificant)
. (period)	decimal point
, (comma)	group (thousands) separator
PR	negative value in angle brackets
S	sign anchored to number (uses locale)
L	currency symbol (uses locale)
D	decimal point (uses locale)
G	group separator (uses locale)
MI	minus sign in specified position (if number < 0)
PL	plus sign in specified position (if number > 0)
SG	plus/minus sign in specified position
RN	Roman numeral (input between 1 and 3999)
TH or th	ordinal number suffix
V	shift specified number of digits (see notes)
EEEE	exponent for scientific notation

Usage notes for numeric formatting:

- 0 specifies a digit position that will always be printed, even if it contains a leading/trailing zero. 9 also specifies a digit position, but if it is a leading zero then it will be replaced by a space, while if it is a trailing zero and fill mode is specified then it will be deleted. (For `to_number()`, these two pattern characters are equivalent.)
- The pattern characters S, L, D, and G represent the sign, currency symbol, decimal point, and thousands separator characters defined by the current locale (see `lc_monetary` and `lc_numeric`). The pattern characters period and comma represent those exact characters, with the meanings of decimal point and thousands separator, regardless of locale.
- If no explicit provision is made for a sign in `to_char()`'s pattern, one column will be reserved for the sign, and it will be anchored to (appear just left of) the number. If S appears just left of some 9's, it will likewise be anchored to the number.
- A sign formatted using SG, PL, or MI is not anchored to the number; for example, `to_char(-12, 'MI9999')` produces '- 12' but `to_char(-12, 'S9999')` produces '-12'. (The Oracle implementation does not allow the use of MI before 9, but rather requires that 9 precede MI.)
- TH does not convert values less than zero and does not convert fractional numbers.
- PL, SG, and TH are LightDB extensions.
- In `to_number`, if non-data template patterns such as L or TH are used, the corresponding number of input characters are skipped, whether or not they match the template pattern, unless they are data characters (that is, digits, sign, decimal point, or comma). For example, TH would skip two non-data characters.
- V with `to_char` multiplies the input values by  $10^n$ , where  $n$  is the number of digits following V. V with `to_number` divides in a similar manner. `to_char` and `to_number` do not support the use of V combined with a decimal point (e.g., `99.9V99` is not allowed).
- EEEE (scientific notation) cannot be used in combination with any of the other formatting patterns or modifiers other than digit and decimal point patterns, and must be at the end of the format string (e.g., `9.99EEEE` is a valid pattern).

Certain modifiers can be applied to any template pattern to alter its behavior. For example, `FM99.99` is the `99.99` pattern with the FM modifier. Table 9.29 shows the modifier patterns for numeric formatting.

**Table 9.29. Template Pattern Modifiers for Numeric Formatting**

Modifier	Description	Example
FM prefix	fill mode (suppress trailing zeroes and padding blanks)	FM99.99
TH suffix	upper case ordinal number suffix	999TH
th suffix	lower case ordinal number suffix	999th

Table 9.30 shows some examples of the use of the `to_char` function.

**Table 9.30. to\_char Examples**

Expression	Result
<code>to_char(current_timestamp, 'Day, DD HH12:MI:SS')</code>	'Tuesday , 06 05:39:18'
<code>to_char(current_timestamp, 'FMDay, FMDD HH12:MI:SS')</code>	'Tuesday, 6 05:39:18'
<code>to_char(-0.1, '99.99')</code>	' -.10'

Expression	Result
to_char(-0.1, 'FM9.99')	'-.1'
to_char(-0.1, 'FM90.99')	'-0.1'
to_char(0.1, '0.9')	' 0.1'
to_char(12, '9990999.9')	' 0012.0'
to_char(12, 'FM9990999.9')	'0012.'
to_char(485, '999')	' 485'
to_char(-485, '999')	'-485'
to_char(485, '9 9 9')	' 4 8 5'
to_char(1485, '9,999')	' 1,485'
to_char(1485, '9G999')	' 1 485'
to_char(148.5, '999.999')	' 148.500'
to_char(148.5, 'FM999.999')	'148.5'
to_char(148.5, 'FM999.990')	'148.500'
to_char(148.5, '999D999')	' 148,500'
to_char(3148.5, '9G999D999')	' 3 148,500'
to_char(-485, '999S')	'485-'
to_char(-485, '999MI')	'485-'
to_char(485, '999MI')	'485 '
to_char(485, 'FM999MI')	'485'
to_char(485, 'PL999')	'+485'
to_char(485, 'SG999')	'+485'
to_char(-485, 'SG999')	'-485'
to_char(-485, '9SG99')	'4-85'
to_char(-485, '999PR')	'<485>'
to_char(485, 'L999')	'DM 485'
to_char(485, 'RN')	' CDLXXXV'
to_char(485, 'FMRN')	'CDLXXXV'
to_char(5.2, 'FMRN')	'V'
to_char(482, '999th')	' 482nd'
to_char(485, '"Good number:"999')	'Good number: 485'
to_char(485.8, '"Pre:"999" Post:" .999')	'Pre: 485 Post: .800'
to_char(12, '99V999')	' 12000'
to_char(12.4, '99V999')	' 12400'
to_char(12.45, '99V9')	' 125'
to_char(0.0004859, '9.99EEEE')	' 4.86e-04'

## 9.9. Date/Time Functions and Operators

Table 9.32 shows the available functions for date/time value processing, with details appearing in the following subsections. Table 9.31 illustrates the behaviors of the basic arithmetic operators (+,

\*, etc.). For formatting functions, refer to Section 9.8. You should be familiar with the background information on date/time data types from Section 8.5.

In addition, the usual comparison operators shown in Table 9.1 are available for the date/time types. Dates and timestamps (with or without time zone) are all comparable, while times (with or without time zone) and intervals can only be compared to other values of the same data type. When comparing a timestamp without time zone to a timestamp with time zone, the former value is assumed to be given in the time zone specified by the `TimeZone` configuration parameter, and is rotated to UTC for comparison to the latter value (which is already in UTC internally). Similarly, a date value is assumed to represent midnight in the `TimeZone` zone when comparing it to a timestamp.

All the functions and operators described below that take `time` or `timestamp` inputs actually come in two variants: one that takes `time with time zone` or `timestamp with time zone`, and one that takes `time without time zone` or `timestamp without time zone`. For brevity, these variants are not shown separately. Also, the `+` and `*` operators come in commutative pairs (for example both `date + integer` and `integer + date`); we show only one of each such pair.

**Table 9.31. Date/Time Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<code>date + integer</code>	→ <code>date</code> Add a number of days to a date	<code>date '2001-09-28' + 7</code> → <code>2001-10-05</code>
<code>date + interval</code>	→ <code>timestamp</code> Add an interval to a date	<code>date '2001-09-28' + interval '1 hour'</code> → <code>2001-09-28 01:00:00</code>
<code>date + time</code>	→ <code>timestamp</code> Add a time-of-day to a date	<code>date '2001-09-28' + time '03:00'</code> → <code>2001-09-28 03:00:00</code>
<code>interval + interval</code>	→ <code>interval</code> Add intervals	<code>interval '1 day' + interval '1 hour'</code> → <code>1 day 01:00:00</code>
<code>timestamp + interval</code>	→ <code>timestamp</code> Add an interval to a timestamp	<code>timestamp '2001-09-28 01:00' + interval '23 hours'</code> → <code>2001-09-29 00:00:00</code>
<code>time + interval</code>	→ <code>time</code> Add an interval to a time	<code>time '01:00' + interval '3 hours'</code> → <code>04:00:00</code>
<code>- interval</code>	→ <code>interval</code> Negate an interval	<code>- interval '23 hours'</code> → <code>-23:00:00</code>
<code>date - date</code>	→ <code>integer</code> Subtract dates, producing the number of days elapsed	<code>date '2001-10-01' - date '2001-09-28'</code> → <code>3</code>
<code>date - integer</code>	→ <code>date</code> Subtract a number of days from a date	



<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
	date - interval → timestamp	date '2001-10-01' - 7 → 2001-09-24
	date - interval → timestamp Subtract an interval from a date	date '2001-09-28' - interval '1 hour' → 2001-09-27 23:00:00
	time - time → interval Subtract times	time '05:00' - time '03:00' → 02:00:00
	time - interval → time Subtract an interval from a time	time '05:00' - interval '2 hours' → 03:00:00
	timestamp - interval → timestamp Subtract an interval from a timestamp	timestamp '2001-09-28 23:00' - interval '23 hours' → 2001-09-28 00:00:00
	interval - interval → interval Subtract intervals	interval '1 day' - interval '1 hour' → 1 day -01:00:00
	timestamp - timestamp → interval Subtract timestamps (converting 24-hour intervals into days, similarly to justify_hours())	timestamp '2001-09-29 03:00' - timestamp '2001-07-27 12:00' → 63 days 15:00:00
	interval * double precision → interval Multiply an interval by a scalar	interval '1 second' * 900 → 00:15:00 interval '1 day' * 21 → 21 days interval '1 hour' * 3.5 → 03:30:00
	interval / double precision → interval Divide an interval by a scalar	interval '1 hour' / 1.5 → 00:40:00

**Table 9.32. Date/Time Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
age(timestamp, timestamp) → interval	Subtract arguments, producing a “symbolic” result that uses years and months, rather than just days	age(timestamp '2001-04-10', timestamp '1957-06-13') → 43 years 9 mons 27 days
age(timestamp) → interval	Subtract argument from current_date (at midnight)	

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
	<code>age(timestamp '1957-06-13')</code>	<code>→ 62 years 6 mons 10 days</code>
	<code>clock_timestamp()</code>	<code>→ timestamp with time zone</code> Current date and time (changes during statement execution); see Section 9.9.4 <code>clock_timestamp() → 2019-12-23 14:39:53.662522-05</code>
	<code>sys_timestamp</code>	<code>→ timestamp with time zone</code> Current date and time (start of current statement); see Section 9.9.4 <code>sys_timestamp → 2019-12-23 14:39:53.662522-05</code>
	<code>sys_timestamp(integer)</code>	<code>→ timestamp with time zone</code> Current date and time (start of current statement); see Section 9.9.4 <code>sys_timestamp(6) → 2019-12-23 14:39:53.662522-05</code>
	<code>current_date</code>	<code>→ date</code> Current date; see Section 9.9.4 <code>current_date → 2019-12-23</code>
	<code>current_date()</code>	<code>→ date</code> Current date, only supported in mysql mode; see Section 9.9.4 <code>current_date() → 2019-12-23</code>
	<code>current_time</code>	<code>→ time with time zone</code> Current time of day; see Section 9.9.4 <code>current_time → 14:39:53.662522-05</code>
	<code>current_time(integer)</code>	<code>→ time with time zone</code> Current time of day, with limited precision; see Section 9.9.4 <code>current_time(2) → 14:39:53.66-05</code>
	<code>current_timestamp</code>	<code>→ timestamp with time zone</code> Current date and time (start of current transaction); see Section 9.9.4 <code>current_timestamp → 2019-12-23 14:39:53.662522-05</code>
	<code>current_timestamp(integer)</code>	<code>→ timestamp with time zone</code> Current date and time (start of current transaction), with limited precision; see Section 9.9.4 <code>current_timestamp(0) → 2019-12-23 14:39:53-05</code>
	<code>date_part(text, timestamp)</code>	<code>→ double precision</code> Get timestamp subfield (equivalent to <code>extract</code> ); see Section 9.9.1 <code>date_part('hour', timestamp '2001-02-16 20:38:40') → 20</code>
	<code>date_part(text, interval)</code>	<code>→ double precision</code> Get interval subfield (equivalent to <code>extract</code> ); see Section 9.9.1 <code>date_part('month', interval '2 years 3 months') → 3</code>
	<code>date_trunc(text, timestamp)</code>	<code>→ timestamp</code> Truncate to specified precision; see Section 9.9.2 <code>date_trunc('hour', timestamp '2001-02-16 20:38:40') → 2001-02-16 20:00:00</code>
	<code>date_trunc(text, timestamp with time zone, text)</code>	<code>→ timestamp with time zone</code>

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
	Truncate to specified precision in the specified time zone; see Section 9.9.2	<code>date_trunc('day', timestampz '2001-02-16 20:38:40+00', 'Australia/Sydney') → 2001-02-16 13:00:00+00</code>
<code>date_trunc ( text, interval ) → interval</code>	Truncate to specified precision; see Section 9.9.2	<code>date_trunc('hour', interval '2 days 3 hours 40 minutes') → 2 days 03:00:00</code>
<code>extract ( field from timestamp ) → double precision</code>	Get timestamp subfield; see Section 9.9.1	<code>extract(hour from timestamp '2001-02-16 20:38:40') → 20</code>
<code>extract ( field from interval ) → double precision</code>	Get interval subfield; see Section 9.9.1	<code>extract(month from interval '2 years 3 months') → 3</code>
<code>isfinite ( date ) → boolean</code>	Test for finite date (not +/-infinity)	<code>isfinite(date '2001-02-16') → true</code>
<code>isfinite ( timestamp ) → boolean</code>	Test for finite timestamp (not +/-infinity)	<code>isfinite(timestamp 'infinity') → false</code>
<code>isfinite ( interval ) → boolean</code>	Test for finite interval (currently always true)	<code>isfinite(interval '4 hours') → true</code>
<code>justify_days ( interval ) → interval</code>	Adjust interval so 30-day time periods are represented as months	<code>justify_days(interval '35 days') → 1 mon 5 days</code>
<code>justify_hours ( interval ) → interval</code>	Adjust interval so 24-hour time periods are represented as days	<code>justify_hours(interval '27 hours') → 1 day 03:00:00</code>
<code>justify_interval ( interval ) → interval</code>	Adjust interval using <code>justify_days</code> and <code>justify_hours</code> , with additional sign adjustments	<code>justify_interval(interval '1 mon -1 hour') → 29 days 23:00:00</code>
<code>localtime → time</code>	Current time of day; see Section 9.9.4	<code>localtime → 14:39:53.662522</code>
<code>localtime ( integer ) → time</code>	Current time of day, with limited precision; see Section 9.9.4	<code>localtime(0) → 14:39:53</code>
<code>localtimestamp → timestamp</code>	Current date and time (start of current transaction); see Section 9.9.4	

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
	<code>localtimestamp</code>	<code>→ 2019-12-23 14:39:53.662522</code>
<code>localtimestamp ( integer )</code>	<code>→ timestamp</code> Current date and time (start of current transaction), with limited precision; see Section 9.9.4	<code>localtimestamp(2) → 2019-12-23 14:39:53.66</code>
<code>sysdate</code>	<code>→ timestamp</code> Current date and time (start of current statement); see Section 9.9.4	<code>sysdate → 2019-12-23 14:39:53</code>
<code>make_date ( year int, month int, day int )</code>	<code>→ date</code> Create date from year, month and day fields	<code>make_date(2013, 7, 15) → 2013-07-15</code>
<code>make_interval ( [ years int [, months int [, weeks int [, days int [, hours int [, mins int [, secs double precision ]]]]] ] )</code>	<code>→ interval</code> Create interval from years, months, weeks, days, hours, minutes and seconds fields, each of which can default to zero	<code>make_interval(days =&gt; 10) → 10 days</code>
<code>make_time ( hour int, min int, sec double precision )</code>	<code>→ time</code> Create time from hour, minute and seconds fields	<code>make_time(8, 15, 23.5) → 08:15:23.5</code>
<code>make_timestamp ( year int, month int, day int, hour int, min int, sec double precision )</code>	<code>→ timestamp</code> Create timestamp from year, month, day, hour, minute and seconds fields	<code>make_timestamp(2013, 7, 15, 8, 15, 23.5) → 2013-07-15 08:15:23.5</code>
<code>make_timestamptz ( year int, month int, day int, hour int, min int, sec double precision [, timezone text ] )</code>	<code>→ timestamp with time zone</code> Create timestamp with time zone from year, month, day, hour, minute and seconds fields; if <i>timezone</i> is not specified, the current time zone is used	<code>make_timestamptz(2013, 7, 15, 8, 15, 23.5) → 2013-07-15 08:15:23.5+01</code>
<code>now ( )</code>	<code>→ timestamp with time zone</code> Current date and time (start of current transaction); see Section 9.9.4	<code>now ( ) → 2019-12-23 14:39:53.662522-05</code>
<code>statement_timestamp ( )</code>	<code>→ timestamp with time zone</code> Current date and time (start of current statement); see Section 9.9.4	<code>statement_timestamp ( ) → 2019-12-23 14:39:53.662522-05</code>
<code>timeofday ( )</code>	<code>→ text</code> Current date and time (like <code>clock_timestamp</code> , but as a text string); see Section 9.9.4	<code>timeofday ( ) → Mon Dec 23 14:39:53.662522 2019 EST</code>
<code>transaction_timestamp ( )</code>	<code>→ timestamp with time zone</code> Current date and time (start of current transaction); see Section 9.9.4	

Function
<b>Description</b> <b>Example(s)</b> transaction_timestamp() → 2019-12-23 14:39:53.662522-05
to_timestamp(double precision) → timestamp with time zone Convert Unix epoch (seconds since 1970-01-01 00:00:00+00) to timestamp with time zone to_timestamp(1284352323) → 2010-09-13 04:32:03+00

In addition to these functions, the SQL OVERLAPS operator is supported:

```
(start1, end1) OVERLAPS (start2, end2)
(start1, length1) OVERLAPS (start2, length2)
```

This expression yields true when two time periods (defined by their endpoints) overlap, false when they do not overlap. The endpoints can be specified as pairs of dates, times, or time stamps; or as a date, time, or time stamp followed by an interval. When a pair of values is provided, either the start or the end can be written first; OVERLAPS automatically takes the earlier value of the pair as the start. Each time period is considered to represent the half-open interval  $start \leq time < end$ , unless  $start$  and  $end$  are equal in which case it represents that single time instant. This means for instance that two time periods with only an endpoint in common do not overlap.

```
SELECT (DATE '2001-02-16', DATE '2001-12-21') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: true
SELECT (DATE '2001-02-16', INTERVAL '100 days') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: false
SELECT (DATE '2001-10-29', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: false
SELECT (DATE '2001-10-30', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: true
```

When adding an interval value to (or subtracting an interval value from) a timestamp with time zone value, the days component advances or decrements the date of the timestamp with time zone by the indicated number of days, keeping the time of day the same. Across daylight saving time changes (when the session time zone is set to a time zone that recognizes DST), this means interval '1 day' does not necessarily equal interval '24 hours'. For example, with the session time zone set to America/Denver:

```
SELECT timestamp with time zone '2005-04-02 12:00:00-07' + interval
       '1 day';
Result: 2005-04-03 12:00:00-06
SELECT timestamp with time zone '2005-04-02 12:00:00-07' + interval
       '24 hours';
Result: 2005-04-03 13:00:00-06
```

This happens because an hour was skipped due to a change in daylight saving time at 2005-04-03 02:00:00 in time zone America/Denver.

Note there can be ambiguity in the months field returned by age because different months have different numbers of days. LightDB's approach uses the month from the earlier of the two dates when calculating partial months. For example, age('2004-06-01', '2004-04-30') uses April to

yield 1 mon 1 day, while using May would yield 1 mon 2 days because May has 31 days, while April has only 30.

Subtraction of dates and timestamps can also be complex. One conceptually simple way to perform subtraction is to convert each value to a number of seconds using `EXTRACT(EPOCH FROM ...)`, then subtract the results; this produces the number of *seconds* between the two values. This will adjust for the number of days in each month, timezone changes, and daylight saving time adjustments. Subtraction of date or timestamp values with the “-” operator returns the number of days (24-hours) and hours/minutes/seconds between the values, making the same adjustments. The `age` function returns years, months, days, and hours/minutes/seconds, performing field-by-field subtraction and then adjusting for negative field values. The following queries illustrate the differences in these approaches. The sample results were produced with `timezone = 'US/Eastern'`; there is a daylight saving time change between the two dates used:

```
SELECT EXTRACT(EPOCH FROM timestampz '2013-07-01 12:00:00') -
       EXTRACT(EPOCH FROM timestampz '2013-03-01 12:00:00');
Result: 10537200
SELECT (EXTRACT(EPOCH FROM timestampz '2013-07-01 12:00:00') -
       EXTRACT(EPOCH FROM timestampz '2013-03-01 12:00:00'))
       / 60 / 60 / 24;
Result: 121.958333333333
SELECT timestampz '2013-07-01 12:00:00' - timestampz '2013-03-01
       12:00:00';
Result: 121 days 23:00:00
SELECT age(timestampz '2013-07-01 12:00:00', timestampz
       '2013-03-01 12:00:00');
Result: 4 mons
```

## 9.9.1. EXTRACT, date\_part

```
EXTRACT(field FROM source)
```

The `extract` function retrieves subfields such as year or hour from date/time values. *source* must be a value expression of type `timestamp`, `time`, or `interval`. (Expressions of type `date` are cast to `timestamp` and can therefore be used as well.) *field* is an identifier or string that selects what field to extract from the source value. The `extract` function returns values of type double precision. The following are valid field names:

`century`

The century

```
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2000-12-16 12:21:13');
Result: 20
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 21
```

The first century starts at 0001-01-01 00:00:00 AD, although they did not know it at the time. This definition applies to all Gregorian calendar countries. There is no century number 0, you go from -1 century to 1 century. If you disagree with this, please write your complaint to: Pope, Cathedral Saint-Peter of Roma, Vatican.

`day`

For `timestamp` values, the day (of the month) field (1–31); for `interval` values, the number of days

```
SELECT EXTRACT(DAY FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 16
```

```
SELECT EXTRACT(DAY FROM INTERVAL '40 days 1 minute');  
Result: 40
```

decade

The year field divided by 10

```
SELECT EXTRACT(DECADE FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 200
```

dow

The day of the week as Sunday (0) to Saturday (6)

```
SELECT EXTRACT(DOW FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 5
```

Note that `extract`'s day of the week numbering differs from that of the `to_char(..., 'D')` function.

doy

The day of the year (1–365/366)

```
SELECT EXTRACT(DOY FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 47
```

epoch

For timestamp with time zone values, the number of seconds since 1970-01-01 00:00:00 UTC (negative for timestamps before that); for date and timestamp values, the nominal number of seconds since 1970-01-01 00:00:00, without regard to timezone or daylight-savings rules; for interval values, the total number of seconds in the interval

```
SELECT EXTRACT(EPOCH FROM TIMESTAMP WITH TIME ZONE '2001-02-16  
20:38:40.12-08');  
Result: 982384720.12
```

```
SELECT EXTRACT(EPOCH FROM TIMESTAMP '2001-02-16 20:38:40.12');  
Result: 982355920.12
```

```
SELECT EXTRACT(EPOCH FROM INTERVAL '5 days 3 hours');  
Result: 442800
```

You can convert an epoch value back to a timestamp with time zone with `to_timestamp`:

```
SELECT to_timestamp(982384720.12);  
Result: 2001-02-17 04:38:40.12+00
```

Beware that applying `to_timestamp` to an epoch extracted from a date or timestamp value could produce a misleading result: the result will effectively assume that the original value had been given in UTC, which might not be the case.

hour

The hour field (0–23)

```
SELECT EXTRACT(HOUR FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 20
```

isodow

The day of the week as Monday (1) to Sunday (7)

```
SELECT EXTRACT(ISODOW FROM TIMESTAMP '2001-02-18 20:38:40');  
Result: 7
```

This is identical to `dow` except for Sunday. This matches the ISO 8601 day of the week numbering.

isoyear

The ISO 8601 week-numbering year that the date falls in (not applicable to intervals)

```
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-01');  
Result: 2005  
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-02');  
Result: 2006
```

Each ISO 8601 week-numbering year begins with the Monday of the week containing the 4th of January, so in early January or late December the ISO year may be different from the Gregorian year. See the `week` field for more information.

julian

The *Julian Date* corresponding to the date or timestamp (not applicable to intervals). Timestamps that are not local midnight result in a fractional value. See Section B.7 for more information.

```
SELECT EXTRACT(JULIAN FROM DATE '2006-01-01');  
Result: 2453737  
SELECT EXTRACT(JULIAN FROM TIMESTAMP '2006-01-01 12:00');  
Result: 2453737.5
```

microseconds

The seconds field, including fractional parts, multiplied by 1 000 000; note that this includes full seconds

```
SELECT EXTRACT(MICROSECONDS FROM TIME '17:12:28.5');  
Result: 28500000
```

millennium

The millennium

```
SELECT EXTRACT(MILLENNIUM FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 3
```

Years in the 1900s are in the second millennium. The third millennium started January 1, 2001.



### milliseconds

The seconds field, including fractional parts, multiplied by 1000. Note that this includes full seconds.

```
SELECT EXTRACT(MILLISECONDS FROM TIME '17:12:28.5');  
Result: 28500
```

### minute

The minutes field (0–59)

```
SELECT EXTRACT(MINUTE FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 38
```

### month

For timestamp values, the number of the month within the year (1–12); for interval values, the number of months, modulo 12 (0–11)

```
SELECT EXTRACT(MONTH FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 2
```

```
SELECT EXTRACT(MONTH FROM INTERVAL '2 years 3 months');  
Result: 3
```

```
SELECT EXTRACT(MONTH FROM INTERVAL '2 years 13 months');  
Result: 1
```

### quarter

The quarter of the year (1–4) that the date is in

```
SELECT EXTRACT(QUARTER FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 1
```

### second

The seconds field, including any fractional seconds

```
SELECT EXTRACT(SECOND FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 40
```

```
SELECT EXTRACT(SECOND FROM TIME '17:12:28.5');  
Result: 28.5
```

### timezone

The time zone offset from UTC, measured in seconds. Positive values correspond to time zones east of UTC, negative values to zones west of UTC. (Technically, LightDB does not use UTC because leap seconds are not handled.)

### timezone\_hour

The hour component of the time zone offset

timezone\_minute

The minute component of the time zone offset

week

The number of the ISO 8601 week-numbering week of the year. By definition, ISO weeks start on Mondays and the first week of a year contains January 4 of that year. In other words, the first Thursday of a year is in week 1 of that year.

In the ISO week-numbering system, it is possible for early-January dates to be part of the 52nd or 53rd week of the previous year, and for late-December dates to be part of the first week of the next year. For example, 2005-01-01 is part of the 53rd week of year 2004, and 2006-01-01 is part of the 52nd week of year 2005, while 2012-12-31 is part of the first week of 2013. It's recommended to use the `isoyear` field together with `week` to get consistent results.

```
SELECT EXTRACT(WEEK FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 7
```

year

The year field. Keep in mind there is no 0 AD, so subtracting BC years from AD years should be done with care.

```
SELECT EXTRACT(YEAR FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 2001
```

### Note

When the input value is +/-Infinity, `extract` returns +/-Infinity for monotonically-increasing fields (`epoch`, `julian`, `year`, `isoyear`, `decade`, `century`, and `millennium`). For other fields, NULL is returned. LightDB versions before 9.6 returned zero for all cases of infinite input.

The `extract` function is primarily intended for computational processing. For formatting date/time values for display, see Section 9.8.

The `date_part` function is modeled on the traditional Ingres equivalent to the SQL-standard function `extract`:

```
date_part('field', source)
```

Note that here the `field` parameter needs to be a string value, not a name. The valid field names for `date_part` are the same as for `extract`.

```
SELECT date_part('day', TIMESTAMP '2001-02-16 20:38:40');
Result: 16
```

```
SELECT date_part('hour', INTERVAL '4 hours 3 minutes');
Result: 4
```

## 9.9.2. date\_trunc

The function `date_trunc` is conceptually similar to the `trunc` function for numbers.

```
date_trunc(field, source [, time_zone ])
```

*source* is a value expression of type `timestamp`, `timestamp with time zone`, or `interval`. (Values of type `date` and `time` are cast automatically to `timestamp` or `interval`, respectively.) *field* selects to which precision to truncate the input value. The return value is likewise of type `timestamp`, `timestamp with time zone`, or `interval`, and it has all fields that are less significant than the selected one set to zero (or one, for day and month).

Valid values for *field* are:

```
microseconds
milliseconds
second
minute
hour
day
week
month
quarter
year
decade
century
millennium
```

When the input value is of type `timestamp with time zone`, the truncation is performed with respect to a particular time zone; for example, truncation to `day` produces a value that is midnight in that zone. By default, truncation is done with respect to the current `TimeZone` setting, but the optional *time\_zone* argument can be provided to specify a different time zone. The time zone name can be specified in any of the ways described in Section 8.5.3.

A time zone cannot be specified when processing `timestamp without time zone` or `interval` inputs. These are always taken at face value.

Examples (assuming the local time zone is `America/New_York`):

```
SELECT date_trunc('hour', TIMESTAMP '2001-02-16 20:38:40');
Result: 2001-02-16 20:00:00
```

```
SELECT date_trunc('year', TIMESTAMP '2001-02-16 20:38:40');
Result: 2001-01-01 00:00:00
```

```
SELECT date_trunc('day', TIMESTAMP WITH TIME ZONE '2001-02-16
20:38:40+00');
Result: 2001-02-16 00:00:00-05
```

```
SELECT date_trunc('day', TIMESTAMP WITH TIME ZONE '2001-02-16
20:38:40+00', 'Australia/Sydney');
Result: 2001-02-16 08:00:00-05
```

```
SELECT date_trunc('hour', INTERVAL '3 days 02:47:33');
Result: 3 days 02:00:00
```

### 9.9.3. AT TIME ZONE

The `AT TIME ZONE` operator converts time stamp *without time zone* to/from time stamp *with time zone*, and time *with time zone* values to different time zones. Table 9.33 shows its variants.

**Table 9.33. AT TIME ZONE Variants**

Operator	Description	Example(s)
<code>timestamp without time zone</code>	<code>AT TIME ZONE zone</code>	<code>timestamp with time zone</code>
	Converts given time stamp <i>without</i> time zone to time stamp <i>with</i> time zone, assuming the given value is in the named time zone.	<code>timestamp '2001-02-16 20:38:40' at time zone 'America/Denver' → 2001-02-17 03:38:40+00</code>
<code>timestamp with time zone</code>	<code>AT TIME ZONE zone</code>	<code>timestamp without time zone</code>
	Converts given time stamp <i>with</i> time zone to time stamp <i>without</i> time zone, as the time would appear in that zone.	<code>timestamp with time zone '2001-02-16 20:38:40-05' at time zone 'America/Denver' → 2001-02-16 18:38:40</code>
<code>time with time zone</code>	<code>AT TIME ZONE zone</code>	<code>time with time zone</code>
	Converts given time <i>with</i> time zone to a new time zone. Since no date is supplied, this uses the currently active UTC offset for the named destination zone.	<code>time with time zone '05:34:17-05' at time zone 'UTC' → 10:34:17+00</code>

In these expressions, the desired time zone *zone* can be specified either as a text value (e.g., 'America/Los\_Angeles') or as an interval (e.g., INTERVAL '-08:00'). In the text case, a time zone name can be specified in any of the ways described in Section 8.5.3. The interval case is only useful for zones that have fixed offsets from UTC, so it is not very common in practice.

Examples (assuming the current TimeZone setting is America/Los\_Angeles):

```
SELECT TIMESTAMP '2001-02-16 20:38:40' AT TIME ZONE 'America/Denver';
Result: 2001-02-16 19:38:40-08
```

```
SELECT TIMESTAMP WITH TIME ZONE '2001-02-16 20:38:40-05' AT TIME ZONE 'America/Denver';
Result: 2001-02-16 18:38:40
```

```
SELECT TIMESTAMP '2001-02-16 20:38:40' AT TIME ZONE 'Asia/Tokyo' AT TIME ZONE 'America/Chicago';
Result: 2001-02-16 05:38:40
```

The first example adds a time zone to a value that lacks it, and displays the value using the current TimeZone setting. The second example shifts the time stamp with time zone value to the specified time zone, and returns the value without a time zone. This allows storage and display of values different from the current TimeZone setting. The third example converts Tokyo time to Chicago time.

The function `timezone(zone, timestamp)` is equivalent to the SQL-conforming construct `timestamp AT TIME ZONE zone`.

## 9.9.4. Current Date/Time

LightDB provides a number of functions that return values related to the current date and time. These SQL-standard functions all return values based on the start time of the current transaction:

CURRENT\_DATE  
CURRENT\_DATE()  
CURRENT\_TIME  
CURRENT\_TIMESTAMP  
CURRENT\_TIME(*precision*)  
CURRENT\_TIMESTAMP(*precision*)  
LOCALTIME  
LOCALTIMESTAMP  
LOCALTIME(*precision*)  
LOCALTIMESTAMP(*precision*)  
SYSDATE  
SYSTIMESTAMP  
SYSTIMESTAMP(*precision*)

CURRENT\_TIME and CURRENT\_TIMESTAMP and SYSTIMESTAMP deliver values with time zone; SYSDATE and LOCALTIME and LOCALTIMESTAMP deliver values without time zone.

CURRENT\_TIME, CURRENT\_TIMESTAMP, LOCALTIME, and LOCALTIMESTAMP SYSDATE can optionally take a precision parameter, which causes the result to be rounded to that many fractional digits in the seconds field. Without a precision parameter, the result is given to the full available precision.

CURRENT\_DATE() is same with CURRENT\_DATE.

Some examples:

```
SELECT CURRENT_TIME;  
Result: 14:39:53.662522-05
```

```
SELECT CURRENT_DATE;  
Result: 2019-12-23
```

```
SELECT CURRENT_DATE();  
Result: 2019-12-23
```

```
SELECT CURRENT_TIMESTAMP;  
Result: 2019-12-23 14:39:53.662522-05
```

```
SELECT CURRENT_TIMESTAMP(2);  
Result: 2019-12-23 14:39:53.66-05
```

```
SELECT LOCALTIMESTAMP;  
Result: 2019-12-23 14:39:53.662522
```

```
SELECT SYSDATE;  
Result: 2019-12-23 14:39:53
```

```
SELECT SYSTIMESTAMP;  
Result: 2019-12-23 14:39:53.662522-05
```

```
SELECT SYSTIMESTAMP(6);  
Result: 2019-12-23 14:39:53.662522-05
```

Since these functions return the start time of the current transaction, their values do not change during the transaction. This is considered a feature: the intent is to allow a single transaction to have a consistent notion of the “current” time, so that multiple modifications within the same transaction bear the same time stamp.

**Note**

Other database systems might advance these values more frequently.

LightDB also provides functions that return the start time of the current statement, as well as the actual current time at the instant the function is called. The complete list of non-SQL-standard time functions is:

```
transaction_timestamp()
statement_timestamp()
clock_timestamp()
timeofday()
now()
```

`transaction_timestamp()` is equivalent to `CURRENT_TIMESTAMP`, but is named to clearly reflect what it returns. `statement_timestamp()` returns the start time of the current statement (more specifically, the time of receipt of the latest command message from the client). `statement_timestamp()` and `transaction_timestamp()` return the same value during the first command of a transaction, but might differ during subsequent commands. `clock_timestamp()` returns the actual current time, and therefore its value changes even within a single SQL command. `timeofday()` is a historical LightDB function. Like `clock_timestamp()`, it returns the actual current time, but as a formatted text string rather than a timestamp with time zone value. `now()` is a traditional LightDB equivalent to `transaction_timestamp()`.

All the date/time data types also accept the special literal value `now` to specify the current date and time (again, interpreted as the transaction start time). Thus, the following three all return the same result:

```
SELECT CURRENT_TIMESTAMP;
SELECT now();
SELECT TIMESTAMP 'now'; -- but see tip below
```

**Tip**

Do not use the third form when specifying a value to be evaluated later, for example in a `DEFAULT` clause for a table column. The system will convert `now` to a `timestamp` as soon as the constant is parsed, so that when the default value is needed, the time of the table creation would be used! The first two forms will not be evaluated until the default value is used, because they are function calls. Thus they will give the desired behavior of defaulting to the time of row insertion. (See also Section 8.5.1.4.)

### 9.9.5. nls\_date\_format/nls\_timestamp\_format

Only in Oracle compatible mode, `lightdb` can configure `nls_date_format/nls_timestamp_format` parameter sets the display output format of `sysdate` and `systimestamp`.

You must set a `sysdate/systimestamp` format for the `nls_date_format/nls_timestamp_format` variable in advance. A setting example using the `SET` statement is shown below.

```
SET nls_date_format = 'YYYY/MM/DD HH24:MI:SS';
SET nls_timestamp_format = 'YYYY/MM/DD HH24:MI:SS.FF6TZH';
```

Table 9.34 shows the template patterns available for formatting `sysdate` and `systimestamp` values.

**Table 9.34. Template Patterns for nls\_date\_format/nls\_timestamp\_format Formatting**

Pattern	Description
HH	hour of day (01–12)
HH12	hour of day (01–12)
HH24	hour of day (00–23)
MI	minute (00–59)
SS	second (00–59)
MS	millisecond (000–999)
US	microsecond (000000–999999)
FF1	tenth of second (0–9)
FF2	hundredth of second (00–99)
FF3	millisecond (000–999)
FF4	tenth of a millisecond (0000–9999)
FF5	hundredth of a millisecond (00000–99999)
FF6	microsecond (000000–999999)
SSSS, SSSSS	seconds past midnight (0–86399)
AM, am, PM or pm	meridiem indicator (without periods)
A.M., a.m., P.M. or p.m.	meridiem indicator (with periods)
Y, YYYY	year (4 or more digits) with comma
YYYY	year (4 or more digits)
YYY	last 3 digits of year
YY	last 2 digits of year
Y	last digit of year
IYYY	ISO 8601 week-numbering year (4 or more digits)
IYY	last 3 digits of ISO 8601 week-numbering year
IY	last 2 digits of ISO 8601 week-numbering year
I	last digit of ISO 8601 week-numbering year
BC, bc, AD or ad	era indicator (without periods)
B.C., b.c., A.D. or a.d.	era indicator (with periods)
MONTH	full upper case month name (blank-padded to 9 chars)
Month	full capitalized month name (blank-padded to 9 chars)
month	full lower case month name (blank-padded to 9 chars)
MON	abbreviated upper case month name (3 chars in English, localized lengths vary)
Mon	abbreviated capitalized month name (3 chars in English, localized lengths vary)
mon	abbreviated lower case month name (3 chars in English, localized lengths vary)
MM	month number (01–12)

Pattern	Description
DAY	full upper case day name (blank-padded to 9 chars)
Day	full capitalized day name (blank-padded to 9 chars)
day	full lower case day name (blank-padded to 9 chars)
DY	abbreviated upper case day name (3 chars in English, localized lengths vary)
Dy	abbreviated capitalized day name (3 chars in English, localized lengths vary)
dy	abbreviated lower case day name (3 chars in English, localized lengths vary)
DDD	day of year (001–366)
IDDD	day of ISO 8601 week-numbering year (001–371; day 1 of the year is Monday of the first ISO week)
DD	day of month (01–31)
D	day of the week, Sunday (1) to Saturday (7)
ID	ISO 8601 day of the week, Monday (1) to Sunday (7)
W	week of month (1–5) (the first week starts on the first day of the month)
WW	week number of year (1–53) (the first week starts on the first day of the year)
IW	week number of ISO 8601 week-numbering year (01–53; the first Thursday of the year is in week 1)
CC	century (2 digits) (the twenty-first century starts on 2001-01-01)
J	Julian Date (integer days since November 24, 4714 BC at local midnight; see Section B.7)
Q	quarter
RM	month in upper case Roman numerals (I–XII; I=January)
rm	month in lower case Roman numerals (i–xii; i=January)
TZ	upper case time-zone abbreviation
tz	lower case time-zone abbreviation
TZH	time-zone hours
TZM	time-zone minutes
OF	time-zone offset from UTC

## 9.9.6. Delaying Execution

The following functions are available to delay execution of the server process:

```
pg_sleep ( double precision )
```



```
pg_sleep_for ( interval )
pg_sleep_until ( timestamp with time zone )
```

`pg_sleep` makes the current session's process sleep until the given number of seconds have elapsed. Fractional-second delays can be specified. `pg_sleep_for` is a convenience function to allow the sleep time to be specified as an `interval`. `pg_sleep_until` is a convenience function for when a specific wake-up time is desired. For example:

```
SELECT pg_sleep(1.5);
SELECT pg_sleep_for('5 minutes');
SELECT pg_sleep_until('tomorrow 03:00');
```

**Note**

The effective resolution of the sleep interval is platform-specific; 0.01 seconds is a common value. The sleep delay will be at least as long as specified. It might be longer depending on factors such as server load. In particular, `pg_sleep_until` is not guaranteed to wake up exactly at the specified time, but it will not wake up any earlier.

**Warning**

Make sure that your session does not hold more locks than necessary when calling `pg_sleep` or its variants. Otherwise other sessions might have to wait for your sleeping process, slowing down the entire system.

## 9.10. Enum Support Functions

For enum types (described in Section 8.7), there are several functions that allow cleaner programming without hard-coding particular values of an enum type. These are listed in Table 9.35. The examples assume an enum type created as:

```
CREATE TYPE rainbow AS ENUM ('red', 'orange', 'yellow', 'green',
    'blue', 'purple');
```

**Table 9.35. Enum Support Functions**

Function	Description	Example(s)
<code>enum_first ( anyenum )</code>	→ anyenum	Returns the first value of the input enum type. <code>enum_first(null::rainbow) → red</code>
<code>enum_last ( anyenum )</code>	→ anyenum	Returns the last value of the input enum type. <code>enum_last(null::rainbow) → purple</code>
<code>enum_range ( anyenum )</code>	→ anyarray	Returns all values of the input enum type in an ordered array. <code>enum_range(null::rainbow) → {red, orange, yellow, green, blue, purple}</code>

Function
<p><b>Description</b> <b>Example(s)</b></p>
<pre>enum_range ( anyenum, anyenum ) → anyarray Returns the range between the two given enum values, as an ordered array. The values must be from the same enum type. If the first parameter is null, the result will start with the first value of the enum type. If the second parameter is null, the result will end with the last value of the enum type.  enum_range( 'orange'::rainbow, 'green'::rainbow ) → {orange,yellow,green}  enum_range(NULL, 'green'::rainbow) → {red,orange, yellow,green}  enum_range( 'orange'::rainbow, NULL ) → {orange,yellow,green, blue,purple}</pre>

Notice that except for the two-argument form of `enum_range`, these functions disregard the specific value passed to them; they care only about its declared data type. Either null or a specific value of the type can be passed, with the same result. It is more common to apply these functions to a table column or function argument than to a hardwired type name as used in the examples.

## 9.11. Geometric Functions and Operators

The geometric types `point`, `box`, `lseg`, `line`, `path`, `polygon`, and `circle` have a large set of native support functions and operators, shown in Table 9.36, Table 9.37, and Table 9.38.

**Table 9.36. Geometric Operators**

Operator
<p><b>Description</b> <b>Example(s)</b></p>
<pre><i>geometric_type</i> + point → <i>geometric_type</i> Adds the coordinates of the second point to those of each point of the first argument, thus performing translation. Available for point, box, path, circle. box '(1,1),(0,0)' + point '(2,0)' → (3,1),(2,0)</pre>
<pre>path + path → path Concatenates two open paths (returns NULL if either path is closed). path '[(0,0),(1,1)]' + path '[(2,2),(3,3),(4,4)]' → [(0,0), (1,1),(2,2),(3,3),(4,4)]</pre>
<pre><i>geometric_type</i> - point → <i>geometric_type</i> Subtracts the coordinates of the second point from those of each point of the first argument, thus performing translation. Available for point, box, path, circle. box '(1,1),(0,0)' - point '(2,0)' → (-1,1),(-2,0)</pre>
<pre><i>geometric_type</i> * point → <i>geometric_type</i> Multiplies each point of the first argument by the second point (treating a point as being a complex number represented by real and imaginary parts, and performing standard complex multiplication). If one interprets the second point as a vector, this is equivalent to scaling the object's size and distance from the origin by the length of the vector, and rotating it counterclockwise around the origin by the vector's angle from the x axis. Available for point, box,<sup>a</sup> path, circle. path '((0,0),(1,0),(1,1))' * point '(3.0,0)' → ((0,0),(3,0), (3,3))</pre>

<b>Operator</b>	<b>Description</b> <b>Example(s)</b>
	<pre>path '((0,0),(1,0),(1,1))' * point(cosd(45), sind(45)) → ((0,0),(0.7071067811865475,0.7071067811865475), (0,1.414213562373095))</pre>
	<p><i>geometric_type</i> / <i>point</i> → <i>geometric_type</i></p> <p>Divides each point of the first argument by the second point (treating a point as being a complex number represented by real and imaginary parts, and performing standard complex division). If one interprets the second point as a vector, this is equivalent to scaling the object's size and distance from the origin down by the length of the vector, and rotating it clockwise around the origin by the vector's angle from the <i>x</i> axis. Available for <i>point</i>, <i>box</i>,<sup>a</sup> <i>path</i>, <i>circle</i>.</p> <pre>path '((0,0),(1,0),(1,1))' / point '(2.0,0)' → ((0,0), (0.5,0),(0.5,0.5)) path '((0,0),(1,0),(1,1))' / point(cosd(45), sind(45)) → ((0,0),(0.7071067811865476,-0.7071067811865476), (1.4142135623730951,0))</pre>
	<p>@-@ <i>geometric_type</i> → double precision</p> <p>Computes the total length. Available for <i>lseg</i>, <i>path</i>.</p> <pre>@-@ path '((0,0),(1,0),(1,1))' → 2</pre>
	<p>@@ <i>geometric_type</i> → point</p> <p>Computes the center point. Available for <i>box</i>, <i>lseg</i>, <i>polygon</i>, <i>circle</i>.</p> <pre>@@ box '(2,2),(0,0)' → (1,1)</pre>
	<p># <i>geometric_type</i> → integer</p> <p>Returns the number of points. Available for <i>path</i>, <i>polygon</i>.</p> <pre># path '((1,0),(0,1),(-1,0))' → 3</pre>
	<p><i>geometric_type</i> # <i>geometric_type</i> → point</p> <p>Computes the point of intersection, or NULL if there is none. Available for <i>lseg</i>, <i>line</i>.</p> <pre>lseg '((0,0),(1,1))' # lseg '((1,0),(0,1))' → (0.5,0.5)</pre>
	<p><i>box</i> # <i>box</i> → <i>box</i></p> <p>Computes the intersection of two boxes, or NULL if there is none.</p> <pre>box '(2,2),(-1,-1)' # box '(1,1),(-2,-2)' → (1,1),(-1,-1)</pre>
	<p><i>geometric_type</i> ## <i>geometric_type</i> → point</p> <p>Computes the closest point to the first object on the second object. Available for these pairs of types: (<i>point</i>, <i>box</i>), (<i>point</i>, <i>lseg</i>), (<i>point</i>, <i>line</i>), (<i>lseg</i>, <i>box</i>), (<i>lseg</i>, <i>lseg</i>), (<i>line</i>, <i>lseg</i>).</p> <pre>point '(0,0)' ## lseg '((2,0),(0,2))' → (1,1)</pre>
	<p><i>geometric_type</i> &lt;-&gt; <i>geometric_type</i> → double precision</p> <p>Computes the distance between the objects. Available for all geometric types except <i>polygon</i>, for all combinations of <i>point</i> with another geometric type, and for these additional pairs of types: (<i>box</i>, <i>lseg</i>), (<i>lseg</i>, <i>line</i>), (<i>polygon</i>, <i>circle</i>) (and the commutator cases).</p> <pre>circle '&lt;(0,0),1&gt;' &lt;-&gt; circle '&lt;(5,0),1&gt;' → 3</pre>
	<p><i>geometric_type</i> @&gt; <i>geometric_type</i> → boolean</p>

<b>Operator</b>	<b>Description</b> <b>Example(s)</b>
	Does first object contain second? Available for these pairs of types: (box, point), (box, box), (path, point), (polygon, point), (polygon, polygon), (circle, point), (circle, circle). circle '<(0,0),2>' @> point '(1,1)' → t
<i>geometric_type</i> <@ <i>geometric_type</i>	→ boolean Is first object contained in or on second? Available for these pairs of types: (point, box), (point, lseg), (point, line), (point, path), (point, polygon), (point, circle), (box, box), (lseg, box), (lseg, line), (polygon, polygon), (circle, circle). point '(1,1)' <@ circle '<(0,0),2>' → t
<i>geometric_type</i> && <i>geometric_type</i>	→ boolean Do these objects overlap? (One point in common makes this true.) Available for box, polygon, circle. box '(1,1),(0,0)' && box '(2,2),(0,0)' → t
<i>geometric_type</i> << <i>geometric_type</i>	→ boolean Is first object strictly left of second? Available for point, box, polygon, circle. circle '<(0,0),1>' << circle '<(5,0),1>' → t
<i>geometric_type</i> >> <i>geometric_type</i>	→ boolean Is first object strictly right of second? Available for point, box, polygon, circle. circle '<(5,0),1>' >> circle '<(0,0),1>' → t
<i>geometric_type</i> &< <i>geometric_type</i>	→ boolean Does first object not extend to the right of second? Available for box, polygon, circle. box '(1,1),(0,0)' &< box '(2,2),(0,0)' → t
<i>geometric_type</i> &> <i>geometric_type</i>	→ boolean Does first object not extend to the left of second? Available for box, polygon, circle. box '(3,3),(0,0)' &> box '(2,2),(0,0)' → t
<i>geometric_type</i> <<  <i>geometric_type</i>	→ boolean Is first object strictly below second? Available for box, polygon, circle. box '(3,3),(0,0)' <<  box '(5,5),(3,4)' → t
<i>geometric_type</i>  >> <i>geometric_type</i>	→ boolean Is first object strictly above second? Available for box, polygon, circle. box '(5,5),(3,4)'  >> box '(3,3),(0,0)' → t
<i>geometric_type</i> &<  <i>geometric_type</i>	→ boolean Does first object not extend above second? Available for box, polygon, circle. box '(1,1),(0,0)' &<  box '(2,2),(0,0)' → t
<i>geometric_type</i>  &> <i>geometric_type</i>	→ boolean Does first object not extend below second? Available for box, polygon, circle. box '(3,3),(0,0)'  &> box '(2,2),(0,0)' → t
box <^ box	→ boolean Is first object below second (allows edges to touch)?

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
		<code>box '((1,1),(0,0))' &lt;^ box '((2,2),(1,1))' → t</code>
<code>point &lt;^ point</code>	→ boolean Is first object strictly below second? (This operator is misnamed; it should be << .)	<code>point '(1,0)' &lt;^ point '(1,1)' → t</code>
<code>box &gt;^ box</code>	→ boolean Is first object above second (allows edges to touch)?	<code>box '((2,2),(1,1))' &gt;^ box '((1,1),(0,0))' → t</code>
<code>point &gt;^ point</code>	→ boolean Is first object strictly above second? (This operator is misnamed; it should be  >>.)	<code>point '(1,1)' &gt;^ point '(1,0)' → t</code>
<code>geometric_type ?# geometric_type</code>	→ boolean Do these objects intersect? Available for these pairs of types: (box, box), (lseg, box), (lseg, lseg), (lseg, line), (line, box), (line, line), (path, path).	<code>lseg '((-1,0),(1,0))' ?# box '(2,2),(-2,-2)' → t</code>
<code>?- line</code>	→ boolean	
<code>?- lseg</code>	→ boolean Is line horizontal?	<code>?- lseg '((-1,0),(1,0))' → t</code>
<code>point ?- point</code>	→ boolean Are points horizontally aligned (that is, have same y coordinate)?	<code>point '(1,0)' ?- point '(0,0)' → t</code>
<code>?  line</code>	→ boolean	
<code>?  lseg</code>	→ boolean Is line vertical?	<code>?  lseg '((-1,0),(1,0))' → f</code>
<code>point ?  point</code>	→ boolean Are points vertically aligned (that is, have same x coordinate)?	<code>point '(0,1)' ?  point '(0,0)' → t</code>
<code>line ?-  line</code>	→ boolean	
<code>lseg ?-  lseg</code>	→ boolean Are lines perpendicular?	<code>lseg '((0,0),(0,1))' ?-  lseg '((0,0),(1,0))' → t</code>
<code>line ?   line</code>	→ boolean	
<code>lseg ?   lseg</code>	→ boolean Are lines parallel?	<code>lseg '((-1,0),(1,0))' ?   lseg '((-1,2),(1,2))' → t</code>
<code>geometric_type ~= geometric_type</code>	→ boolean Are these objects the same? Available for point, box, polygon, circle.	<code>polygon '((0,0),(1,1))' ~= polygon '((1,1),(0,0))' → t</code>

<sup>a</sup>“Rotating” a box with these operators only moves its corner points: the box is still considered to have sides parallel to the axes. Hence the box’s size is not preserved, as a true rotation would do.

### Caution

Note that the “same as” operator, `~=`, represents the usual notion of equality for the `point`, `box`, `polygon`, and `circle` types. Some of the geometric types also have an `=` operator, but `=` compares for equal *areas* only. The other scalar comparison operators (`<=` and so on), where available for these types, likewise compare areas.

### Note

Before LightDB 8.2, the containment operators `@>` and `<@` were respectively called `~` and `@`. These names are still available, but are deprecated and will eventually be removed.

**Table 9.37. Geometric Functions**

Function	Description	Example(s)
<code>area</code>	<code>(geometric_type) → double precision</code> Computes area. Available for <code>box</code> , <code>path</code> , <code>circle</code> . A <code>path</code> input must be closed, else <code>NULL</code> is returned. Also, if the <code>path</code> is self-intersecting, the result may be meaningless.	<code>area(box '(2,2),(0,0)') → 4</code>
<code>center</code>	<code>(geometric_type) → point</code> Computes center point. Available for <code>box</code> , <code>circle</code> .	<code>center(box '(1,2),(0,0)') → (0.5,1)</code>
<code>diagonal</code>	<code>(box) → lseg</code> Extracts <code>box</code> 's diagonal as a line segment (same as <code>lseg(box)</code> ).	<code>diagonal(box '(1,2),(0,0)') → [(1,2),(0,0)]</code>
<code>diameter</code>	<code>(circle) → double precision</code> Computes diameter of circle.	<code>diameter(circle '&lt;(0,0),2&gt;') → 4</code>
<code>height</code>	<code>(box) → double precision</code> Computes vertical size of <code>box</code> .	<code>height(box '(1,2),(0,0)') → 2</code>
<code>isclosed</code>	<code>(path) → boolean</code> Is path closed?	<code>isclosed(path '((0,0),(1,1),(2,0))') → t</code>
<code>isopen</code>	<code>(path) → boolean</code> Is path open?	<code>isopen(path '[(0,0),(1,1),(2,0)]') → t</code>
<code>length</code>	<code>(geometric_type) → double precision</code> Computes the total length. Available for <code>lseg</code> , <code>path</code> .	<code>length(path '((-1,0),(1,0))') → 4</code>
<code>npoints</code>	<code>(geometric_type) → integer</code>	

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
	Returns the number of points. Available for path, polygon.	<code>npoints(path '(0,0),(1,1),(2,0)') → 3</code>
<code>pclose(path) → path</code>	Converts path to closed form.	<code>pclose(path '(0,0),(1,1),(2,0)') → ((0,0),(1,1),(2,0))</code>
<code>popen(path) → path</code>	Converts path to open form.	<code>popen(path '((0,0),(1,1),(2,0))') → [(0,0),(1,1),(2,0)]</code>
<code>radius(circle) → double precision</code>	Computes radius of circle.	<code>radius(circle '&lt;(0,0),2&gt;') → 2</code>
<code>slope(point,point) → double precision</code>	Computes slope of a line drawn through the two points.	<code>slope(point '(0,0)', point '(2,1)') → 0.5</code>
<code>width(box) → double precision</code>	Computes horizontal size of box.	<code>width(box '(1,2),(0,0)') → 1</code>

**Table 9.38. Geometric Type Conversion Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>box(circle) → box</code>	Computes box inscribed within the circle.	<code>box(circle '&lt;(0,0),2&gt;') → (1.414213562373095,1.414213562373095), (-1.414213562373095,-1.414213562373095)</code>
<code>box(point) → box</code>	Converts point to empty box.	<code>box(point '(1,0)') → (1,0),(1,0)</code>
<code>box(point,point) → box</code>	Converts any two corner points to box.	<code>box(point '(0,1)', point '(1,0)') → (1,1),(0,0)</code>
<code>box(polygon) → box</code>	Computes bounding box of polygon.	<code>box(polygon '((0,0),(1,1),(2,0))') → (2,1),(0,0)</code>
<code>bound_box(box,box) → box</code>	Computes bounding box of two boxes.	<code>bound_box(box '(1,1),(0,0)', box '(4,4),(3,3)') → (4,4),(0,0)</code>
<code>circle(box) → circle</code>	Computes smallest circle enclosing box.	

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
		<code>circle(box '(1,1),(0,0)') → &lt;(0.5,0.5),0.7071067811865476&gt;</code>
<code>circle(point, double precision)</code>	Constructs circle from center and radius.	<code>circle(point '(0,0)', 2.0) → &lt;(0,0),2&gt;</code>
<code>circle(polygon)</code>	Converts polygon to circle. The circle's center is the mean of the positions of the polygon's points, and the radius is the average distance of the polygon's points from that center.	<code>circle(polygon '((0,0),(1,3),(2,0))') → &lt;(1,1),1.6094757082487299&gt;</code>
<code>line(point, point)</code>	Converts two points to the line through them.	<code>line(point '(-1,0)', point '(1,0)') → {0,-1,0}</code>
<code>lseg(box)</code>	Extracts box's diagonal as a line segment.	<code>lseg(box '(1,0),(-1,0)') → [(1,0),(-1,0)]</code>
<code>lseg(point, point)</code>	Constructs line segment from two endpoints.	<code>lseg(point '(-1,0)', point '(1,0)') → [(-1,0),(1,0)]</code>
<code>path(polygon)</code>	Converts polygon to a closed path with the same list of points.	<code>path(polygon '((0,0),(1,1),(2,0))') → ((0,0),(1,1),(2,0))</code>
<code>point(double precision, double precision)</code>	Constructs point from its coordinates.	<code>point(23.4, -44.5) → (23.4,-44.5)</code>
<code>point(box)</code>	Computes center of box.	<code>point(box '(1,0),(-1,0)') → (0,0)</code>
<code>point(circle)</code>	Computes center of circle.	<code>point(circle '&lt;(0,0),2&gt;') → (0,0)</code>
<code>point(lseg)</code>	Computes center of line segment.	<code>point(lseg '[(-1,0),(1,0)]') → (0,0)</code>
<code>point(polygon)</code>	Computes center of polygon (the mean of the positions of the polygon's points).	<code>point(polygon '((0,0),(1,1),(2,0))') → (1,0.3333333333333333)</code>
<code>polygon(box)</code>	Converts box to a 4-point polygon.	<code>polygon(box '(1,1),(0,0)') → ((0,0),(0,1),(1,1),(1,0))</code>



Function
<p><b>Description</b> <b>Example(s)</b></p> <p><code>polygon ( circle ) → polygon</code>                      Converts circle to a 12-point polygon.</p> <pre> polygon(circle '&lt;(0,0),2&gt;') → ((-2,0), (-1.7320508075688774,0.9999999999999999), (-1.0000000000000002,1.7320508075688772), (-1.2246063538223773e-16,2), (0.9999999999999996,1.7320508075688774), (1.732050807568877,1.0000000000000007), (2,2.4492127076447545e-16), (1.7320508075688776,-0.9999999999999994), (1.0000000000000009,-1.7320508075688767), (3.673819061467132e-16,-2), (-0.9999999999999987,-1.732050807568878), (-1.7320508075688767,-1.0000000000000009))                     </pre>
<p><code>polygon ( integer, circle ) → polygon</code>                      Converts circle to an <i>n</i>-point polygon.</p> <pre> polygon(4, circle '&lt;(3,0),1&gt;') → ((2,0),(3,1), (4,1.2246063538223773e-16),(3,-1))                     </pre>
<p><code>polygon ( path ) → polygon</code>                      Converts closed path to a polygon with the same list of points.</p> <pre> polygon(path '((0,0),(1,1),(2,0))') → ((0,0),(1,1),(2,0))                     </pre>

It is possible to access the two component numbers of a point as though the point were an array with indexes 0 and 1. For example, if `t.p` is a point column then `SELECT p[0] FROM t` retrieves the X coordinate and `UPDATE t SET p[1] = ...` changes the Y coordinate. In the same way, a value of type `box` or `lseg` can be treated as an array of two point values.

## 9.12. Network Address Functions and Operators

The IP network address types, `cidr` and `inet`, support the usual comparison operators shown in Table 9.1 as well as the specialized operators and functions shown in Table 9.39 and Table 9.40.

Any `cidr` value can be cast to `inet` implicitly; therefore, the operators and functions shown below as operating on `inet` also work on `cidr` values. (Where there are separate functions for `inet` and `cidr`, it is because the behavior should be different for the two cases.) Also, it is permitted to cast an `inet` value to `cidr`. When this is done, any bits to the right of the netmask are silently zeroed to create a valid `cidr` value.

**Table 9.39. IP Address Operators**

Operator
<p><b>Description</b> <b>Example(s)</b></p> <p><code>inet &lt;&lt; inet → boolean</code></p> <p>Is subnet strictly contained by subnet? This operator, and the next four, test for subnet inclusion. They consider only the network parts of the two addresses (ignoring any bits to the right of the netmasks) and determine whether one network is identical to or a subnet of the other.</p> <pre> inet '192.168.1.5' &lt;&lt; inet '192.168.1/24' → t                     </pre>

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
		<pre>inet '192.168.0.5' &lt;&lt; inet '192.168.1/24' → f inet '192.168.1/24' &lt;&lt; inet '192.168.1/24' → f</pre>
	<pre>inet &lt;= inet → boolean Is subnet contained by or equal to subnet?</pre>	<pre>inet '192.168.1/24' &lt;= inet '192.168.1/24' → t</pre>
	<pre>inet &gt;&gt; inet → boolean Does subnet strictly contain subnet?</pre>	<pre>inet '192.168.1/24' &gt;&gt; inet '192.168.1.5' → t</pre>
	<pre>inet &gt;= inet → boolean Does subnet contain or equal subnet?</pre>	<pre>inet '192.168.1/24' &gt;= inet '192.168.1/24' → t</pre>
	<pre>inet &amp;&amp; inet → boolean Does either subnet contain or equal the other?</pre>	<pre>inet '192.168.1/24' &amp;&amp; inet '192.168.1.80/28' → t inet '192.168.1/24' &amp;&amp; inet '192.168.2.0/28' → f</pre>
	<pre>~ inet → inet Computes bitwise NOT.</pre>	<pre>~ inet '192.168.1.6' → 63.87.254.249</pre>
	<pre>inet &amp; inet → inet Computes bitwise AND.</pre>	<pre>inet '192.168.1.6' &amp; inet '0.0.0.255' → 0.0.0.6</pre>
	<pre>inet   inet → inet Computes bitwise OR.</pre>	<pre>inet '192.168.1.6'   inet '0.0.0.255' → 192.168.1.255</pre>
	<pre>inet + bigint → inet Adds an offset to an address.</pre>	<pre>inet '192.168.1.6' + 25 → 192.168.1.31</pre>
	<pre>bigint + inet → inet Adds an offset to an address.</pre>	<pre>200 + inet '::ffff:fff0:1' → ::ffff:255.240.0.201</pre>
	<pre>inet - bigint → inet Subtracts an offset from an address.</pre>	<pre>inet '192.168.1.43' - 36 → 192.168.1.7</pre>
	<pre>inet - inet → bigint Computes the difference of two addresses.</pre>	<pre>inet '192.168.1.43' - inet '192.168.1.19' → 24 inet ':::1' - inet ':::ffff:1' → -4294901760</pre>

**Table 9.40. IP Address Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>abbrev ( inet )</code>	Creates an abbreviated display format as text. (The result is the same as the <code>inet</code> output function produces; it is “abbreviated” only in comparison to the result of an explicit cast to <code>text</code> , which for historical reasons will never suppress the netmask part.)	<code>abbrev ( inet '10.1.0.0/32' ) → 10.1.0.0</code>
<code>abbrev ( cidr )</code>	Creates an abbreviated display format as text. (The abbreviation consists of dropping all-zero octets to the right of the netmask; more examples are in Table 8.22.)	<code>abbrev ( cidr '10.1.0.0/16' ) → 10.1/16</code>
<code>broadcast ( inet )</code>	Computes the broadcast address for the address's network.	<code>broadcast ( inet '192.168.1.5/24' ) → 192.168.1.255/24</code>
<code>family ( inet )</code>	Returns the address's family: 4 for IPv4, 6 for IPv6.	<code>family ( inet ':::1' ) → 6</code>
<code>host ( inet )</code>	Returns the IP address as text, ignoring the netmask.	<code>host ( inet '192.168.1.0/24' ) → 192.168.1.0</code>
<code>hostmask ( inet )</code>	Computes the host mask for the address's network.	<code>hostmask ( inet '192.168.23.20/30' ) → 0.0.0.3</code>
<code>inet_merge ( inet, inet )</code>	Computes the smallest network that includes both of the given networks.	<code>inet_merge ( inet '192.168.1.5/24', inet '192.168.2.5/24' ) → 192.168.0.0/22</code>
<code>inet_same_family ( inet, inet )</code>	Tests whether the addresses belong to the same IP family.	<code>inet_same_family ( inet '192.168.1.5/24', inet ':::1' ) → f</code>
<code>masklen ( inet )</code>	Returns the netmask length in bits.	<code>masklen ( inet '192.168.1.5/24' ) → 24</code>
<code>netmask ( inet )</code>	Computes the network mask for the address's network.	<code>netmask ( inet '192.168.1.5/24' ) → 255.255.255.0</code>
<code>network ( inet )</code>	Returns the network part of the address, zeroing out whatever is to the right of the netmask. (This is equivalent to casting the value to <code>cidr</code> .)	<code>network ( inet '192.168.1.5/24' ) → 192.168.1.0/24</code>
<code>set_masklen ( inet, integer )</code>	Sets the netmask length for an <code>inet</code> value. The address part does not change.	

Function	Description	Example(s)
		<code>set_masklen(inet '192.168.1.5/24', 16) → 192.168.1.5/16</code>
	<code>set_masklen(cidr, integer) → cidr</code> Sets the netmask length for a <code>cidr</code> value. Address bits to the right of the new netmask are set to zero.	<code>set_masklen(cidr '192.168.1.0/24', 16) → 192.168.0.0/16</code>
	<code>text(inet) → text</code> Returns the unabbreviated IP address and netmask length as text. (This has the same result as an explicit cast to <code>text</code> .)	<code>text(inet '192.168.1.5') → 192.168.1.5/32</code>

**Tip**

The `abbrev`, `host`, and `text` functions are primarily intended to offer alternative display formats for IP addresses.

The MAC address types, `macaddr` and `macaddr8`, support the usual comparison operators shown in Table 9.1 as well as the specialized functions shown in Table 9.41. In addition, they support the bitwise logical operators `~`, `&` and `|` (NOT, AND and OR), just as shown above for IP addresses.

**Table 9.41. MAC Address Functions**

Function	Description	Example(s)
	<code>trunc(macaddr) → macaddr</code> Sets the last 3 bytes of the address to zero. The remaining prefix can be associated with a particular manufacturer (using data not included in LightDB).	<code>trunc(macaddr '12:34:56:78:90:ab') → 12:34:56:00:00:00</code>
	<code>trunc(macaddr8) → macaddr8</code> Sets the last 5 bytes of the address to zero. The remaining prefix can be associated with a particular manufacturer (using data not included in LightDB).	<code>trunc(macaddr8 '12:34:56:78:90:ab:cd:ef') → 12:34:56:00:00:00:00:00</code>
	<code>macaddr8_set7bit(macaddr8) → macaddr8</code> Sets the 7th bit of the address to one, creating what is known as modified EUI-64, for inclusion in an IPv6 address.	<code>macaddr8_set7bit(macaddr8 '00:34:56:ab:cd:ef') → 02:34:56:ff:fe:ab:cd:ef</code>

## 9.13. Text Search Functions and Operators

Table 9.42, Table 9.43 and Table 9.44 summarize the functions and operators that are provided for full text searching. See Chapter 12 for a detailed explanation of LightDB's text search facility.

**Table 9.42. Text Search Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<code>tsvector @@ tsquery</code>	<code>→ boolean</code>	
<code>tsquery @@ tsvector</code>	<code>→ boolean</code>	
	Does <code>tsvector</code> match <code>tsquery</code> ? (The arguments can be given in either order.)	<code>to_tsvector('fat cats ate rats') @@ to_tsquery('cat &amp; rat')</code> <code>→ t</code>
<code>text @@ tsquery</code>	<code>→ boolean</code>	
	Does text string, after implicit invocation of <code>to_tsvector()</code> , match <code>tsquery</code> ?	<code>'fat cats ate rats' @@ to_tsquery('cat &amp; rat')</code> <code>→ t</code>
<code>tsvector @@@ tsquery</code>	<code>→ boolean</code>	
<code>tsquery @@@ tsvector</code>	<code>→ boolean</code>	
	This is a deprecated synonym for <code>@@</code> .	<code>to_tsvector('fat cats ate rats') @@@ to_tsquery('cat &amp; rat')</code> <code>→ t</code>
<code>tsvector    tsvector</code>	<code>→ tsvector</code>	
	Concatenates two <code>tsvector</code> s. If both inputs contain lexeme positions, the second input's positions are adjusted accordingly.	<code>'a:1 b:2'::tsvector    'c:1 d:2 b:3'::tsvector</code> <code>→ 'a':1</code> <code>'b':2,5 'c':3 'd':4</code>
<code>tsquery &amp;&amp; tsquery</code>	<code>→ tsquery</code>	
	ANDs two <code>tsquery</code> s together, producing a query that matches documents that match both input queries.	<code>'fat   rat'::tsquery &amp;&amp; 'cat'::tsquery</code> <code>→ ('fat'   'rat') &amp; 'cat'</code>
<code>tsquery    tsquery</code>	<code>→ tsquery</code>	
	ORs two <code>tsquery</code> s together, producing a query that matches documents that match either input query.	<code>'fat   rat'::tsquery    'cat'::tsquery</code> <code>→ 'fat'   'rat'   'cat'</code>
<code>!! tsquery</code>	<code>→ tsquery</code>	
	Negates a <code>tsquery</code> , producing a query that matches documents that do not match the input query.	<code>!! 'cat'::tsquery</code> <code>→ !'cat'</code>
<code>tsquery &lt;-&gt; tsquery</code>	<code>→ tsquery</code>	
	Constructs a phrase query, which matches if the two input queries match at successive lexemes.	<code>to_tsquery('fat') &lt;-&gt; to_tsquery('rat')</code> <code>→ 'fat' &lt;-&gt; 'rat'</code>
<code>tsquery @&gt; tsquery</code>	<code>→ boolean</code>	
	Does first <code>tsquery</code> contain the second? (This considers only whether all the lexemes appearing in one query appear in the other, ignoring the combining operators.)	<code>'cat'::tsquery @&gt; 'cat &amp; rat'::tsquery</code> <code>→ f</code>
<code>tsquery &lt;@ tsquery</code>	<code>→ boolean</code>	

<b>Operator</b>
<p><b>Description</b> <b>Example(s)</b></p> <p>Is first <code>tsquery</code> contained in the second? (This considers only whether all the lexemes appearing in one query appear in the other, ignoring the combining operators.)</p> <pre>'cat'::tsquery &lt;@ 'cat &amp; rat'::tsquery → t</pre> <pre>'cat'::tsquery &lt;@ '!cat &amp; rat'::tsquery → t</pre>

In addition to these specialized operators, the usual comparison operators shown in Table 9.1 are available for types `tsvector` and `tsquery`. These are not very useful for text searching but allow, for example, unique indexes to be built on columns of these types.

**Table 9.43. Text Search Functions**

<b>Function</b>
<p><b>Description</b> <b>Example(s)</b></p> <p><code>array_to_tsvector(text[]) → tsvector</code> Converts an array of lexemes to a <code>tsvector</code>. The given strings are used as-is without further processing.</p> <pre>array_to_tsvector('{fat,cat,rat'}::text[]) → 'cat' 'fat' 'rat'</pre>
<p><code>get_current_ts_config() → regconfig</code> Returns the OID of the current default text search configuration (as set by <code>default_text_search_config</code>).</p> <pre>get_current_ts_config() → english</pre>
<p><code>length(tsvector) → integer</code> Returns the number of lexemes in the <code>tsvector</code>.</p> <pre>length('fat:2,4 cat:3 rat:5A'::tsvector) → 3</pre>
<p><code>numnode(tsquery) → integer</code> Returns the number of lexemes plus operators in the <code>tsquery</code>.</p> <pre>numnode('(fat &amp; rat)   cat'::tsquery) → 5</pre>
<p><code>plainto_tsquery([config regconfig,] query text) → tsquery</code> Converts text to a <code>tsquery</code>, normalizing words according to the specified or default configuration. Any punctuation in the string is ignored (it does not determine query operators). The resulting query matches documents containing all non-stopwords in the text.</p> <pre>plainto_tsquery('english', 'The Fat Rats') → 'fat' &amp; 'rat'</pre>
<p><code>phraseto_tsquery([config regconfig,] query text) → tsquery</code> Converts text to a <code>tsquery</code>, normalizing words according to the specified or default configuration. Any punctuation in the string is ignored (it does not determine query operators). The resulting query matches phrases containing all non-stopwords in the text.</p> <pre>phraseto_tsquery('english', 'The Fat Rats') → 'fat' &lt;-&gt; 'rat'</pre> <pre>phraseto_tsquery('english', 'The Cat and Rats') → 'cat' &lt;2&gt; 'rat'</pre>
<p><code>websearch_to_tsquery([config regconfig,] query text) → tsquery</code> Converts text to a <code>tsquery</code>, normalizing words according to the specified or default configuration. Quoted word sequences are converted to phrase tests. The word “or” is understood as producing an OR operator, and a dash produces a NOT operator; other</p>

Function	Description	Example(s)
	punctuation is ignored. This approximates the behavior of some common web search tools.	<code>websearch_to_tsquery('english', '"fat rat" or cat dog') → 'fat' &lt;-&gt; 'rat'   'cat' &amp; 'dog'</code>
	<code>querytree ( tsquery ) → text</code> Produces a representation of the indexable portion of a <code>tsquery</code> . A result that is empty or just <code>T</code> indicates a non-indexable query.	<code>querytree('foo &amp; ! bar'::tsquery) → 'foo'</code>
	<code>setweight ( vector tsvector, weight "char" ) → tsvector</code> Assigns the specified <i>weight</i> to each element of the <i>vector</i> .	<code>setweight('fat:2,4 cat:3 rat:5B'::tsvector, 'A') → 'cat':3A 'fat':2A,4A 'rat':5A</code>
	<code>setweight ( vector tsvector, weight "char", lexemes text[] ) → tsvector</code> Assigns the specified <i>weight</i> to elements of the <i>vector</i> that are listed in <i>lexemes</i> .	<code>setweight('fat:2,4 cat:3 rat:5,6B'::tsvector, 'A', '{cat,rat}') → 'cat':3A 'fat':2,4 'rat':5A,6A</code>
	<code>strip ( tsvector ) → tsvector</code> Removes positions and weights from the <code>tsvector</code> .	<code>strip('fat:2,4 cat:3 rat:5A'::tsvector) → 'cat' 'fat' 'rat'</code>
	<code>to_tsquery ( [ config regconfig, ] query text ) → tsquery</code> Converts text to a <code>tsquery</code> , normalizing words according to the specified or default configuration. The words must be combined by valid <code>tsquery</code> operators.	<code>to_tsquery('english', 'The &amp; Fat &amp; Rats') → 'fat' &amp; 'rat'</code>
	<code>to_tsvector ( [ config regconfig, ] document text ) → tsvector</code> Converts text to a <code>tsvector</code> , normalizing words according to the specified or default configuration. Position information is included in the result.	<code>to_tsvector('english', 'The Fat Rats') → 'fat':2 'rat':3</code>
	<code>to_tsvector ( [ config regconfig, ] document json ) → tsvector</code> <code>to_tsvector ( [ config regconfig, ] document jsonb ) → tsvector</code> Converts each string value in the JSON document to a <code>tsvector</code> , normalizing words according to the specified or default configuration. The results are then concatenated in document order to produce the output. Position information is generated as though one stopword exists between each pair of string values. (Beware that “document order” of the fields of a JSON object is implementation-dependent when the input is <code>jsonb</code> ; observe the difference in the examples.)	<code>to_tsvector('english', '{"aa": "The Fat Rats", "b": "dog"}'::json) → 'dog':5 'fat':2 'rat':3</code> <code>to_tsvector('english', '{"aa": "The Fat Rats", "b": "dog"}'::jsonb) → 'dog':1 'fat':4 'rat':5</code>
	<code>json_to_tsvector ( [ config regconfig, ] document json, filter jsonb ) → tsvector</code> <code>jsonb_to_tsvector ( [ config regconfig, ] document jsonb, filter jsonb ) → tsvector</code> Selects each item in the JSON document that is requested by the <i>filter</i> and converts each one to a <code>tsvector</code> , normalizing words according to the specified or default	

Function	Description Example(s)
	<p>configuration. The results are then concatenated in document order to produce the output. Position information is generated as though one stopwords exists between each pair of selected items. (Beware that “document order” of the fields of a JSON object is implementation-dependent when the input is <code>jsonb</code>.) The <i>filter</i> must be a <code>jsonb</code> array containing zero or more of these keywords: "string" (to include all string values), "numeric" (to include all numeric values), "boolean" (to include all boolean values), "key" (to include all keys), or "all" (to include all the above). As a special case, the <i>filter</i> can also be a simple JSON value that is one of these keywords.</p> <pre> json_to_tsvector('english', '{"a": "The Fat Rats", "b": 123}':::json, ['"string", "numeric"]) → '123':5 'fat':2 'rat':3 json_to_tsvector('english', '{"cat": "The Fat Rats", "dog": 123}':::json, '"all"') → '123':9 'cat':1 'dog':7 'fat':4 'rat':5 </pre>
	<pre> ts_delete(vector tsvector, lexeme text) → tsvector </pre> <p>Removes any occurrence of the given <i>lexeme</i> from the <i>vector</i>.</p> <pre> ts_delete('fat:2,4 cat:3 rat:5A':::tsvector, 'fat') → 'cat':3 'rat':5A </pre>
	<pre> ts_delete(vector tsvector, lexemes text[]) → tsvector </pre> <p>Removes any occurrences of the <i>lexemes</i> in <i>lexemes</i> from the <i>vector</i>.</p> <pre> ts_delete('fat:2,4 cat:3 rat:5A':::tsvector, ARRAY['fat', 'rat']) → 'cat':3 </pre>
	<pre> ts_filter(vector tsvector, weights "char"[]) → tsvector </pre> <p>Selects only elements with the given <i>weights</i> from the <i>vector</i>.</p> <pre> ts_filter('fat:2,4 cat:3b,7c rat:5A':::tsvector, '{a,b}') → 'cat':3B 'rat':5A </pre>
	<pre> ts_headline([ config regconfig, ] document text, query tsquery [, options text ]) → text </pre> <p>Displays, in an abbreviated form, the match(es) for the <i>query</i> in the <i>document</i>, which must be raw text not a <code>tsvector</code>. Words in the document are normalized according to the specified or default configuration before matching to the query. Use of this function is discussed in Section 12.3.4, which also describes the available <i>options</i>.</p> <pre> ts_headline('The fat cat ate the rat.', 'cat') → The fat &lt;b&gt;cat&lt;/b&gt; ate the rat. </pre>
	<pre> ts_headline([ config regconfig, ] document json, query tsquery [, options text ]) → text ts_headline([ config regconfig, ] document jsonb, query tsquery [, options text ]) → text </pre> <p>Displays, in an abbreviated form, match(es) for the <i>query</i> that occur in string values within the JSON <i>document</i>. See Section 12.3.4 for more details.</p> <pre> ts_headline('{"cat": "raining cats and dogs"}':::jsonb, 'cat') → {"cat": "raining &lt;b&gt;cats&lt;/b&gt; and dogs"} </pre>
	<pre> ts_rank([ weights real[], ] vector tsvector, query tsquery [, normalization integer ]) → real </pre> <p>Computes a score showing how well the <i>vector</i> matches the <i>query</i>. See Section 12.3.3 for details.</p>



Function	Description	Example(s)												
	<code>ts_rank(to_tsvector('raining cats and dogs'), 'cat') →</code>	<code>0.06079271</code>												
	<code>ts_rank_cd([weights real[],] vector tsvector, query tsquery [, normalization integer]) → real</code> Computes a score showing how well the <i>vector</i> matches the <i>query</i> , using a cover density algorithm. See Section 12.3.3 for details.	<code>ts_rank_cd(to_tsvector('raining cats and dogs'), 'cat') →</code> <code>0.1</code>												
	<code>ts_rewrite(query tsquery, target tsquery, substitute tsquery) → tsquery</code> Replaces occurrences of <i>target</i> with <i>substitute</i> within the <i>query</i> . See Section 12.4.2.1 for details.	<code>ts_rewrite('a &amp; b'::tsquery, 'a'::tsquery, 'foo bar'::tsquery) → 'b' &amp; ( 'foo'   'bar' )</code>												
	<code>ts_rewrite(query tsquery, select text) → tsquery</code> Replaces portions of the <i>query</i> according to target(s) and substitute(s) obtained by executing a <code>SELECT</code> command. See Section 12.4.2.1 for details.	<code>SELECT ts_rewrite('a &amp; b'::tsquery, 'SELECT t,s FROM aliases') → 'b' &amp; ( 'foo'   'bar' )</code>												
	<code>tsquery_phrase(query1 tsquery, query2 tsquery) → tsquery</code> Constructs a phrase query that searches for matches of <i>query1</i> and <i>query2</i> at successive lexemes (same as <code>&lt;-&gt;</code> operator).	<code>tsquery_phrase(to_tsquery('fat'), to_tsquery('cat')) → 'fat' &lt;-&gt; 'cat'</code>												
	<code>tsquery_phrase(query1 tsquery, query2 tsquery, distance integer) → tsquery</code> Constructs a phrase query that searches for matches of <i>query1</i> and <i>query2</i> that occur exactly <i>distance</i> lexemes apart.	<code>tsquery_phrase(to_tsquery('fat'), to_tsquery('cat'), 10) → 'fat' &lt;10&gt; 'cat'</code>												
	<code>tsvector_to_array(tsvector) → text[]</code> Converts a <i>tsvector</i> to an array of lexemes.	<code>tsvector_to_array('fat:2,4 cat:3 rat:5A'::tsvector) → {cat,fat, rat}</code>												
	<code>unnest(tsvector) → setof record(lexeme text, positions smallint[], weights text)</code> Expands a <i>tsvector</i> into a set of rows, one per lexeme.	<code>select * from unnest('cat:3 fat:2,4 rat:5A'::tsvector) →</code>												
		<table border="1"> <thead> <tr> <th>lexeme</th> <th>positions</th> <th>weights</th> </tr> </thead> <tbody> <tr> <td>cat</td> <td>{3}</td> <td>{D}</td> </tr> <tr> <td>fat</td> <td>{2,4}</td> <td>{D,D}</td> </tr> <tr> <td>rat</td> <td>{5}</td> <td>{A}</td> </tr> </tbody> </table>	lexeme	positions	weights	cat	{3}	{D}	fat	{2,4}	{D,D}	rat	{5}	{A}
lexeme	positions	weights												
cat	{3}	{D}												
fat	{2,4}	{D,D}												
rat	{5}	{A}												

**Note**

All the text search functions that accept an optional `regconfig` argument will use the configuration specified by `default_text_search_config` when that argument is omitted.

The functions in Table 9.44 are listed separately because they are not usually used in everyday text searching operations. They are primarily helpful for development and debugging of new text search configurations.

**Table 9.44. Text Search Debugging Functions**

Function	Description	Example(s)
<code>ts_debug</code>	<code>( [ config regconfig, ] document text ) → setof record ( alias text, description text, token text, dictionaries regdictionary[], dictionary regdictionary, lexemes text[] )</code> Extracts and normalizes tokens from the <i>document</i> according to the specified or default text search configuration, and returns information about how each token was processed. See Section 12.8.1 for details.	<code>ts_debug('english', 'The Brightest supernovae') → (asciword, "Word, all ASCII", The, {english_stem}, english_stem, { }) ...</code>
<code>ts_lexize</code>	<code>( dict regdictionary, token text ) → text[]</code> Returns an array of replacement lexemes if the input token is known to the dictionary, or an empty array if the token is known to the dictionary but it is a stop word, or NULL if it is not a known word. See Section 12.8.3 for details.	<code>ts_lexize('english_stem', 'stars') → {star}</code>
<code>ts_parse</code>	<code>( parser_name text, document text ) → setof record ( tokid integer, token text )</code> Extracts tokens from the <i>document</i> using the named parser. See Section 12.8.2 for details.	<code>ts_parse('default', 'foo - bar') → (1,foo) ...</code>
<code>ts_parse</code>	<code>( parser_oid oid, document text ) → setof record ( tokid integer, token text )</code> Extracts tokens from the <i>document</i> using a parser specified by OID. See Section 12.8.2 for details.	<code>ts_parse(3722, 'foo - bar') → (1,foo) ...</code>
<code>ts_token_type</code>	<code>( parser_name text ) → setof record ( tokid integer, alias text, description text )</code> Returns a table that describes each type of token the named parser can recognize. See Section 12.8.2 for details.	<code>ts_token_type('default') → (1,asciword, "Word, all ASCII") ...</code>
<code>ts_token_type</code>	<code>( parser_oid oid ) → setof record ( tokid integer, alias text, description text )</code> Returns a table that describes each type of token a parser specified by OID can recognize. See Section 12.8.2 for details.	<code>ts_token_type(3722) → (1,asciword, "Word, all ASCII") ...</code>

Function	Description	Example(s)
<code>ts_stat</code>	<code>( sqlquery text [, weights text ] ) → setof record ( word text, ndoc integer, nentry integer )</code> Executes the <code>sqlquery</code> , which must return a single <code>tsvector</code> column, and returns statistics about each distinct lexeme contained in the data. See Section 12.4.4 for details.	<code>ts_stat( 'SELECT vector FROM apod' ) → ( foo, 10, 15 ) ...</code>

## 9.14. UUID Functions

LightDB includes one function to generate a UUID:

```
gen_random_uuid () → uuid
```

This function returns a version 4 (random) UUID. This is the most commonly used type of UUID and is appropriate for most applications.

The `uuid-osp` module provides additional functions that implement other standard algorithms for generating UUIDs.

LightDB also provides the usual comparison operators shown in Table 9.1 for UUIDs.

## 9.15. XML Functions

The functions and function-like expressions described in this section operate on values of type `xml`. See Section 8.13 for information about the `xml` type. The function-like expressions `xmlparse` and `xmlserialize` for converting to and from type `xml` are documented there, not in this section.

Use of most of these functions requires LightDB to have been built with `configure --with-libxml`.

### 9.15.1. Producing XML Content

A set of functions and function-like expressions is available for producing XML content from SQL data. As such, they are particularly suitable for formatting query results into XML documents for processing in client applications.

#### 9.15.1.1. `xmlcomment`

```
xmlcomment ( text ) → xml
```

The function `xmlcomment` creates an XML value containing an XML comment with the specified text as content. The text cannot contain “--” or end with a “-”, otherwise the resulting construct would not be a valid XML comment. If the argument is null, the result is null.

Example:

```
SELECT xmlcomment('hello');
```

```
xmlcomment
-----
<!--hello-->
```

### 9.15.1.2. xmlconcat

```
xmlconcat ( xml [, ...] ) → xml
```

The function `xmlconcat` concatenates a list of individual XML values to create a single value containing an XML content fragment. Null values are omitted; the result is only null if there are no nonnull arguments.

Example:

```
SELECT xmlconcat(' <abc/>', ' <bar>foo</bar>' );
```

```
      xmlconcat
-----
<abc/><bar>foo</bar>
```

XML declarations, if present, are combined as follows. If all argument values have the same XML version declaration, that version is used in the result, else no version is used. If all argument values have the standalone declaration value “yes”, then that value is used in the result. If all argument values have a standalone declaration value and at least one is “no”, then that is used in the result. Else the result will have no standalone declaration. If the result is determined to require a standalone declaration but no version declaration, a version declaration with version 1.0 will be used because XML requires an XML declaration to contain a version declaration. Encoding declarations are ignored and removed in all cases.

Example:

```
SELECT xmlconcat('<?xml version="1.1"?><foo/>', '<?xml
version="1.1" standalone="no"?><bar/>');
```

```
      xmlconcat
-----
<?xml version="1.1"?><foo/><bar/>
```

### 9.15.1.3. xmlelement

```
xmlelement ( NAME name [, XMLATTRIBUTES ( attvalue [ AS attname ]
[, ...] ) ] [, content [, ...]] ) → xml
```

The `xmlelement` expression produces an XML element with the given name, attributes, and content. The `name` and `attname` items shown in the syntax are simple identifiers, not values. The `attvalue` and `content` items are expressions, which can yield any LightDB data type. The argument(s) within `XMLATTRIBUTES` generate attributes of the XML element; the `content` value(s) are concatenated to form its content.

Examples:

```
SELECT xmlelement(name foo);
```

```
      xmlelement
-----
<foo/>
```

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar));
```

```

      xmlelement
-----
<foo bar="xyz"/>

SELECT xmlelement(name foo, xmlattributes(current_date as bar),
  'cont', 'ent');
```

```

      xmlelement
-----
<foo bar="2007-01-26">content</foo>
```

Element and attribute names that are not valid XML names are escaped by replacing the offending characters by the sequence `_xHHHH_`, where `HHHH` is the character's Unicode codepoint in hexadecimal notation. For example:

```
SELECT xmlelement(name "foo$bar", xmlattributes('xyz' as "a&b"));
```

```

      xmlelement
-----
<foo_x0024_bar a_x0026_b="xyz"/>
```

An explicit attribute name need not be specified if the attribute value is a column reference, in which case the column's name will be used as the attribute name by default. In other cases, the attribute must be given an explicit name. So this example is valid:

```
CREATE TABLE test (a xml, b xml);
SELECT xmlelement(name test, xmlattributes(a, b)) FROM test;
```

But these are not:

```
SELECT xmlelement(name test, xmlattributes('constant'), a, b) FROM
test;
SELECT xmlelement(name test, xmlattributes(func(a, b))) FROM test;
```

Element content, if specified, will be formatted according to its data type. If the content is itself of type `xml`, complex XML documents can be constructed. For example:

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar),
  xmlelement(name abc),
  xmlcomment('test'),
  xmlelement(name xyz));
```

```

      xmlelement
-----
<foo bar="xyz"><abc/><!--test--><xyz/></foo>
```

Content of other types will be formatted into valid XML character data. This means in particular that the characters `<`, `>`, and `&` will be converted to entities. Binary data (data type `bytea`) will be represented in base64 or hex encoding, depending on the setting of the configuration parameter `xmlbinary`. The particular behavior for individual data types is expected to evolve in order to align the LightDB mappings with those specified in SQL:2006 and later, as discussed in Section D.3.1.3.

### 9.15.1.4. xmlforest

```
xmlforest ( content [ AS name ] [, ...] ) → xml
```

The `xmlforest` expression produces an XML forest (sequence) of elements using the given names and content. As for `xmlelement`, each *name* must be a simple identifier, while the *content* expressions can have any data type.

Examples:

```
SELECT xmlforest('abc' AS foo, 123 AS bar);
```

```

                xmlforest
-----
<foo>abc</foo><bar>123</bar>

```

```
SELECT xmlforest(table_name, column_name)
FROM information_schema.columns
WHERE table_schema = 'pg_catalog';
```

```

                                xmlforest
-----
<table_name>pg_authid</table_name><column_name>rolname</
column_name>
<table_name>pg_authid</table_name><column_name>rolsuper</
column_name>
...

```

As seen in the second example, the element name can be omitted if the content value is a column reference, in which case the column name is used by default. Otherwise, a name must be specified.

Element names that are not valid XML names are escaped as shown for `xmlelement` above. Similarly, content data is escaped to make valid XML content, unless it is already of type `xml`.

Note that XML forests are not valid XML documents if they consist of more than one element, so it might be useful to wrap `xmlforest` expressions in `xmlelement`.

### 9.15.1.5. `xmlpi`

```
xmlpi ( NAME name [, content ] ) → xml
```

The `xmlpi` expression creates an XML processing instruction. As for `xmlelement`, the *name* must be a simple identifier, while the *content* expression can have any data type. The *content*, if present, must not contain the character sequence `?>`.

Example:

```
SELECT xmlpi(name php, 'echo "hello world";');
```

```

                xmlpi
-----
<?php echo "hello world";?>

```

### 9.15.1.6. `xmlroot`

```
xmlroot ( xml, VERSION {text|NO VALUE} [, STANDALONE {YES|NO|NO
VALUE} ] ) → xml
```

The `xmlroot` expression alters the properties of the root node of an XML value. If a version is specified, it replaces the value in the root node's version declaration; if a standalone setting is specified, it replaces the value in the root node's standalone declaration.

```
SELECT xmlroot(xmlparse(document '<?xml version="1.1"?
><content>abc</content>'),
          version '1.0', standalone yes);

          xmlroot
-----
<?xml version="1.0" standalone="yes"?>
<content>abc</content>
```

### 9.15.1.7. `xmlagg`

```
xmlagg ( xml ) → xml
```

The function `xmlagg` is, unlike the other functions described here, an aggregate function. It concatenates the input values to the aggregate function call, much like `xmlconcat` does, except that concatenation occurs across rows rather than across expressions in a single row. See Section 9.21 for additional information about aggregate functions.

Example:

```
CREATE TABLE test (y int, x xml);
INSERT INTO test VALUES (1, '<foo>abc</foo>');
INSERT INTO test VALUES (2, '<bar/>');
SELECT xmlagg(x) FROM test;
          xmlagg
-----
<foo>abc</foo><bar/>
```

To determine the order of the concatenation, an `ORDER BY` clause may be added to the aggregate call as described in Section 4.2.7. For example:

```
SELECT xmlagg(x ORDER BY y DESC) FROM test;
          xmlagg
-----
<bar/><foo>abc</foo>
```

The following non-standard approach used to be recommended in previous versions, and may still be useful in specific cases:

```
SELECT xmlagg(x) FROM (SELECT * FROM test ORDER BY y DESC) AS tab;
          xmlagg
-----
<bar/><foo>abc</foo>
```

The following approach used together with `getclobval()` in oracle compatible mode cases:

```
SELECT xmlagg(xmlparse(content '1,2,3,')).getclobval() FROM dual;
```

```
getclobval
-----
1,2,3,
(1 row)
```

## 9.15.2. XML Predicates

The expressions described in this section check properties of xml values.

### 9.15.2.1. IS DOCUMENT

```
xml IS DOCUMENT → boolean
```

The expression `IS DOCUMENT` returns true if the argument XML value is a proper XML document, false if it is not (that is, it is a content fragment), or null if the argument is null. See Section 8.13 about the difference between documents and content fragments.

### 9.15.2.2. IS NOT DOCUMENT

```
xml IS NOT DOCUMENT → boolean
```

The expression `IS NOT DOCUMENT` returns false if the argument XML value is a proper XML document, true if it is not (that is, it is a content fragment), or null if the argument is null.

### 9.15.2.3. XMLEXISTS

```
XMLEXISTS ( text PASSING [BY {REF|VALUE}] xml [BY
{REF|VALUE}] ) → boolean
```

The function `xmlexists` evaluates an XPath 1.0 expression (the first argument), with the passed XML value as its context item. The function returns false if the result of that evaluation yields an empty node-set, true if it yields any other value. The function returns null if any argument is null. A nonnull value passed as the context item must be an XML document, not a content fragment or any non-XML value.

Example:

```
SELECT xmlexists('//*[town[text() = ''Toronto'']]' PASSING BY VALUE
 '<towns><town>Toronto</town><town>Ottawa</town></towns>');
```

```
xmlexists
-----
t
(1 row)
```

The `BY REF` and `BY VALUE` clauses are accepted in LightDB, but are ignored, as discussed in Section D.3.2.

In the SQL standard, the `xmlexists` function evaluates an expression in the XML Query language, but LightDB allows only an XPath 1.0 expression, as discussed in Section D.3.1.

### 9.15.2.4. xml\_is\_well\_formed



```
xml_is_well_formed ( text ) →boolean
xml_is_well_formed_document ( text ) →boolean
xml_is_well_formed_content ( text ) →boolean
```

These functions check whether a text string represents well-formed XML, returning a Boolean result. `xml_is_well_formed_document` checks for a well-formed document, while `xml_is_well_formed_content` checks for well-formed content. `xml_is_well_formed` does the former if the `xmloption` configuration parameter is set to `DOCUMENT`, or the latter if it is set to `CONTENT`. This means that `xml_is_well_formed` is useful for seeing whether a simple cast to type `xml` will succeed, whereas the other two functions are useful for seeing whether the corresponding variants of `XMLPARSE` will succeed.

Examples:

```
SET xmloption TO DOCUMENT;
SELECT xml_is_well_formed('<>');
  xml_is_well_formed
-----
  f
(1 row)

SELECT xml_is_well_formed('<abc/>');
  xml_is_well_formed
-----
  t
(1 row)

SET xmloption TO CONTENT;
SELECT xml_is_well_formed('abc');
  xml_is_well_formed
-----
  t
(1 row)

SELECT xml_is_well_formed_document('<lt:foo xmlns:pg="http://
example.org/stuff">bar</lt:foo>');
  xml_is_well_formed_document
-----
  t
(1 row)

SELECT xml_is_well_formed_document('<lt:foo xmlns:pg="http://
example.org/stuff">bar</my:foo>');
  xml_is_well_formed_document
-----
  f
(1 row)
```

The last example shows that the checks include whether namespaces are correctly matched.

## 9.15.3. Processing XML

To process values of data type `xml`, LightDB offers the functions `xpath` and `xpath_exists`, which evaluate XPath 1.0 expressions, and the `XMLTABLE` table function.

### 9.15.3.1. xpath

```
xpath ( xpath text, xml xml [, nsarray text[] ] ) →xml[]
```

The function `xpath` evaluates the XPath 1.0 expression `xpath` (given as `text`) against the XML value `xml`. It returns an array of XML values corresponding to the node-set produced by the XPath expression. If the XPath expression returns a scalar value rather than a node-set, a single-element array is returned.

The second argument must be a well formed XML document. In particular, it must have a single root node element.

The optional third argument of the function is an array of namespace mappings. This array should be a two-dimensional `text` array with the length of the second axis being equal to 2 (i.e., it should be an array of arrays, each of which consists of exactly 2 elements). The first element of each array entry is the namespace name (alias), the second the namespace URI. It is not required that aliases provided in this array be the same as those being used in the XML document itself (in other words, both in the XML document and in the `xpath` function context, aliases are *local*).

Example:

```
SELECT xpath('/my:a/text()', '<my:a xmlns:my="http://
example.com">test</my:a>',
           ARRAY[ARRAY['my', 'http://example.com']]);
```

```
  xpath
-----
 {test}
(1 row)
```

To deal with default (anonymous) namespaces, do something like this:

```
SELECT xpath('//mydefns:b/text()', '<a xmlns="http://
example.com"><b>test</b></a>',
           ARRAY[ARRAY['mydefns', 'http://example.com']]);
```

```
  xpath
-----
 {test}
(1 row)
```

### 9.15.3.2. xpath\_exists

```
xpath_exists ( xpath text, xml xml [, nsarray text[] ] ) →boolean
```

The function `xpath_exists` is a specialized form of the `xpath` function. Instead of returning the individual XML values that satisfy the XPath 1.0 expression, this function returns a Boolean indicating whether the query was satisfied or not (specifically, whether it produced any value other than an empty node-set). This function is equivalent to the `XMLEXISTS` predicate, except that it also offers support for a namespace mapping argument.

Example:

```
SELECT xpath_exists('/my:a/text()', '<my:a xmlns:my="http://
example.com">test</my:a>',
           ARRAY[ARRAY['my', 'http://example.com']]);
```

```

xpath_exists
-----
t
(1 row)

```

### 9.15.3.3. xmltable

```

XMLTABLE (
  [ XMLNAMESPACES ( namespace_uri AS namespace_name [, ...] ), ]
  row_expression PASSING [BY {REF|VALUE}] document_expression [BY
  {REF|VALUE}]
  COLUMNS name { type [PATH column_expression]
  [DEFAULT default_expression] [NOT NULL | NULL]
  | FOR ORDINALITY }
  [, ...]
) → setof record

```

The `xmltable` expression produces a table based on an XML value, an XPath filter to extract rows, and a set of column definitions. Although it syntactically resembles a function, it can only appear as a table in a query's FROM clause.

The optional `XMLNAMESPACES` clause gives a comma-separated list of namespace definitions, where each `namespace_uri` is a text expression and each `namespace_name` is a simple identifier. It specifies the XML namespaces used in the document and their aliases. A default namespace specification is not currently supported.

The required `row_expression` argument is an XPath 1.0 expression (given as text) that is evaluated, passing the XML value `document_expression` as its context item, to obtain a set of XML nodes. These nodes are what `xmltable` transforms into output rows. No rows will be produced if the `document_expression` is null, nor if the `row_expression` produces an empty node-set or any value other than a node-set.

`document_expression` provides the context item for the `row_expression`. It must be a well-formed XML document; fragments/forests are not accepted. The `BY REF` and `BY VALUE` clauses are accepted but ignored, as discussed in Section D.3.2.

In the SQL standard, the `xmltable` function evaluates expressions in the XML Query language, but LightDB allows only XPath 1.0 expressions, as discussed in Section D.3.1.

The required `COLUMNS` clause specifies the column(s) that will be produced in the output table. See the syntax summary above for the format. A name is required for each column, as is a data type (unless `FOR ORDINALITY` is specified, in which case type `integer` is implicit). The path, default and nullability clauses are optional.

A column marked `FOR ORDINALITY` will be populated with row numbers, starting with 1, in the order of nodes retrieved from the `row_expression`'s result node-set. At most one column may be marked `FOR ORDINALITY`.

#### Note

XPath 1.0 does not specify an order for nodes in a node-set, so code that relies on a particular order of the results will be implementation-dependent. Details can be found in Section D.3.1.2.

The `column_expression` for a column is an XPath 1.0 expression that is evaluated for each row, with the current node from the `row_expression` result as its context item, to find the value of the column. If no `column_expression` is given, then the column name is used as an implicit path.

If a column's XPath expression returns a non-XML value (which is limited to string, boolean, or double in XPath 1.0) and the column has a LightDB type other than `xml`, the column will be set as if by assigning the value's string representation to the LightDB type. (If the value is a boolean, its string representation is taken to be 1 or 0 if the output column's type category is numeric, otherwise `true` or `false`.)

If a column's XPath expression returns a non-empty set of XML nodes and the column's LightDB type is `xml`, the column will be assigned the expression result exactly, if it is of document or content form.<sup>2</sup>

A non-XML result assigned to an `xml` output column produces content, a single text node with the string value of the result. An XML result assigned to a column of any other type may not have more than one node, or an error is raised. If there is exactly one node, the column will be set as if by assigning the node's string value (as defined for the XPath 1.0 `string` function) to the LightDB type.

The string value of an XML element is the concatenation, in document order, of all text nodes contained in that element and its descendants. The string value of an element with no descendant text nodes is an empty string (not `NULL`). Any `xsi:nil` attributes are ignored. Note that the whitespace-only `text()` node between two non-text elements is preserved, and that leading whitespace on a `text()` node is not flattened. The XPath 1.0 `string` function may be consulted for the rules defining the string value of other XML node types and non-XML values.

The conversion rules presented here are not exactly those of the SQL standard, as discussed in Section D.3.1.3.

If the path expression returns an empty node-set (typically, when it does not match) for a given row, the column will be set to `NULL`, unless a `default_expression` is specified; then the value resulting from evaluating that expression is used.

A `default_expression`, rather than being evaluated immediately when `xmltable` is called, is evaluated each time a default is needed for the column. If the expression qualifies as stable or immutable, the repeat evaluation may be skipped. This means that you can usefully use volatile functions like `nextval` in `default_expression`.

Columns may be marked `NOT NULL`. If the `column_expression` for a `NOT NULL` column does not match anything and there is no `DEFAULT` or the `default_expression` also evaluates to null, an error is reported.

Examples:

```
CREATE TABLE xmldata AS SELECT
xml $$
<ROWS>
  <ROW id="1">
    <COUNTRY_ID>AU</COUNTRY_ID>
    <COUNTRY_NAME>Australia</COUNTRY_NAME>
  </ROW>
  <ROW id="5">
    <COUNTRY_ID>JP</COUNTRY_ID>
    <COUNTRY_NAME>Japan</COUNTRY_NAME>
    <PREMIER_NAME>Shinzo Abe</PREMIER_NAME>
    <SIZE unit="sq_mi">145935</SIZE>
  </ROW>
  <ROW id="6">
    <COUNTRY_ID>SG</COUNTRY_ID>
    <COUNTRY_NAME>Singapore</COUNTRY_NAME>
    <SIZE unit="sq_km">697</SIZE>
```

<sup>2</sup> A result containing more than one element node at the top level, or non-whitespace text outside of an element, is an example of content form. An XPath result can be of neither form, for example if it returns an attribute node selected from the element that contains it. Such a result will be put into content form with each such disallowed node replaced by its string value, as defined for the XPath 1.0 `string` function.

```

</ROW>
</ROWS>
$$ AS data;

SELECT xmltable.*
  FROM xmldata,
       XMLTABLE('//ROWS/ROW'
                PASSING data
                COLUMNS id int PATH '@id',
                        ordinality FOR ORDINALITY,
                        "COUNTRY_NAME" text,
                        country_id text PATH 'COUNTRY_ID',
                        size_sq_km float PATH 'SIZE[@unit =
"sq_km"]',
                        size_other text PATH
                        'concat(SIZE[@unit!="sq_km"], " ",
SIZE[@unit!="sq_km"]/@unit)',
                        premier_name text PATH 'PREMIER_NAME'
                DEFAULT 'not specified');

```

id	ordinality	COUNTRY_NAME	country_id	size_sq_km	size_other	premier_name
1	1	Australia	AU			not specified
5	2	Japan	JP		145935	Shinzo Abe
6	3	Singapore	SG	697		not specified

The following example shows concatenation of multiple text() nodes, usage of the column name as XPath filter, and the treatment of whitespace, XML comments and processing instructions:

```

CREATE TABLE xmlelements AS SELECT
xml $$
  <root>
    <element> Hello<!-- xyxxz -->2a2<?aaaaa?> <!--x--> bbb<x>xxx</
x>CC </element>
  </root>
$$ AS data;

SELECT xmltable.*
  FROM xmlelements, XMLTABLE('/root' PASSING data COLUMNS element
text);
      element
-----
Hello2a2  bbbxxxCC

```

The following example illustrates how the XMLNAMESPACES clause can be used to specify a list of namespaces used in the XML document as well as in the XPath expressions:

```

WITH xmldata(data) AS (VALUES ('
<example xmlns="http://example.com/myns" xmlns:B="http://
example.com/b">
  <item foo="1" B:bar="2"/>
  <item foo="3" B:bar="4"/>

```

```

<item foo="4" B:bar="5"/>
</example>'::xml)
)
SELECT xmltable.*
   FROM XMLTABLE(XMLNAMESPACES('http://example.com/myns' AS x,
                                'http://example.com/b' AS "B"),
                 '/x:example/x:item'
                 PASSING (SELECT data FROM xmldata)
                 COLUMNS foo int PATH '@foo',
                          bar int PATH '@B:bar');

```

foo	bar
1	2
3	4
4	5

(3 rows)

## 9.15.4. Mapping Tables to XML

The following functions map the contents of relational tables to XML values. They can be thought of as XML export functionality:

```

table_to_xml ( table regclass, nulls boolean,
               tableforest boolean, targetns text ) →xml
query_to_xml ( query text, nulls boolean,
               tableforest boolean, targetns text ) →xml
cursor_to_xml ( cursor refcursor, count integer, nulls boolean,
                tableforest boolean, targetns text ) →xml

```

`table_to_xml` maps the content of the named table, passed as parameter *table*. The *regclass* type accepts strings identifying tables using the usual notation, including optional schema qualifications and double quotes. `query_to_xml` executes the query whose text is passed as parameter *query* and maps the result set. `cursor_to_xml` fetches the indicated number of rows from the cursor specified by the parameter *cursor*. This variant is recommended if large tables have to be mapped, because the result value is built up in memory by each function.

If *tableforest* is false, then the resulting XML document looks like this:

```

<tablename>
  <row>
    <columnname1>data</columnname1>
    <columnname2>data</columnname2>
  </row>

  <row>
    ...
  </row>

  ...
</tablename>

```

If *tableforest* is true, the result is an XML content fragment that looks like this:

```

<tablename>
  <columnname1>data</columnname1>

```

```

    <columnname2>data</columnname2>
</tablename>

<tablename>
...
</tablename>

...

```

If no table name is available, that is, when mapping a query or a cursor, the string `table` is used in the first format, `row` in the second format.

The choice between these formats is up to the user. The first format is a proper XML document, which will be important in many applications. The second format tends to be more useful in the `cursor_to_xml` function if the result values are to be reassembled into one document later on. The functions for producing XML content discussed above, in particular `xmlElement`, can be used to alter the results to taste.

The data values are mapped in the same way as described for the function `xmlElement` above.

The parameter `nulls` determines whether null values should be included in the output. If true, null values in columns are represented as:

```
<columnname xsi:nil="true"/>
```

where `xsi` is the XML namespace prefix for XML Schema Instance. An appropriate namespace declaration will be added to the result value. If false, columns containing null values are simply omitted from the output.

The parameter `targetns` specifies the desired XML namespace of the result. If no particular namespace is wanted, an empty string should be passed.

The following functions return XML Schema documents describing the mappings performed by the corresponding functions above:

```

table_to_xmlschema ( table regclass, nulls boolean,
                    tableforest boolean, targetns text ) → xml
query_to_xmlschema ( query text, nulls boolean,
                    tableforest boolean, targetns text ) → xml
cursor_to_xmlschema ( cursor refcursor, nulls boolean,
                     tableforest boolean, targetns text ) → xml

```

It is essential that the same parameters are passed in order to obtain matching XML data mappings and XML Schema documents.

The following functions produce XML data mappings and the corresponding XML Schema in one document (or forest), linked together. They can be useful where self-contained and self-describing results are wanted:

```

table_to_xml_and_xmlschema ( table regclass, nulls boolean,
                             tableforest boolean, targetns text
                           ) → xml
query_to_xml_and_xmlschema ( query text, nulls boolean,
                             tableforest boolean, targetns text
                           ) → xml

```

In addition, the following functions are available to produce analogous mappings of entire schemas or the entire current database:

```

schema_to_xml ( schema name, nulls boolean,
                tableforest boolean, targetns text ) →xml
schema_to_xmlschema ( schema name, nulls boolean,
                      tableforest boolean, targetns text ) →xml
schema_to_xml_and_xmlschema ( schema name, nulls boolean,
                              tableforest boolean, targetns text
                              ) →xml

database_to_xml ( nulls boolean,
                  tableforest boolean, targetns text ) →xml
database_to_xmlschema ( nulls boolean,
                        tableforest boolean, targetns text ) →xml
database_to_xml_and_xmlschema ( nulls boolean,
                                tableforest boolean, targetns text
                                ) →xml

```

These functions ignore tables that are not readable by the current user. The database-wide functions additionally ignore schemas that the current user does not have USAGE (lookup) privilege for.

Note that these potentially produce a lot of data, which needs to be built up in memory. When requesting content mappings of large schemas or databases, it might be worthwhile to consider mapping the tables separately instead, possibly even through a cursor.

The result of a schema content mapping looks like this:

```

<schemaname>
table1-mapping
table2-mapping
...
</schemaname>

```

where the format of a table mapping depends on the *tableforest* parameter as explained above.

The result of a database content mapping looks like this:

```

<dbname>
<schemaname1>
...
</schemaname1>
<schemaname2>
...
</schemaname2>
...

```



</dbname>

where the schema mapping is as above.

As an example of using the output produced by these functions, Example 9.1 shows an XSLT stylesheet that converts the output of `table_to_xml_and_xmlschema` to an HTML document containing a tabular rendition of the table data. In a similar manner, the results from these functions can be converted into other XML-based formats.

### Example 9.1. XSLT Stylesheet for Converting SQL/XML Output to HTML

```
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns="http://www.w3.org/1999/xhtml"
>

  <xsl:output method="xml"
    doctype-system="http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
    doctype-public="-//W3C/DTD XHTML 1.0 Strict//EN"
    indent="yes"/>

  <xsl:template match="/*">
    <xsl:variable name="schema" select="//xsd:schema"/>
    <xsl:variable name="tabletypename"
      select="$schema/
xsd:element[@name=name(current())]/@type"/>
    <xsl:variable name="rowtypename"
      select="$schema/xsd:complexType[@name=
$tabletypename]/xsd:sequence/xsd:element[@name='row']/@type"/>

    <html>
      <head>
        <title><xsl:value-of select="name(current())"/></title>
      </head>
      <body>
        <table>
          <tr>
            <xsl:for-each select="$schema/xsd:complexType[@name=
$rowtypename]/xsd:sequence/xsd:element/@name">
              <th><xsl:value-of select="."/></th>
            </xsl:for-each>
          </tr>

          <xsl:for-each select="row">
            <tr>
              <xsl:for-each select="*">
                <td><xsl:value-of select="."/></td>
              </xsl:for-each>
            </tr>
          </xsl:for-each>
        </table>
      </body>
    </html>
  </xsl:template>
```

</xsl:stylesheet>

## 9.16. JSON Functions and Operators

This section describes:

- functions and operators for processing and creating JSON data
- the SQL/JSON path language

To learn more about the SQL/JSON standard, see [sqltr-19075-6]. For details on JSON types supported in LightDB, see Section 8.14.

### 9.16.1. Processing and Creating JSON Data

Table 9.45 shows the operators that are available for use with JSON data types (see Section 8.14). In addition, the usual comparison operators shown in Table 9.1 are available for `jsonb`, though not for `json`. The comparison operators follow the ordering rules for B-tree operations outlined in Section 8.14.4.

**Table 9.45. json and jsonb Operators**

Operator	Description Example(s)
<code>json -&gt; integer → json</code> <code>jsonb -&gt; integer → jsonb</code>	Extracts <i>n</i> 'th element of JSON array (array elements are indexed from zero, but negative integers count from the end). <code>' [{"a": "foo"}, {"b": "bar"}, {"c": "baz"} ] ':: json -&gt; 2 → {"c": "baz" }</code> <code>' [{"a": "foo"}, {"b": "bar"}, {"c": "baz"} ] ':: json -&gt; -3 → {"a": "foo" }</code>
<code>json -&gt; text → json</code> <code>jsonb -&gt; text → jsonb</code>	Extracts JSON object field with the given key. <code>' {"a": {"b": "foo"} } ':: json -&gt; 'a' → {"b": "foo" }</code>
<code>json -&gt;&gt; integer → text</code> <code>jsonb -&gt;&gt; integer → text</code>	Extracts <i>n</i> 'th element of JSON array, as text. <code>' [1,2,3] ':: json -&gt;&gt; 2 → 3</code>
<code>json -&gt;&gt; text → text</code> <code>jsonb -&gt;&gt; text → text</code>	Extracts JSON object field with the given key, as text. <code>' {"a": 1, "b": 2} ':: json -&gt;&gt; 'b' → 2</code>
<code>json #&gt; text [ ] → json</code> <code>jsonb #&gt; text [ ] → jsonb</code>	Extracts JSON sub-object at the specified path, where path elements can be either field keys or array indexes.

<b>Operator</b>	<b>Description</b> <b>Example(s)</b>
	<code>'{"a": {"b": ["foo", "bar"]}}'::json #&gt; '{a,b,1}' → "bar"</code>
	<code>json #&gt;&gt; text[] → text</code> <code>jsonb #&gt;&gt; text[] → text</code> Extracts JSON sub-object at the specified path as text. <code>'{"a": {"b": ["foo", "bar"]}}'::json #&gt;&gt; '{a,b,1}' → bar</code>

**Note**

The field/element/path extraction operators return NULL, rather than failing, if the JSON input does not have the right structure to match the request; for example if no such key or array element exists.

Some further operators exist only for `jsonb`, as shown in Table 9.46. Section 8.14.4 describes how these operators can be used to effectively search indexed `jsonb` data.

**Table 9.46. Additional jsonb Operators**

<b>Operator</b>	<b>Description</b> <b>Example(s)</b>
<code>jsonb @&gt; jsonb → boolean</code>	Does the first JSON value contain the second? (See Section 8.14.3 for details about containment.) <code>'{"a":1, "b":2}'::jsonb @&gt; '{"b":2}'::jsonb → t</code>
<code>jsonb &lt;@ jsonb → boolean</code>	Is the first JSON value contained in the second? <code>'{"b":2}'::jsonb &lt;@ '{"a":1, "b":2}'::jsonb → t</code>
<code>jsonb ? text → boolean</code>	Does the text string exist as a top-level key or array element within the JSON value? <code>'{"a":1, "b":2}'::jsonb ? 'b' → t</code> <code>'["a", "b", "c"]'::jsonb ? 'b' → t</code>
<code>jsonb ?  text[] → boolean</code>	Do any of the strings in the text array exist as top-level keys or array elements? <code>'{"a":1, "b":2, "c":3}'::jsonb ?  array['b', 'd'] → t</code>
<code>jsonb ?&amp; text[] → boolean</code>	Do all of the strings in the text array exist as top-level keys or array elements? <code>'["a", "b", "c"]'::jsonb ?&amp; array['a', 'b'] → t</code>
<code>jsonb    jsonb → jsonb</code>	Concatenates two <code>jsonb</code> values. Concatenating two arrays generates an array containing all the elements of each input. Concatenating two objects generates an object containing the union of their keys, taking the second object's value when there are duplicate keys. All other cases are treated by converting a non-array input into a single-element array, and then proceeding as for two arrays. Does not operate recursively: only the top-level array or object structure is merged.

Operator	Description Example(s)
	<pre>'["a", "b"]'::jsonb    '["a", "d"]'::jsonb → ["a", "b", "a", "d"]</pre> <pre>'{"a": "b"}'::jsonb    '{"c": "d"}'::jsonb → {"a": "b", "c": "d"}</pre> <pre>'[1, 2]'::jsonb    '3'::jsonb → [1, 2, 3]</pre> <pre>'{"a": "b"}'::jsonb    '42'::jsonb → [{"a": "b"}, 42]</pre> <p>To append an array to another array as a single entry, wrap it in an additional layer of array, for example:</p> <pre>'[1, 2]'::jsonb    jsonb_build_array('3, 4')::jsonb → [1, 2, [3, 4]]</pre>
<code>jsonb - text</code>	<p><code>jsonb - text</code> → jsonb Deletes a key (and its value) from a JSON object, or matching string value(s) from a JSON array.</p> <pre>'{"a": "b", "c": "d"}'::jsonb - 'a' → {"c": "d"}</pre> <pre>'["a", "b", "c", "b"]'::jsonb - 'b' → ["a", "c"]</pre>
<code>jsonb - text[]</code>	<p><code>jsonb - text[]</code> → jsonb Deletes all matching keys or array elements from the left operand.</p> <pre>'{"a": "b", "c": "d"}'::jsonb - '{a,c}'::text[] → {}</pre>
<code>jsonb - integer</code>	<p><code>jsonb - integer</code> → jsonb Deletes the array element with specified index (negative integers count from the end). Throws an error if JSON value is not an array.</p> <pre>'["a", "b"]'::jsonb - 1 → ["a"]</pre>
<code>jsonb #- text[]</code>	<p><code>jsonb #- text[]</code> → jsonb Deletes the field or array element at the specified path, where path elements can be either field keys or array indexes.</p> <pre>'["a", {"b":1}]'::jsonb #- '{1,b}' → ["a", {}]</pre>
<code>jsonb @? jsonpath</code>	<p><code>jsonb @? jsonpath</code> → boolean Does JSON path return any item for the specified JSON value?</p> <pre>'{"a":[1,2,3,4,5]}'::jsonb @? '\$.a[*] ? (@ &gt; 2)' → t</pre>
<code>jsonb @@ jsonpath</code>	<p><code>jsonb @@ jsonpath</code> → boolean Returns the result of a JSON path predicate check for the specified JSON value. Only the first item of the result is taken into account. If the result is not Boolean, then NULL is returned.</p> <pre>'{"a":[1,2,3,4,5]}'::jsonb @@ '\$.a[*] &gt; 2' → t</pre>

**Note**

The jsonpath operators @? and @@ suppress the following errors: missing object field or array element, unexpected JSON item type, datetime and numeric errors. The jsonpath-related functions described below can also be told to suppress these types of errors. This behavior might be helpful when searching JSON document collections of varying structure.

Table 9.47 shows the functions that are available for constructing json and jsonb values.

**Table 9.47. JSON Creation Functions**

Function	Description Example(s)
<code>to_json ( anyelement ) → json</code> <code>to_jsonb ( anyelement ) → jsonb</code>	<p>Converts any SQL value to json or jsonb. Arrays and composites are converted recursively to arrays and objects (multidimensional arrays become arrays of arrays in JSON). Otherwise, if there is a cast from the SQL data type to json, the cast function will be used to perform the conversion;<sup>a</sup> otherwise, a scalar JSON value is produced. For any scalar other than a number, a Boolean, or a null value, the text representation will be used, with escaping as necessary to make it a valid JSON string value.</p> <p><code>to_json('Fred said "Hi."'::text) → "Fred said \"Hi.\""</code>  <code>to_jsonb(row(42, 'Fred said "Hi."'::text)) → {"f1": 42, "f2": "Fred said \"Hi.\""}"</code></p>
<code>array_to_json ( anyarray [, boolean ] ) → json</code>	<p>Converts a SQL array to a JSON array. The behavior is the same as to_json except that line feeds will be added between top-level array elements if the optional boolean parameter is true.</p> <p><code>array_to_json( '{ {1,5}, {99,100} } '::int[] ) → [[1,5],[99,100]]</code></p>
<code>row_to_json ( record [, boolean ] ) → json</code>	<p>Converts a SQL composite value to a JSON object. The behavior is the same as to_json except that line feeds will be added between top-level elements if the optional boolean parameter is true.</p> <p><code>row_to_json(row(1, 'foo')) → {"f1":1, "f2":"foo"}</code></p>
<code>json_build_array ( VARIADIC "any" ) → json</code> <code>jsonb_build_array ( VARIADIC "any" ) → jsonb</code>	<p>Builds a possibly-heterogeneously-typed JSON array out of a variadic argument list. Each argument is converted as per to_json or to_jsonb.</p> <p><code>json_build_array(1, 2, 'foo', 4, 5) → [1, 2, "foo", 4, 5]</code></p>
<code>json_build_object ( VARIADIC "any" ) → json</code> <code>jsonb_build_object ( VARIADIC "any" ) → jsonb</code>	<p>Builds a JSON object out of a variadic argument list. By convention, the argument list consists of alternating keys and values. Key arguments are coerced to text; value arguments are converted as per to_json or to_jsonb.</p> <p><code>json_build_object('foo', 1, 2, row(3, 'bar')) → {"foo" : 1, "2" : {"f1":3, "f2":"bar"}}</code></p>
<code>json_object ( text[] ) → json</code> <code>jsonb_object ( text[] ) → jsonb</code>	<p>Builds a JSON object out of a text array. The array must have either exactly one dimension with an even number of members, in which case they are taken as alternating key/value pairs, or two dimensions such that each inner array has exactly two elements, which are taken as a key/value pair. All values are converted to JSON strings.</p> <p><code>json_object(' {a, 1, b, "def", c, 3.5} ') → {"a" : "1", "b" : "def", "c" : "3.5"}</code>  <code>json_object(' { {a, 1}, {b, "def"}, {c, 3.5} } ') → {"a" : "1", "b" : "def", "c" : "3.5"}</code></p>
<code>json_object ( keys text[], values text[] ) → json</code>	

Function
<p><b>Description</b> <b>Example(s)</b></p>
<pre>jsonb_object ( keys text[ ], values text[ ] ) → jsonb This form of json_object takes keys and values pairwise from separate text arrays. Otherwise it is identical to the one-argument form. json_object( '{a,b}', '{1,2}' ) → { "a": "1", "b": "2" }</pre>

<sup>a</sup> For example, the hstore extension has a cast from hstore to json, so that hstore values converted via the JSON creation functions will be represented as JSON objects, not as primitive string values.

Table 9.48 shows the functions that are available for processing json and jsonb values.

**Table 9.48. JSON Processing Functions**

Function
<p><b>Description</b> <b>Example(s)</b></p>
<pre>json_array_elements ( json ) → setof json jsonb_array_elements ( jsonb ) → setof jsonb Expands the top-level JSON array into a set of JSON values. select * from json_array_elements( '[1,true, [2,false]]' ) →        value -----       1       true       [2,false]</pre>
<pre>json_array_elements_text ( json ) → setof text jsonb_array_elements_text ( jsonb ) → setof text Expands the top-level JSON array into a set of text values. select * from json_array_elements_text( '["foo", "bar"]' ) →        value -----       foo       bar</pre>
<pre>json_array_length ( json ) → integer jsonb_array_length ( jsonb ) → integer Returns the number of elements in the top-level JSON array. json_array_length( '[1,2,3, {"f1":1, "f2":[5,6]},4]' ) → 5 jsonb_array_length( '[]' ) → 0</pre>
<pre>json_each ( json ) → setof record ( key text, value json ) jsonb_each ( jsonb ) → setof record ( key text, value jsonb ) Expands the top-level JSON object into a set of key/value pairs. select * from json_each( '{"a":"foo", "b":"bar"}' ) →        key   value -----+-----       a     "foo"</pre>

Function
<p><b>Description</b> <b>Example(s)</b></p> <pre>b   "bar"</pre>
<pre>json_each_text ( json ) → setof record ( key text, value text ) jsonb_each_text ( jsonb ) → setof record ( key text, value text )</pre> <p>Expands the top-level JSON object into a set of key/value pairs. The returned <i>values</i> will be of type <i>text</i>.</p> <pre>select * from json_each_text ('{"a":"foo", "b":"bar"}') →</pre> <pre> key   value -----+----- a     foo b     bar </pre>
<pre>json_extract_path ( from_json json, VARIADIC path_elems text[] ) → json jsonb_extract_path ( from_json jsonb, VARIADIC path_elems text[] ) → jsonb</pre> <p>Extracts JSON sub-object at the specified path. (This is functionally equivalent to the #&gt; operator, but writing the path out as a variadic list can be more convenient in some cases.)</p> <pre>json_extract_path ('{"f2":{"f3":1}, "f4": {"f5":99, "f6":"foo"}'} , 'f4', 'f6') → "foo"</pre>
<pre>json_extract_path_text ( from_json json, VARIADIC path_elems text[] ) → text jsonb_extract_path_text ( from_json jsonb, VARIADIC path_elems text[] ) → text</pre> <p>Extracts JSON sub-object at the specified path as <i>text</i>. (This is functionally equivalent to the #&gt;&gt; operator.)</p> <pre>json_extract_path_text ('{"f2":{"f3":1}, "f4": {"f5":99, "f6":"foo"}'} , 'f4', 'f6') → foo</pre>
<pre>json_object_keys ( json ) → setof text jsonb_object_keys ( jsonb ) → setof text</pre> <p>Returns the set of keys in the top-level JSON object.</p> <pre>select * from json_object_keys ('{"f1":"abc", "f2":{"f3":"a", "f4":"b"}'} ) →</pre> <pre> json_object_keys ----- f1 f2 </pre>
<pre>json_populate_record ( base anyelement, from_json json ) → anyelement jsonb_populate_record ( base anyelement, from_json jsonb ) → anyelement</pre> <p>Expands the top-level JSON object to a row having the composite type of the <i>base</i> argument. The JSON object is scanned for fields whose names match column names of the output row type, and their values are inserted into those columns of the output. (Fields that do not correspond to any output column name are ignored.) In typical use, the value of <i>base</i> is just NULL, which means that any output columns that do not match</p>

Function
<p><b>Description</b> <b>Example(s)</b></p> <p>any object field will be filled with nulls. However, if <i>base</i> isn't NULL then the values it contains will be used for unmatched columns. To convert a JSON value to the SQL type of an output column, the following rules are applied in sequence:</p> <ul style="list-style-type: none"> <li>• A JSON null value is converted to a SQL null in all cases.</li> <li>• If the output column is of type <code>json</code> or <code>jsonb</code>, the JSON value is just reproduced exactly.</li> <li>• If the output column is a composite (row) type, and the JSON value is a JSON object, the fields of the object are converted to columns of the output row type by recursive application of these rules.</li> <li>• Likewise, if the output column is an array type and the JSON value is a JSON array, the elements of the JSON array are converted to elements of the output array by recursive application of these rules.</li> <li>• Otherwise, if the JSON value is a string, the contents of the string are fed to the input conversion function for the column's data type.</li> <li>• Otherwise, the ordinary text representation of the JSON value is fed to the input conversion function for the column's data type.</li> </ul> <p>While the example below uses a constant JSON value, typical use would be to reference a <code>json</code> or <code>jsonb</code> column laterally from another table in the query's <code>FROM</code> clause. Writing <code>json_populate_record</code> in the <code>FROM</code> clause is good practice, since all of the extracted columns are available for use without duplicate function calls.</p> <pre>create type subrowtype as (d int, e text); create type myrowtype as (a int, b text[], c subrowtype); select * from json_populate_record(null::myrowtype, '{"a": 1, "b": ["2", "a b"], "c": {"d": 4, "e": "a b c"}, "x": "foo"}') →</pre> <pre> a        b             c ---+-----+----- 1   {2,"a b"}   (4,"a b c")</pre>
<pre>json_populate_recordset ( base anyelement, from_json json ) → setof anyelement jsonb_populate_recordset ( base anyelement, from_json jsonb ) → setof anyelement Expands the top-level JSON array of objects to a set of rows having the composite type of the <i>base</i> argument. Each element of the JSON array is processed as described above for <code>json[b]_populate_record</code>.</pre> <pre>create type twoints as (a int, b int); select * from json_populate_recordset(null::twoints, ' [{"a":1,"b":2}, {"a":3,"b":4} ]' ) →</pre> <pre> a   b ---+--- 1   2 3   4</pre>
<pre>json_to_record ( json ) → record jsonb_to_record ( jsonb ) → record</pre>



Function										
<p><b>Description</b> <b>Example(s)</b></p> <p>Expands the top-level JSON object to a row having the composite type defined by an AS clause. (As with all functions returning <code>record</code>, the calling query must explicitly define the structure of the record with an AS clause.) The output record is filled from fields of the JSON object, in the same way as described above for <code>json[b]_populate_record</code>. Since there is no input record value, unmatched columns are always filled with nulls.</p> <pre>create type myrowtype as (a int, b text); select * from json_to_record('{ "a":1, "b":[1,2,3], "c": [1,2,3], "e":"bar", "r": { "a": 123, "b": "a b c" } }') as x(a int, b text, c int[], d text, r myrowtype) →</pre> <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>a</th> <th>b</th> <th>c</th> <th>d</th> <th>r</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>[1,2,3]</td> <td>{1,2,3}</td> <td></td> <td>(123,"a b c")</td> </tr> </tbody> </table>	a	b	c	d	r	1	[1,2,3]	{1,2,3}		(123,"a b c")
a	b	c	d	r						
1	[1,2,3]	{1,2,3}		(123,"a b c")						
<pre>json_to_recordset ( json ) → setof record jsonb_to_recordset ( jsonb ) → setof record</pre> <p>Expands the top-level JSON array of objects to a set of rows having the composite type defined by an AS clause. (As with all functions returning <code>record</code>, the calling query must explicitly define the structure of the record with an AS clause.) Each element of the JSON array is processed as described above for <code>json[b]_populate_record</code>.</p> <pre>select * from json_to_recordset(' [{"a":1, "b": "foo"}, {"a": "2", "c": "bar"} ]') as x(a int, b text) →</pre> <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>a</th> <th>b</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>foo</td> </tr> <tr> <td>2</td> <td></td> </tr> </tbody> </table>	a	b	1	foo	2					
a	b									
1	foo									
2										
<pre>jsonb_set ( target jsonb, path text[], new_value jsonb [, create_if_missing boolean ] ) → jsonb</pre> <p>Returns <code>target</code> with the item designated by <code>path</code> replaced by <code>new_value</code>, or with <code>new_value</code> added if <code>create_if_missing</code> is true (which is the default) and the item designated by <code>path</code> does not exist. All earlier steps in the path must exist, or the <code>target</code> is returned unchanged. As with the path oriented operators, negative integers that appear in the <code>path</code> count from the end of JSON arrays. If the last path step is an array index that is out of range, and <code>create_if_missing</code> is true, the new value is added at the beginning of the array if the index is negative, or at the end of the array if it is positive.</p> <pre>jsonb_set(' [{"f1":1, "f2":null}, 2, null, 3]', '{0, f1}', '[2,3,4]', false) → [{"f1": [2, 3, 4], "f2": null}, 2, null, 3] jsonb_set(' [{"f1":1, "f2":null}, 2]', '{0, f3}', '[2,3,4]') → [{"f1": 1, "f2": null, "f3": [2, 3, 4]}, 2]</pre>										
<pre>jsonb_set_lax ( target jsonb, path text[], new_value jsonb [, create_if_missing boolean [, null_value_treatment text ] ] ) → jsonb</pre> <p>If <code>new_value</code> is not NULL, behaves identically to <code>jsonb_set</code>. Otherwise behaves according to the value of <code>null_value_treatment</code> which must be one of <code>'raise_exception'</code>, <code>'use_json_null'</code>, <code>'delete_key'</code>, or <code>'return_target'</code>. The default is <code>'use_json_null'</code>.</p>										

Function
<p><b>Description</b> <b>Example(s)</b></p> <pre>jsonb_set_lax(' [{"f1":1,"f2":null},2,null,3]', '{0,f1}', null) → [{"f1":null,"f2":null},2,null,3] jsonb_set_lax(' [{"f1":99,"f2":null},2]', '{0,f3}', null, true, 'return_target') → [{"f1": 99, "f2": null}, 2]</pre>
<pre>jsonb_insert ( target jsonb, path text [], new_value jsonb [, insert_after boolean ]) → jsonb</pre> <p>Returns <i>target</i> with <i>new_value</i> inserted. If the item designated by the <i>path</i> is an array element, <i>new_value</i> will be inserted before that item if <i>insert_after</i> is false (which is the default), or after it if <i>insert_after</i> is true. If the item designated by the <i>path</i> is an object field, <i>new_value</i> will be inserted only if the object does not already contain that key. All earlier steps in the path must exist, or the <i>target</i> is returned unchanged. As with the path oriented operators, negative integers that appear in the <i>path</i> count from the end of JSON arrays. If the last path step is an array index that is out of range, the new value is added at the beginning of the array if the index is negative, or at the end of the array if it is positive.</p> <pre>jsonb_insert(' {"a": [0,1,2]}', '{a, 1}', 'new_value') → {"a": [0, "new_value", 1, 2]} jsonb_insert(' {"a": [0,1,2]}', '{a, 1}', 'new_value', true) → {"a": [0, 1, "new_value", 2]}</pre>
<pre>json_strip_nulls ( json ) → json jsonb_strip_nulls ( jsonb ) → jsonb</pre> <p>Deletes all object fields that have null values from the given JSON value, recursively. Null values that are not object fields are untouched.</p> <pre>json_strip_nulls(' [{"f1":1, "f2":null}, 2, null, 3]') → [{"f1":1},2,null,3]</pre>
<pre>jsonb_path_exists ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]] ) → boolean</pre> <p>Checks whether the JSON path returns any item for the specified JSON value. If the <i>vars</i> argument is specified, it must be a JSON object, and its fields provide named values to be substituted into the <i>jsonpath</i> expression. If the <i>silent</i> argument is specified and is true, the function suppresses the same errors as the @? and @@ operators do.</p> <pre>jsonb_path_exists(' {"a":[1,2,3,4,5]}', '\$.a[*] ? (@ &gt;= \$min &amp;&amp; @ &lt;= \$max)', '{"min":2, "max":4}') → t</pre>
<pre>jsonb_path_match ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]] ) → boolean</pre> <p>Returns the result of a JSON path predicate check for the specified JSON value. Only the first item of the result is taken into account. If the result is not Boolean, then NULL is returned. The optional <i>vars</i> and <i>silent</i> arguments act the same as for <i>jsonb_path_exists</i>.</p> <pre>jsonb_path_match(' {"a":[1,2,3,4,5]}', 'exists(\$.a[*] ? (@ &gt;= \$min &amp;&amp; @ &lt;= \$max))', '{"min":2, "max":4}') → t</pre>
<pre>jsonb_path_query ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]] ) → setof jsonb</pre> <p>Returns all JSON items returned by the JSON path for the specified JSON value. The optional <i>vars</i> and <i>silent</i> arguments act the same as for <i>jsonb_path_exists</i>.</p>

Function
<p><b>Description</b> <b>Example(s)</b></p> <pre>select * from jsonb_path_query('{ "a": [1,2,3,4,5] }', '\$ .a[*] ? (@ &gt;= \$min &amp;&amp; @ &lt;= \$max)', '{ "min":2, "max":4 }') →      jsonb_path_query     -----     2     3     4</pre>
<pre>jsonb_path_query_array ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → jsonb Returns all JSON items returned by the JSON path for the specified JSON value, as a JSON array. The optional vars and silent arguments act the same as for jsonb_path_exists. jsonb_path_query_array ('{ "a": [1,2,3,4,5] }', '\$ .a[*] ? (@ &gt;= \$min &amp;&amp; @ &lt;= \$max)', '{ "min":2, "max":4 }') → [2, 3, 4]</pre>
<pre>jsonb_path_query_first ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → jsonb Returns the first JSON item returned by the JSON path for the specified JSON value. Returns NULL if there are no results. The optional vars and silent arguments act the same as for jsonb_path_exists. jsonb_path_query_first ('{ "a": [1,2,3,4,5] }', '\$ .a[*] ? (@ &gt;= \$min &amp;&amp; @ &lt;= \$max)', '{ "min":2, "max":4 }') → 2</pre>
<pre>jsonb_path_exists_tz ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → boolean jsonb_path_match_tz ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → boolean jsonb_path_query_tz ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → setof jsonb jsonb_path_query_array_tz ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → jsonb jsonb_path_query_first_tz ( target jsonb, path jsonpath [, vars jsonb [, silent boolean ]]) → jsonb These functions act like their counterparts described above without the _tz suffix, except that these functions support comparisons of date/time values that require timezone-aware conversions. The example below requires interpretation of the date-only value 2015-08-02 as a timestamp with time zone, so the result depends on the current TimeZone setting. Due to this dependency, these functions are marked as stable, which means these functions cannot be used in indexes. Their counterparts are immutable, and so can be used in indexes; but they will throw errors if asked to make such comparisons. jsonb_path_exists_tz ('["2015-08-01 12:00:00 -05"]', '\$[*] ? (@.datetime() &lt; "2015-08-02".datetime())') → t</pre>
<pre>jsonb_pretty ( jsonb ) → text Converts the given JSON value to pretty-printed, indented text. jsonb_pretty ('[{"f1":1,"f2":null}, 2]') →  [</pre>

Function	Description
	<pre> Example(s) {   "f1": 1,   "f2": null }, 2 ]</pre>
<pre> json_typeof ( json ) → text jsonb_typeof ( jsonb ) → text</pre>	<p>Returns the type of the top-level JSON value as a text string. Possible types are object, array, string, number, boolean, and null. (The null result should not be confused with a SQL NULL; see the examples.)</p> <pre> json_typeof ( '-123.4' ) → number json_typeof ( 'null' :: json ) → null json_typeof ( NULL :: json ) IS NULL → t</pre>

See also Section 9.21 for the aggregate function `json_agg` which aggregates record values as JSON, the aggregate function `json_object_agg` which aggregates pairs of values into a JSON object, and their `jsonb` equivalents, `jsonb_agg` and `jsonb_object_agg`.

## 9.16.2. The SQL/JSON Path Language

SQL/JSON path expressions specify the items to be retrieved from the JSON data, similar to XPath expressions used for SQL access to XML. In LightDB, path expressions are implemented as the `jsonpath` data type and can use any elements described in Section 8.14.5.

JSON query functions and operators pass the provided path expression to the *path engine* for evaluation. If the expression matches the queried JSON data, the corresponding JSON item, or set of items, is returned. Path expressions are written in the SQL/JSON path language and can include arithmetic expressions and functions.

A path expression consists of a sequence of elements allowed by the `jsonpath` data type. The path expression is normally evaluated from left to right, but you can use parentheses to change the order of operations. If the evaluation is successful, a sequence of JSON items is produced, and the evaluation result is returned to the JSON query function that completes the specified computation.

To refer to the JSON value being queried (the *context item*), use the `$` variable in the path expression. It can be followed by one or more accessor operators, which go down the JSON structure level by level to retrieve sub-items of the context item. Each operator that follows deals with the result of the previous evaluation step.

For example, suppose you have some JSON data from a GPS tracker that you would like to parse, such as:

```

{
  "track": {
    "segments": [
      {
        "location": [ 47.763, 13.4034 ],
        "start time": "2018-10-14 10:05:14",
        "HR": 73
      },
      {
        "location": [ 47.706, 13.2635 ],
```

```

        "start time": "2018-10-14 10:39:21",
        "HR": 135
    }
]
}
}

```

To retrieve the available track segments, you need to use the `.key` accessor operator to descend through surrounding JSON objects:

```
$.track.segments
```

To retrieve the contents of an array, you typically use the `[ * ]` operator. For example, the following path will return the location coordinates for all the available track segments:

```
$.track.segments[*].location
```

To return the coordinates of the first segment only, you can specify the corresponding subscript in the `[ ]` accessor operator. Recall that JSON array indexes are 0-relative:

```
$.track.segments[0].location
```

The result of each path evaluation step can be processed by one or more `jsonpath` operators and methods listed in Section 9.16.2.2. Each method name must be preceded by a dot. For example, you can get the size of an array:

```
$.track.segments.size()
```

More examples of using `jsonpath` operators and methods within path expressions appear below in Section 9.16.2.2.

When defining a path, you can also use one or more *filter expressions* that work similarly to the `WHERE` clause in SQL. A filter expression begins with a question mark and provides a condition in parentheses:

```
? (condition)
```

Filter expressions must be written just after the path evaluation step to which they should apply. The result of that step is filtered to include only those items that satisfy the provided condition. SQL/JSON defines three-valued logic, so the condition can be `true`, `false`, or `unknown`. The `unknown` value plays the same role as SQL `NULL` and can be tested for with the `is unknown` predicate. Further path evaluation steps use only those items for which the filter expression returned `true`.

The functions and operators that can be used in filter expressions are listed in Table 9.50. Within a filter expression, the `@` variable denotes the value being filtered (i.e., one result of the preceding path step). You can write accessor operators after `@` to retrieve component items.

For example, suppose you would like to retrieve all heart rate values higher than 130. You can achieve this using the following expression:

```
$.track.segments[*].HR ? (@ > 130)
```

To get the start times of segments with such values, you have to filter out irrelevant segments before returning the start times, so the filter expression is applied to the previous step, and the path used in the condition is different:

```
$.track.segments[*] ? (@.HR > 130)."start time"
```

You can use several filter expressions in sequence, if required. For example, the following expression selects start times of all segments that contain locations with relevant coordinates and high heart rate values:

```
$.track.segments[*] ? (@.location[1] < 13.4) ? (@.HR > 130). "start
time"
```

Using filter expressions at different nesting levels is also allowed. The following example first filters all segments by location, and then returns high heart rate values for these segments, if available:

```
$.track.segments[*] ? (@.location[1] < 13.4).HR ? (@ > 130)
```

You can also nest filter expressions within each other:

```
$.track ? (exists(@.segments[*] ? (@.HR > 130))).segments.size()
```

This expression returns the size of the track if it contains any segments with high heart rate values, or an empty sequence otherwise.

LightDB's implementation of the SQL/JSON path language has the following deviations from the SQL/JSON standard:

- A path expression can be a Boolean predicate, although the SQL/JSON standard allows predicates only in filters. This is necessary for implementation of the @@ operator. For example, the following jsonpath expression is valid in LightDB:

```
$.track.segments[*].HR < 70
```

- There are minor differences in the interpretation of regular expression patterns used in like\_regex filters, as described in Section 9.16.2.3.

### 9.16.2.1. Strict and Lax Modes

When you query JSON data, the path expression may not match the actual JSON data structure. An attempt to access a non-existent member of an object or element of an array results in a structural error. SQL/JSON path expressions have two modes of handling structural errors:

- lax (default) — the path engine implicitly adapts the queried data to the specified path. Any remaining structural errors are suppressed and converted to empty SQL/JSON sequences.
- strict — if a structural error occurs, an error is raised.

The lax mode facilitates matching of a JSON document structure and path expression if the JSON data does not conform to the expected schema. If an operand does not match the requirements of a particular operation, it can be automatically wrapped as an SQL/JSON array or unwrapped by converting its elements into an SQL/JSON sequence before performing this operation. Besides, comparison operators automatically unwrap their operands in the lax mode, so you can compare SQL/JSON arrays out-of-the-box. An array of size 1 is considered equal to its sole element. Automatic unwrapping is not performed only when:

- The path expression contains type() or size() methods that return the type and the number of elements in the array, respectively.
- The queried JSON data contain nested arrays. In this case, only the outermost array is unwrapped, while all the inner arrays remain unchanged. Thus, implicit unwrapping can only go one level down within each path evaluation step.

For example, when querying the GPS data listed above, you can abstract from the fact that it stores an array of segments when using the lax mode:

```
lax $.track.segments.location
```

In the strict mode, the specified path must exactly match the structure of the queried JSON document to return an SQL/JSON item, so using this path expression will cause an error. To get the same result as in the lax mode, you have to explicitly unwrap the `segments` array:

```
strict $.track.segments[*].location
```

The `.**` accessor can lead to surprising results when using the lax mode. For instance, the following query selects every `HR` value twice:

```
lax $.**.HR
```

This happens because the `.**` accessor selects both the `segments` array and each of its elements, while the `.HR` accessor automatically unwraps arrays when using the lax mode. To avoid surprising results, we recommend using the `.**` accessor only in the strict mode. The following query selects each `HR` value just once:

```
strict $.**.HR
```

### 9.16.2.2. SQL/JSON Path Operators and Methods

Table 9.49 shows the operators and methods available in `jsonpath`. Note that while the unary operators and methods can be applied to multiple values resulting from a preceding path step, the binary operators (addition etc.) can only be applied to single values.

**Table 9.49. `jsonpath` Operators and Methods**

Operator/Method Description Example(s)
$number + number \rightarrow number$ Addition <code>jsonb_path_query('[2]', '\$[0] + 3') → 5</code>
$+ number \rightarrow number$ Unary plus (no operation); unlike addition, this can iterate over multiple values <code>jsonb_path_query_array('{ "x": [2,3,4] }', '+ \$.x') → [2, 3, 4]</code>
$number - number \rightarrow number$ Subtraction <code>jsonb_path_query('[2]', '7 - \$[0]') → 5</code>
$- number \rightarrow number$ Negation; unlike subtraction, this can iterate over multiple values <code>jsonb_path_query_array('{ "x": [2,3,4] }', '- \$.x') → [-2, -3, -4]</code>
$number * number \rightarrow number$ Multiplication <code>jsonb_path_query('[4]', '2 * \$[0]') → 8</code>
$number / number \rightarrow number$ Division

<b>Operator/Method</b>	<b>Description</b>	<b>Example(s)</b>
		<code>jsonb_path_query('[8.5]', '\$[0] / 2') → 4.2500000000000000</code>
	<i>number</i> % <i>number</i> → <i>number</i> Modulo (remainder)	<code>jsonb_path_query('[32]', '\$[0] % 10') → 2</code>
	<i>value</i> . <i>type()</i> → <i>string</i> Type of the JSON item (see <code>json_typeof</code> )	<code>jsonb_path_query_array('[1, "2", {}]', '\$[*].type()') → ["number", "string", "object"]</code>
	<i>value</i> . <i>size()</i> → <i>number</i> Size of the JSON item (number of array elements, or 1 if not an array)	<code>jsonb_path_query('{ "m": [11, 15] }', '\$.m.size()') → 2</code>
	<i>value</i> . <i>double()</i> → <i>number</i> Approximate floating-point number converted from a JSON number or string	<code>jsonb_path_query('{ "len": "1.9" }', '\$.len.double() * 2') → 3.8</code>
	<i>number</i> . <i>ceiling()</i> → <i>number</i> Nearest integer greater than or equal to the given number	<code>jsonb_path_query('{ "h": 1.3 }', '\$.h.ceiling()') → 2</code>
	<i>number</i> . <i>floor()</i> → <i>number</i> Nearest integer less than or equal to the given number	<code>jsonb_path_query('{ "h": 1.7 }', '\$.h.floor()') → 1</code>
	<i>number</i> . <i>abs()</i> → <i>number</i> Absolute value of the given number	<code>jsonb_path_query('{ "z": -0.3 }', '\$.z.abs()') → 0.3</code>
	<i>string</i> . <i>datetime()</i> → <i>datetime_type</i> (see note) Date/time value converted from a string	<code>jsonb_path_query('["2015-8-1", "2015-08-12"]', '\$[*] ? (@.datetime() &lt; "2015-08-2".datetime())') → "2015-8-1"</code>
	<i>string</i> . <i>datetime(template)</i> → <i>datetime_type</i> (see note) Date/time value converted from a string using the specified <code>to_timestamp</code> template	<code>jsonb_path_query_array('["12:30", "18:40"]', '\$[*].datetime("HH24:MI")') → ["12:30:00", "18:40:00"]</code>
	<i>object</i> . <i>keyvalue()</i> → <i>array</i> The object's key-value pairs, represented as an array of objects containing three fields: "key", "value", and "id"; "id" is a unique identifier of the object the key-value pair belongs to	<code>jsonb_path_query_array('{ "x": "20", "y": 32 }', '\$.keyvalue()') → [{"id": 0, "key": "x", "value": "20"}, {"id": 0, "key": "y", "value": 32}]</code>



### Note

The result type of the `datetime()` and `datetime(template)` methods can be `date`, `timetz`, `time`, `timestamptz`, or `timestamp`. Both methods determine their result type dynamically.

The `datetime()` method sequentially tries to match its input string to the ISO formats for `date`, `timetz`, `time`, `timestamptz`, and `timestamp`. It stops on the first matching format and emits the corresponding data type.

The `datetime(template)` method determines the result type according to the fields used in the provided template string.

The `datetime()` and `datetime(template)` methods use the same parsing rules as the `to_timestamp` SQL function does (see Section 9.8), with three exceptions. First, these methods don't allow unmatched template patterns. Second, only the following separators are allowed in the template string: minus sign, period, solidus (slash), comma, apostrophe, semicolon, colon and space. Third, separators in the template string must exactly match the input string.

If different date/time types need to be compared, an implicit cast is applied. A `date` value can be cast to `timestamp` or `timestamptz`, `timestamp` can be cast to `timestamptz`, and `time` to `timetz`. However, all but the first of these conversions depend on the current `TimeZone` setting, and thus can only be performed within timezone-aware `jsonpath` functions.

Table 9.50 shows the available filter expression elements.

**Table 9.50. jsonpath Filter Expression Elements**

Predicate/Value	Description	Example(s)
<code>value == value</code>	Equality comparison (this, and the other comparison operators, work on all JSON scalar values)	<pre> jsonb_path_query_array('[1, "a", 1, 3]', '\$[*] ? (@ == 1)') → [1, 1] jsonb_path_query_array('[1, "a", 1, 3]', '\$[*] ? (@ == "a"')') → ["a"]                     </pre>
<code>value != value</code>	Non-equality comparison	<pre> jsonb_path_query_array('[1, 2, 1, 3]', '\$[*] ? (@ != 1)') → [2, 3] jsonb_path_query_array('["a", "b", "c"]', '\$[*] ? (@ &lt;&gt; "b"')') → ["a", "c"]                     </pre>
<code>value &lt; value</code>	Less-than comparison	<pre> jsonb_path_query_array('[1, 2, 3]', '\$[*] ? (@ &lt; 2)') → [1]                     </pre>
<code>value &lt;= value</code>	Less-than-or-equal-to comparison	

<b>Predicate/Value</b>	<b>Description</b>	<b>Example(s)</b>
		<code>jsonb_path_query_array('["a", "b", "c"]', '\$[*] ? (@ &lt;= "b")') → ["a", "b"]</code>
<code>value &gt; value</code>	boolean Greater-than comparison	<code>jsonb_path_query_array('[1, 2, 3]', '\$[*] ? (@ &gt; 2)') → [3]</code>
<code>value &gt;= value</code>	boolean Greater-than-or-equal-to comparison	<code>jsonb_path_query_array('[1, 2, 3]', '\$[*] ? (@ &gt;= 2)') → [2, 3]</code>
<code>true</code>	boolean JSON constant true	<code>jsonb_path_query('[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]', '\$[*] ? (@.parent == true)') → {"name": "Chris", "parent": true}</code>
<code>false</code>	boolean JSON constant false	<code>jsonb_path_query('[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]', '\$[*] ? (@.parent == false)') → {"name": "John", "parent": false}</code>
<code>null</code>	<code>value</code> JSON constant null (note that, unlike in SQL, comparison to null works normally)	<code>jsonb_path_query('[{"name": "Mary", "job": null}, {"name": "Michael", "job": "driver"}]', '\$[*] ? (@.job == null) .name') → "Mary"</code>
<code>boolean &amp;&amp; boolean</code>	boolean Boolean AND	<code>jsonb_path_query('[1, 3, 7]', '\$[*] ? (@ &gt; 1 &amp;&amp; @ &lt; 5)') → 3</code>
<code>boolean    boolean</code>	boolean Boolean OR	<code>jsonb_path_query('[1, 3, 7]', '\$[*] ? (@ &lt; 1    @ &gt; 5)') → 7</code>
<code>! boolean</code>	boolean Boolean NOT	<code>jsonb_path_query('[1, 3, 7]', '\$[*] ? (!(@ &lt; 5))') → 7</code>
<code>boolean is unknown</code>	boolean Tests whether a Boolean condition is unknown.	<code>jsonb_path_query('[-1, 2, 7, "foo"]', '\$[*] ? ((@ &gt; 0) is unknown)') → "foo"</code>
<code>string like_regex string [flag string]</code>	boolean Tests whether the first operand matches the regular expression given by the second operand, optionally with modifications described by a string of flag characters (see Section 9.16.2.3).	

Predicate/Value	Description	Example(s)
		<pre>jsonb_path_query_array(['"abc"', "abd", "aBdC", "abdacb", "babC"], '\$[*] ? (@ like_regex "^ab.*c")') → ["abc", "abdacb"] jsonb_path_query_array(['"abc"', "abd", "aBdC", "abdacb", "babC"], '\$[*] ? (@ like_regex "^ab.*c" flag "i")') → ["abc", "aBdC", "abdacb"]</pre>
	<p><i>string</i> starts with <i>string</i> → boolean</p> <p>Tests whether the second operand is an initial substring of the first operand.</p>	<pre>jsonb_path_query(['"John Smith"', "Mary Stone", "Bob Johnson"], '\$[*] ? (@ starts with "John")') → "John Smith"</pre>
	<p><i>exists</i> (<i>path_expression</i>) → boolean</p> <p>Tests whether a path expression matches at least one SQL/JSON item. Returns unknown if the path expression would result in an error; the second example uses this to avoid a no-such-key error in strict mode.</p>	<pre>jsonb_path_query('{ "x": [1, 2], "y": [2, 4] }', 'strict \$.* ? (exists (@ ? (@[*] &gt; 2)))') → [2, 4] jsonb_path_query_array('{ "value": 41 }', 'strict \$ ? (exists (@.name)) .name') → []</pre>

### 9.16.2.3. SQL/JSON Regular Expressions

SQL/JSON path expressions allow matching text to a regular expression with the `like_regex` filter. For example, the following SQL/JSON path query would case-insensitively match all strings in an array that start with an English vowel:

```
$[*] ? (@ like_regex "^[aeiou]" flag "i")
```

The optional `flag` string may include one or more of the characters `i` for case-insensitive match, `m` to allow `^` and `$` to match at newlines, `s` to allow `.` to match a newline, and `q` to quote the whole pattern (reducing the behavior to a simple substring match).

The SQL/JSON standard borrows its definition for regular expressions from the `LIKE_REGEX` operator, which in turn uses the XQuery standard. LightDB does not currently support the `LIKE_REGEX` operator. Therefore, the `like_regex` filter is implemented using the POSIX regular expression engine described in Section 9.7.3. This leads to various minor discrepancies from standard SQL/JSON behavior, which are cataloged in Section 9.7.3.8. Note, however, that the flag-letter incompatibilities described there do not apply to SQL/JSON, as it translates the XQuery flag letters to match what the POSIX engine expects.

Keep in mind that the pattern argument of `like_regex` is a JSON path string literal, written according to the rules given in Section 8.14.5. This means in particular that any backslashes you want to use in the regular expression must be doubled. For example, to match string values of the root document that contain only digits:

```
$.* ? (@ like_regex "^\\d+$")
```

## 9.17. Sequence Manipulation Functions

This section describes functions for operating on *sequence objects*, also called sequence generators or just sequences. Sequence objects are special single-row tables created with `CREATE SEQUENCE`.

Sequence objects are commonly used to generate unique identifiers for rows of a table. The sequence functions, listed in Table 9.51, provide simple, multiuser-safe methods for obtaining successive sequence values from sequence objects.

**Table 9.51. Sequence Functions**

Function	Description
<p><code>nextval ( regclass ) → bigint</code></p>	<p>Advances the sequence object to its next value and returns that value. This is done atomically: even if multiple sessions execute <code>nextval</code> concurrently, each will safely receive a distinct sequence value. If the sequence object has been created with default parameters, successive <code>nextval</code> calls will return successive values beginning with 1. Other behaviors can be obtained by using appropriate parameters in the <code>CREATE SEQUENCE</code> command.</p> <p>This function requires <code>USAGE</code> or <code>UPDATE</code> privilege on the sequence.</p>
<p><code>setval ( regclass, bigint [, boolean ] ) → bigint</code></p>	<p>Sets the sequence object's current value, and optionally its <code>is_called</code> flag. The two-parameter form sets the sequence's <code>last_value</code> field to the specified value and sets its <code>is_called</code> field to <code>true</code>, meaning that the next <code>nextval</code> will advance the sequence before returning a value. The value that will be reported by <code>currval</code> is also set to the specified value. In the three-parameter form, <code>is_called</code> can be set to either <code>true</code> or <code>false</code>. <code>true</code> has the same effect as the two-parameter form. If it is set to <code>false</code>, the next <code>nextval</code> will return exactly the specified value, and sequence advancement commences with the following <code>nextval</code>. Furthermore, the value reported by <code>currval</code> is not changed in this case. For example,</p> <pre> SELECT setval('myseq', 42);           Next nextval will   return 43 SELECT setval('myseq', 42, true);     Same as above SELECT setval('myseq', 42, false);   Next nextval will   return 42 </pre> <p>The result returned by <code>setval</code> is just the value of its second argument.</p> <p>This function requires <code>UPDATE</code> privilege on the sequence.</p>
<p><code>currval ( regclass ) → bigint</code></p>	<p>Returns the value most recently obtained by <code>nextval</code> for this sequence in the current session. (An error is reported if <code>nextval</code> has never been called for this sequence in this session.) Because this is returning a session-local value, it gives a predictable answer whether or not other sessions have executed <code>nextval</code> since the current session did.</p> <p>This function requires <code>USAGE</code> or <code>SELECT</code> privilege on the sequence.</p>
<p><code>lastval () → bigint</code></p>	<p>Returns the value most recently returned by <code>nextval</code> in the current session. This function is identical to <code>currval</code>, except that instead of taking the sequence name as an argument it refers to whichever sequence <code>nextval</code> was most recently applied to in the current session. It is an error to call <code>lastval</code> if <code>nextval</code> has not yet been called in the current session.</p> <p>This function requires <code>USAGE</code> or <code>SELECT</code> privilege on the last used sequence.</p>

**Caution**

To avoid blocking concurrent transactions that obtain numbers from the same sequence, the value obtained by `nextval` is not reclaimed for re-use if the calling transaction later aborts. This means that transaction aborts or database crashes can

result in gaps in the sequence of assigned values. That can happen without a transaction abort, too. For example an `INSERT` with an `ON CONFLICT` clause will compute the to-be-inserted tuple, including doing any required `nextval` calls, before detecting any conflict that would cause it to follow the `ON CONFLICT` rule instead. Thus, LightDB sequence objects *cannot be used to obtain “gapless” sequences*.

Likewise, sequence state changes made by `setval` are immediately visible to other transactions, and are not undone if the calling transaction rolls back.

If the database cluster crashes before committing a transaction containing a `nextval` or `setval` call, the sequence state change might not have made its way to persistent storage, so that it is uncertain whether the sequence will have its original or updated state after the cluster restarts. This is harmless for usage of the sequence within the database, since other effects of uncommitted transactions will not be visible either. However, if you wish to use a sequence value for persistent outside-the-database purposes, make sure that the `nextval` call has been committed before doing so.

The sequence to be operated on by a sequence function is specified by a `regclass` argument, which is simply the OID of the sequence in the `pg_class` system catalog. You do not have to look up the OID by hand, however, since the `regclass` data type's input converter will do the work for you. Just write the sequence name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the sequence name. Thus:

```
nextval('foo')           operates on sequence foo
nextval('FOO')           operates on sequence foo
nextval('"Foo"')         operates on sequence Foo
```

The sequence name can be schema-qualified if necessary:

```
nextval('myschema.foo')  operates on myschema.foo
nextval('"myschema".foo') same as above
nextval('foo')           searches search path for foo
```

See Section 8.19 for more information about `regclass`.

### Note

Before LightDB 8.1, the arguments of the sequence functions were of type `text`, not `regclass`, and the above-described conversion from a text string to an OID value would happen at run time during each call. For backward compatibility, this facility still exists, but internally it is now handled as an implicit coercion from `text` to `regclass` before the function is invoked.

When you write the argument of a sequence function as an unadorned literal string, it becomes a constant of type `regclass`. Since this is really just an OID, it will track the originally identified sequence despite later renaming, schema reassignment, etc. This “early binding” behavior is usually desirable for sequence references in column defaults and views. But sometimes you might want “late binding” where the sequence reference is resolved at run time. To get late-binding behavior, force the constant to be stored as a `text` constant instead of `regclass`:

```
nextval('foo'::text)     foo is looked up at runtime
```

Of course, the argument of a sequence function can be an expression as well as a constant. If it is a text expression then the implicit coercion will result in a run-time lookup.

## 9.18. Conditional Expressions

This section describes the SQL-compliant conditional expressions available in LightDB.

### Tip

If your needs go beyond the capabilities of these conditional expressions, you might want to consider writing a server-side function in a more expressive programming language.

### Note

Although COALESCE, GREATEST, and LEAST are syntactically similar to functions, they are not ordinary functions, and thus cannot be used with explicit VARIADIC array arguments.

### 9.18.1. CASE

The SQL CASE expression is a generic conditional expression, similar to if/else statements in other programming languages:

```
CASE WHEN condition THEN result
      [WHEN ...]
      [ELSE result]
END
```

CASE clauses can be used wherever an expression is valid. Each *condition* is an expression that returns a boolean result. If the condition's result is true, the value of the CASE expression is the *result* that follows the condition, and the remainder of the CASE expression is not processed. If the condition's result is not true, any subsequent WHEN clauses are examined in the same manner. If no WHEN *condition* yields true, the value of the CASE expression is the *result* of the ELSE clause. If the ELSE clause is omitted and no condition is true, the result is null.

An example:

```
SELECT * FROM test;

a
---
1
2
3

SELECT a,
       CASE WHEN a=1 THEN 'one'
            WHEN a=2 THEN 'two'
            ELSE 'other'
```

```

        END
    FROM test;

```

```

a | case
---+-----
1 | one
2 | two
3 | other

```

The data types of all the *result* expressions must be convertible to a single output type. See Section 10.5 for more details.

There is a “simple” form of CASE expression that is a variant of the general form above:

```

CASE expression
    WHEN value THEN result
    [WHEN ...]
    [ELSE result]
END

```

The first *expression* is computed, then compared to each of the *value* expressions in the WHEN clauses until one is found that is equal to it. If no match is found, the *result* of the ELSE clause (or a null value) is returned. This is similar to the *switch* statement in C.

The example above can be written using the simple CASE syntax:

```

SELECT a,
       CASE a WHEN 1 THEN 'one'
             WHEN 2 THEN 'two'
             ELSE 'other'
       END
    FROM test;

```

```

a | case
---+-----
1 | one
2 | two
3 | other

```

A CASE expression does not evaluate any subexpressions that are not needed to determine the result. For example, this is a possible way of avoiding a division-by-zero failure:

```

SELECT ... WHERE CASE WHEN x <> 0 THEN y/x > 1.5 ELSE false END;

```

In MySQL compatibility mode(See `lightdb_dblevel_syntax_compatible_type`), the result set of an expression can be any combination of characters, numeric values, and dates. When the result set contains more than two kinds of characters, numeric values and dates, the type of returned value is a string.

```

SELECT CASE WHEN score >= 60 THEN score ELSE 'not pass' END AS
       score from students;

```

**Note**

As described in Section 4.2.15, there are various situations in which subexpressions of an expression are evaluated at different times, so that the principle that “CASE

evaluates only necessary subexpressions” is not ironclad. For example a constant `1/0` subexpression will usually result in a division-by-zero failure at planning time, even if it's within a CASE arm that would never be entered at run time.

## 9.18.2. COALESCE

```
COALESCE(value [, ...])
```

The COALESCE function returns the first of its arguments that is not null. Null is returned only if all arguments are null. It is often used to substitute a default value for null values when data is retrieved for display, for example:

```
SELECT COALESCE(description, short_description, '(none)') ...
```

This returns `description` if it is not null, otherwise `short_description` if it is not null, otherwise `(none)`.

The arguments must all be convertible to a common data type, which will be the type of the result (see Section 10.5 for details).

Like a CASE expression, COALESCE only evaluates the arguments that are needed to determine the result; that is, arguments to the right of the first non-null argument are not evaluated. This SQL-standard function provides capabilities similar to NVL and IFNULL, which are used in some other database systems.

## 9.18.3. NULLIF

```
NULLIF(value1, value2)
```

The NULLIF function returns a null value if `value1` equals `value2`; otherwise it returns `value1`. This can be used to perform the inverse operation of the COALESCE example given above:

```
SELECT NULLIF(value, '(none)') ...
```

In this example, if `value` is `(none)`, null is returned, otherwise the value of `value` is returned.

The two arguments must be of comparable types. To be specific, they are compared exactly as if you had written `value1 = value2`, so there must be a suitable `=` operator available.

The result has the same type as the first argument — but there is a subtlety. What is actually returned is the first argument of the implied `=` operator, and in some cases that will have been promoted to match the second argument's type. For example, `NULLIF(1, 2.2)` yields `numeric`, because there is no `integer = numeric` operator, only `numeric = numeric`.

## 9.18.4. GREATEST and LEAST

```
GREATEST(value [, ...])
```

```
LEAST(value [, ...])
```

The GREATEST and LEAST functions select the largest or smallest value from a list of any number of expressions. The expressions must all be convertible to a common data type, which will be the type of the result (see Section 10.5 for details). NULL values in the list are ignored. The result will be NULL only if all the expressions evaluate to NULL.



Note that `GREATEST` and `LEAST` are not in the SQL standard, but are a common extension. Some other databases make them return `NULL` if any argument is `NULL`, rather than only when all are `NULL`.

When the GUC parameter `lightdb_dblevel_syntax_compatible_type` is set to `oracle`, the behavior of the `GREATEST` and `LEAST` functions adheres to the Oracle standards. In this mode, if any argument evaluates to `NULL`, the functions return `NULL`. Additionally, the first argument is used to determine the return type. If the first argument is numeric, then `lightdb` determines the argument with the highest numeric precedence, implicitly converts the remaining arguments to that data type before the comparison, and returns that data type. If the first argument is not numeric, then each argument after the first is implicitly converted to the data type of the first argument before the comparison.

## 9.18.5. NVL and NVL2

`NVL(expr1, expr2)`

When `expr1` is `NULL`, `expr2` is returned. When `expr1` is not `NULL`, `expr1` is returned. The data types of `expr1` and `expr2` can be different. we support the following different data types.

Name	Result data type	Argument data types
<code>nvl</code>	<code>bit</code>	<code>bit, "any"</code>
<code>nvl</code>	<code>bytea</code>	<code>bytea, "any"</code>
<code>nvl</code>	<code>date</code>	<code>date, "any"</code>
<code>nvl</code>	<code>numeric</code>	<code>double precision, "any"</code>
<code>nvl</code>	<code>numeric</code>	<code>integer, "any"</code>
<code>nvl</code>	<code>numeric</code>	<code>numeric, "any"</code>
<code>nvl</code>	<code>text</code>	<code>text, "any"</code>
<code>nvl</code>	<code>timestamp without time zone</code>	<code>timestamp without time zone, "any"</code>
<code>nvl</code>	<code>timestamp with time zone</code>	<code>timestamp with time zone, "any"</code>
<code>nvl</code>	<code>time without time zone</code>	<code>time without time zone, "any"</code>

The `NVL` example given above:

```
lightdb@test=# select nvl(1.1, 'test'::text);
nvl
-----
1.1
(1 row)
```

In this example `expr1` data type is `Numeric` and the `expr2` is `text`. So the function `nvl(numeric, "any")` is called and the returned data type is `numeric`.

In some special cases, the type returned when `expr1` is null depends on the source of the data. When the following example is executed, according to the implicit conversion rules, null is actually of unknown type, so the function called is `nvl(text, 'any')` so the function returns the text type.

```
lightdb@test=# select pg_typeof(nvl(null, 1)), nvl(null, 1);
pg_typeof | nvl
-----+-----
text      | 1
(1 row)
```

In the following example, because the null field is int type in the database, So the function returns a numeric type

```
create table test_nvl (id int, func varchar(20));
insert into test_nvl values (null, 'nvl');

lightdb@test=# select pg_typeof(nvl(id, 1)), nvl(id, 1) from test;
pg_typeof | nvl
-----+-----
numeric   | 1
(1 row)
```

Because the type returned by `ltrim` is text, So in the following example the function actually called is `nvl(text, "any")`, so the function returns the text type

```
lightdb@test=# select pg_typeof(nvl(ltrim(func, 'nvl'), 1)),
nvl(ltrim(func, 'nvl'), 1) from test;
pg_typeof | nvl
-----+-----
text      | 1
(1 row)
```

The above features also apply in the functions `nvl2`, `decode`, `decode2`.

`NVL2(expr, substitute1, substitute2)`

`NVL2` returns a substitute value based on whether the specified value is NULL or not NULL. When `expr` is NULL, `substitute2` is returned. When it is not NULL, `substitute1` is returned.

Specify the same data types for `substitute1` and `substitute2`, but the `expr` can be different. For `substitute1` and `substitute2` we support the following data types.

Name	Result data type	Argument data types
<code>nvl2</code>	<code>bit</code>	<code>bit, "any"</code>
<code>nvl2</code>	<code>bytea</code>	<code>bytea, "any"</code>

nv12	date	date, "any"
nv12	numeric	double precision, "any"
nv12	numeric	integer, "any"
nv12	numeric	numeric, "any"
nv12	text	text, "any"
nv12	timestamp without time zone	timestamp without time zone, "any"
nv12	timestamp with time zone	timestamp with time zone, "any"
nv12	time without time zone	time without time zone, "any"

The NVL2 example given above:

```
lightdb@test=# select nv12('2022-01-01'::date,'ab'::text,
'cd'::text);
nv12
-----
ab
(1 row)
```

In this example, the `expr` data type is `date`. `substitute1` and `substitute2` data type is `text`. So the function `nv12("any", text, "any")` is called and the returned data type is `text`.

## 9.18.6. DECODE

The `DECODE` function compares `expr` to each search value one by one. If `expr` is equal to a search, then `LightDB` returns the corresponding result. If no match is found, then `LightDB` returns default. If default is omitted, then `LightDB` returns null.

```
DECODE(expr,
      search, result,
      [search, result],
      [search, result]...,
      [default])
```

The `DECODE` function (with more than 2 parameters) can only be used in oracle mode in `LightDB`. That means the GUC parameter `lightdb_dblevel_syntax_compatible_type` must be set to `oracle` before we call this function.

`LightDB` automatically converts `expr` and each search value to the data type of the first search value before comparing. `LightDB` automatically converts the return value to the same data type as the first result. An error will be thrown out if type conversion is not supported. If the first result is null, then `LightDB` converts the return value to the data type `TEXT`.

```
lightdb@oracle=# create table t(a char(10),b varchar2(10));
CREATE TABLE
lightdb@oracle=# insert into t values('a','a');
INSERT 0 1
lightdb@oracle=# select decode(a,b,1,2) from t;
decode
```

```

-----
      2
(1 row)

lightdb@oracle=# select decode(b,a,1,2) from t;
      decode
-----
      1
(1 row)

lightdb@oracle=# select decode(trim(a),b,1,2) from t;
      decode
-----
      1
(1 row)

lightdb@oracle=# select pg_typeof(decode(1,2,'3',4));
      pg_typeof
-----
      text
(1 row)

```

The search, result, and default values can be derived from expressions. LightDB Database uses short-circuit evaluation to result and default. The database evaluates the result expression only if expr and search are equal, otherwise the evaluation step will be skipped. LightDB evaluates the default expression only if expr is not equal to any search expressions. The above short-circuit rule is based on a precondition, which is there exists a coercion between the source data type and the target data type. If not, an error will be thrown out. But the short-circuit evaluation rule does NOT apply to search expressions which means LightDB will convert the type of all search expressions to that of the first search from the beginning.

```

lightdb@oracle=# select decode(3,
                                1,1/0, --short-circuit on result, no
division by zero error              2,2/0, --short-circuit on result, no
division by zero error              3,300,
                                'x'   --short-circuit on default,
no type conversion error           );
      decode
-----
      300
(1 row)

SELECT DECODE(123,
  123, 'Number Match',
  'Not Match', 'Default') --'Not Match' cannot convert to int(type
of 1st search)
FROM DUAL;
ERROR:  invalid input syntax for type numeric: "Not Match"
LINE 3:   'Not Match', 'Default') --'Not Match' cannot convert to
in...

```

In a DECODE function, LightDB considers two nulls to be equivalent. If expr is null, then LightDB returns the result of the first search that is also null.

```
lightdb@oracle=# select decode(null,null,1,2);
decode
-----
       1
(1 row)
```

## 9.19. Array Functions and Operators

Table 9.52 shows the specialized operators available for array types. In addition to those, the usual comparison operators shown in Table 9.1 are available for arrays. The comparison operators compare the array contents element-by-element, using the default B-tree comparison function for the element data type, and sort based on the first difference. In multidimensional arrays the elements are visited in row-major order (last subscript varies most rapidly). If the contents of two arrays are equal but the dimensionality is different, the first difference in the dimensionality information determines the sort order. (This is a change from versions of LightDB prior to 8.2: older versions would claim that two arrays with the same contents were equal, even if the number of dimensions or subscript ranges were different.)

**Table 9.52. Array Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<code>anyarray @&gt; anyarray</code>	→ boolean Does the first array contain the second, that is, does each element appearing in the second array equal some element of the first array? (Duplicates are not treated specially, thus <code>ARRAY[1]</code> and <code>ARRAY[1,1]</code> are each considered to contain the other.)	<code>ARRAY[1,4,3] @&gt; ARRAY[3,1,3] → t</code>
<code>anyarray &lt;@ anyarray</code>	→ boolean Is the first array contained by the second?	<code>ARRAY[2,2,7] &lt;@ ARRAY[1,7,4,2,6] → t</code>
<code>anyarray &amp;&amp; anyarray</code>	→ boolean Do the arrays overlap, that is, have any elements in common?	<code>ARRAY[1,4,3] &amp;&amp; ARRAY[2,1] → t</code>
<code>anyarray    anyarray</code>	→ anyarray Concatenates the two arrays. Concatenating a null or empty array is a no-op; otherwise the arrays must have the same number of dimensions (as illustrated by the first example) or differ in number of dimensions by one (as illustrated by the second).	<code>ARRAY[1,2,3]    ARRAY[4,5,6,7] → {1,2,3,4,5,6,7}</code> <code>ARRAY[1,2,3]    ARRAY[[4,5,6],[7,8,9]] → {{1,2,3},{4,5,6},{7,8,9}}</code>
<code>anyelement    anyarray</code>	→ anyarray Concatenates an element onto the front of an array (which must be empty or one-dimensional).	<code>3    ARRAY[4,5,6] → {3,4,5,6}</code>
<code>anyarray    anyelement</code>	→ anyarray Concatenates an element onto the end of an array (which must be empty or one-dimensional).	<code>ARRAY[4,5,6]    7 → {4,5,6,7}</code>

See Section 8.15 for more details about array operator behavior. See Section 11.2 for more details about which operators support indexed operations.

Table 9.53 shows the functions available for use with array types. See Section 8.15 for more information and examples of the use of these functions.

**Table 9.53. Array Functions**

Function	Description	Example(s)
<code>array_append</code>	<code>array_append ( anyarray, anyelement ) → anyarray</code> Appends an element to the end of an array (same as the <code>anyarray    anyelement</code> operator).	<code>array_append(ARRAY[1,2], 3) → {1,2,3}</code>
<code>array_cat</code>	<code>array_cat ( anyarray, anyarray ) → anyarray</code> Concatenates two arrays (same as the <code>anyarray    anyarray</code> operator).	<code>array_cat(ARRAY[1,2,3], ARRAY[4,5]) → {1,2,3,4,5}</code>
<code>array_dims</code>	<code>array_dims ( anyarray ) → text</code> Returns a text representation of the array's dimensions.	<code>array_dims(ARRAY[[1,2,3], [4,5,6]]) → [1:2][1:3]</code>
<code>array_fill</code>	<code>array_fill ( anyelement, integer[] [, integer[] ] ) → anyarray</code> Returns an array filled with copies of the given value, having dimensions of the lengths specified by the second argument. The optional third argument supplies lower-bound values for each dimension (which default to all 1).	<code>array_fill(11, ARRAY[2,3]) → {{11,11,11},{11,11,11}}</code> <code>array_fill(7, ARRAY[3], ARRAY[2]) → [2:4]={7,7,7}</code>
<code>array_length</code>	<code>array_length ( anyarray, integer ) → integer</code> Returns the length of the requested array dimension. (Produces NULL instead of 0 for empty or missing array dimensions.)	<code>array_length(array[1,2,3], 1) → 3</code> <code>array_length(array[]::int[], 1) → NULL</code> <code>array_length(array['text'], 2) → NULL</code>
<code>array_lower</code>	<code>array_lower ( anyarray, integer ) → integer</code> Returns the lower bound of the requested array dimension.	<code>array_lower('[0:2]={1,2,3}'::integer[], 1) → 0</code>
<code>array_ndims</code>	<code>array_ndims ( anyarray ) → integer</code> Returns the number of dimensions of the array.	<code>array_ndims(ARRAY[[1,2,3], [4,5,6]]) → 2</code>
<code>array_position</code>	<code>array_position ( anyarray, anyelement [, integer ] ) → integer</code> Returns the subscript of the first occurrence of the second argument in the array, or NULL if it's not present. If the third argument is given, the search begins at that subscript. The array must be one-dimensional. Comparisons are done using IS NOT DISTINCT FROM semantics, so it is possible to search for NULL.	<code>array_position(ARRAY['sun', 'mon', 'tue', 'wed', 'thu', 'fri', 'sat'], 'mon') → 2</code>
<code>array_positions</code>	<code>array_positions ( anyarray, anyelement ) → integer[]</code>	

<b>Function</b>
<p><b>Description</b> <b>Example(s)</b></p> <p>Returns an array of the subscripts of all occurrences of the second argument in the array given as first argument. The array must be one-dimensional. Comparisons are done using <code>IS NOT DISTINCT FROM</code> semantics, so it is possible to search for <code>NULL</code>. <code>NULL</code> is returned only if the array is <code>NULL</code>; if the value is not found in the array, an empty array is returned.</p> <p><code>array_positions(ARRAY[ 'A', 'A', 'B', 'A' ], 'A') → {1,2,4}</code></p>
<p><code>array_prepend( anyelement, anyarray ) → anyarray</code> Prepends an element to the beginning of an array (same as the <code>anyelement    anyarray</code> operator).</p> <p><code>array_prepend(1, ARRAY[2,3]) → {1,2,3}</code></p>
<p><code>array_remove( anyarray, anyelement ) → anyarray</code> Removes all elements equal to the given value from the array. The array must be one-dimensional. Comparisons are done using <code>IS NOT DISTINCT FROM</code> semantics, so it is possible to remove <code>NULL</code>s.</p> <p><code>array_remove(ARRAY[1,2,3,2], 2) → {1,3}</code></p>
<p><code>array_replace( anyarray, anyelement, anyelement ) → anyarray</code> Replaces each array element equal to the second argument with the third argument.</p> <p><code>array_replace(ARRAY[1,2,5,4], 5, 3) → {1,2,3,4}</code></p>
<p><code>array_to_string( array anyarray, delimiter text [, null_string text ] ) → text</code> Converts each array element to its text representation, and concatenates those separated by the <i>delimiter</i> string. If <i>null_string</i> is given and is not <code>NULL</code>, then <code>NULL</code> array entries are represented by that string; otherwise, they are omitted.</p> <p><code>array_to_string(ARRAY[1, 2, 3, NULL, 5], ',', '*') → 1,2,3,*,5</code></p>
<p><code>array_upper( anyarray, integer ) → integer</code> Returns the upper bound of the requested array dimension.</p> <p><code>array_upper(ARRAY[1,8,3,7], 1) → 4</code></p>
<p><code>cardinality( anyarray ) → integer</code> Returns the total number of elements in the array, or 0 if the array is empty.</p> <p><code>cardinality(ARRAY[[1,2],[3,4]]) → 4</code></p>
<p><code>string_to_array( string text, delimiter text [, null_string text ] ) → text[]</code> Splits the <i>string</i> at occurrences of <i>delimiter</i> and forms the remaining data into a <i>text</i> array. If <i>delimiter</i> is <code>NULL</code>, each character in the <i>string</i> will become a separate element in the array. If <i>delimiter</i> is an empty string, then the <i>string</i> is treated as a single field. If <i>null_string</i> is supplied and is not <code>NULL</code>, fields matching that string are converted to <code>NULL</code> entries.</p> <p><code>string_to_array('xx~~yy~~zz', '~~', 'yy') → {xx,NULL,zz}</code></p>
<p><code>unnest( anyarray ) → setof anyelement</code> Expands an array into a set of rows. The array's elements are read out in storage order.</p> <p><code>unnest(ARRAY[1,2]) →</code></p> <p>1 2</p>

Function
<p><b>Description</b> <b>Example(s)</b></p> <pre>unnest (ARRAY[ ['foo', 'bar'], ['baz', 'quux'] ]) →</pre> <pre>foo bar baz quux</pre>
<pre>unnest (anyarray, anyarray [, ... ]) → setof anyelement, anyelement [ , ... ]</pre> <p>Expands multiple arrays (possibly of different data types) into a set of rows. If the arrays are not all the same length then the shorter ones are padded with NULLs. This form is only allowed in a query's FROM clause; see Section 7.2.1.4.</p> <pre>select * from unnest(ARRAY[1,2], ARRAY['foo', 'bar', 'baz']) as x(a,b) →</pre> <pre> a   b ---+--- 1   foo 2   bar     baz</pre>

**Note**

There are two differences in the behavior of `string_to_array` from pre-9.1 versions of LightDB. First, it will return an empty (zero-element) array rather than NULL when the input string is of zero length. Second, if the delimiter string is NULL, the function splits the input into individual characters, rather than returning NULL as before.

See also Section 9.21 about the aggregate function `array_agg` for use with arrays.

## 9.20. Range Functions and Operators

See Section 8.17 for an overview of range types.

Table 9.54 shows the specialized operators available for range types. In addition to those, the usual comparison operators shown in Table 9.1 are available for range types. The comparison operators order first by the range lower bounds, and only if those are equal do they compare the upper bounds. This does not usually result in a useful overall ordering, but the operators are provided to allow unique indexes to be constructed on ranges.

**Table 9.54. Range Operators**

Operator
<p><b>Description</b> <b>Example(s)</b></p> <pre>anyrange @&gt; anyrange → boolean</pre> <p>Does the first range contain the second?</p> <pre>int4range(2,4) @&gt; int4range(2,3) → t</pre>



<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
	anyrange @> anyelement → boolean Does the range contain the element?	'[2011-01-01,2011-03-01]':::tsrange @> '2011-01-10':::timestamp → t
	anyrange <@ anyrange → boolean Is the first range contained by the second?	int4range(2,4) <@ int4range(1,7) → t
	anyelement <@ anyrange → boolean Is the element contained in the range?	42 <@ int4range(1,7) → f
	anyrange && anyrange → boolean Do the ranges overlap, that is, have any elements in common?	int8range(3,7) && int8range(4,12) → t
	anyrange << anyrange → boolean Is the first range strictly left of the second?	int8range(1,10) << int8range(100,110) → t
	anyrange >> anyrange → boolean Is the first range strictly right of the second?	int8range(50,60) >> int8range(20,30) → t
	anyrange &< anyrange → boolean Does the first range not extend to the right of the second?	int8range(1,20) &< int8range(18,20) → t
	anyrange &> anyrange → boolean Does the first range not extend to the left of the second?	int8range(7,20) &> int8range(5,10) → t
	anyrange - - anyrange → boolean Are the ranges adjacent?	numrange(1.1,2.2) - - numrange(2.2,3.3) → t
	anyrange + anyrange → anyrange Computes the union of the ranges. The ranges must overlap or be adjacent, so that the union is a single range (but see range_merge()).	numrange(5,15) + numrange(10,20) → [5,20)
	anyrange * anyrange → anyrange Computes the intersection of the ranges.	int8range(5,15) * int8range(10,20) → [10,15)
	anyrange - anyrange → anyrange Computes the difference of the ranges. The second range must not be contained in the first in such a way that the difference would not be a single range.	int8range(5,15) - int8range(10,20) → [5,10)

The left-of/right-of/adjacent operators always return false when an empty range is involved; that is, an empty range is not considered to be either before or after any other range.

Table 9.55 shows the functions available for use with range types.

**Table 9.55. Range Functions**

Function	Description	Example(s)
<code>lower</code>	<code>lower ( anyrange ) → anyelement</code> Extracts the lower bound of the range (NULL if the range is empty or the lower bound is infinite).	<code>lower ( numrange ( 1.1 , 2.2 ) ) → 1.1</code>
<code>upper</code>	<code>upper ( anyrange ) → anyelement</code> Extracts the upper bound of the range (NULL if the range is empty or the upper bound is infinite).	<code>upper ( numrange ( 1.1 , 2.2 ) ) → 2.2</code>
<code>isempty</code>	<code>isempty ( anyrange ) → boolean</code> Is the range empty?	<code>isempty ( numrange ( 1.1 , 2.2 ) ) → f</code>
<code>lower_inc</code>	<code>lower_inc ( anyrange ) → boolean</code> Is the range's lower bound inclusive?	<code>lower_inc ( numrange ( 1.1 , 2.2 ) ) → t</code>
<code>upper_inc</code>	<code>upper_inc ( anyrange ) → boolean</code> Is the range's upper bound inclusive?	<code>upper_inc ( numrange ( 1.1 , 2.2 ) ) → f</code>
<code>lower_inf</code>	<code>lower_inf ( anyrange ) → boolean</code> Is the range's lower bound infinite?	<code>lower_inf ( ' ( , ) ' ::daterange ) → t</code>
<code>upper_inf</code>	<code>upper_inf ( anyrange ) → boolean</code> Is the range's upper bound infinite?	<code>upper_inf ( ' ( , ) ' ::daterange ) → t</code>
<code>range_merge</code>	<code>range_merge ( anyrange , anyrange ) → anyrange</code> Computes the smallest range that includes both of the given ranges.	<code>range_merge ( '[ 1 , 2 ] ' ::int4range , '[ 3 , 4 ] ' ::int4range ) → [ 1 , 4 ]</code>

The `lower_inc`, `upper_inc`, `lower_inf`, and `upper_inf` functions all return false for an empty range.

## 9.21. Aggregate Functions

*Aggregate functions* compute a single result from a set of input values. The built-in general-purpose aggregate functions are listed in Table 9.56 while statistical aggregates are in Table 9.57. The built-in within-group ordered-set aggregate functions are listed in Table 9.58 while the built-in within-group hypothetical-set ones are in Table 9.59. Grouping operations, which are closely related to aggregate functions, are listed in Table 9.60. The special syntax considerations for aggregate functions are explained in Section 4.2.7. Consult Section 2.7 for additional introductory information.

Aggregate functions that support *Partial Mode* are eligible to participate in various optimizations, such as parallel aggregation.

**Table 9.56. General-Purpose Aggregate Functions**

<b>Function Description</b>	<b>Partial Mode</b>
<code>array_agg ( anynonarray ) → anyarray</code> Collects all the input values, including nulls, into an array.	No
<code>array_agg ( anyarray ) → anyarray</code> Concatenates all the input arrays into an array of one higher dimension. (The inputs must all have the same dimensionality, and cannot be empty or null.)	No
<code>avg ( smallint ) → numeric</code> <code>avg ( integer ) → numeric</code> <code>avg ( bigint ) → numeric</code> <code>avg ( numeric ) → numeric</code> <code>avg ( real ) → double precision</code> <code>avg ( double precision ) → double precision</code> <code>avg ( interval ) → interval</code> Computes the average (arithmetic mean) of all the non-null input values.	Yes
<code>bit_and ( smallint ) → smallint</code> <code>bit_and ( integer ) → integer</code> <code>bit_and ( bigint ) → bigint</code> <code>bit_and ( bit ) → bit</code> Computes the bitwise AND of all non-null input values.	Yes
<code>bit_or ( smallint ) → smallint</code> <code>bit_or ( integer ) → integer</code> <code>bit_or ( bigint ) → bigint</code> <code>bit_or ( bit ) → bit</code> Computes the bitwise OR of all non-null input values.	Yes
<code>bool_and ( boolean ) → boolean</code> Returns true if all non-null input values are true, otherwise false.	Yes
<code>bool_or ( boolean ) → boolean</code> Returns true if any non-null input value is true, otherwise false.	Yes
<code>count ( * ) → bigint</code> Computes the number of input rows.	Yes
<code>count ( "any" ) → bigint</code> Computes the number of input rows in which the input value is not null.	Yes
<code>every ( boolean ) → boolean</code> This is the SQL standard's equivalent to <code>bool_and</code> .	Yes
<code>json_agg ( anyelement ) → json</code> <code>jsonb_agg ( anyelement ) → jsonb</code> Collects all the input values, including nulls, into a JSON array. Values are converted to JSON as per <code>to_json</code> or <code>to_jsonb</code> .	No
<code>json_object_agg ( key "any", value "any" ) → json</code> <code>jsonb_object_agg ( key "any", value "any" ) → jsonb</code>	No

Function Description	Partial Mode
Collects all the key/value pairs into a JSON object. Key arguments are coerced to text; value arguments are converted as per <code>to_json</code> or <code>to_jsonb</code> . Values can be null, but not keys.	
<code>max(see text) → same as input type</code> Computes the maximum of the non-null input values. Available for any numeric, string, date/time, or enum type, as well as <code>inet</code> , <code>interval</code> , <code>money</code> , <code>oid</code> , <code>pg_lsn</code> , <code>tid</code> , and arrays of any of these types.	Yes
<code>min(see text) → same as input type</code> Computes the minimum of the non-null input values. Available for any numeric, string, date/time, or enum type, as well as <code>inet</code> , <code>interval</code> , <code>money</code> , <code>oid</code> , <code>pg_lsn</code> , <code>tid</code> , and arrays of any of these types.	Yes
<code>string_agg(value text, delimiter text) → text</code> <code>string_agg(value bytea, delimiter bytea) → bytea</code> Concatenates the non-null input values into a string. Each value after the first is preceded by the corresponding <i>delimiter</i> (if it's not null).	No
<code>sum(smallint) → bigint</code> <code>sum(integer) → bigint</code> <code>sum(bigint) → numeric</code> <code>sum(numeric) → numeric</code> <code>sum(real) → real</code> <code>sum(double precision) → double precision</code> <code>sum(interval) → interval</code> <code>sum(money) → money</code> Computes the sum of the non-null input values.	Yes
<code>xmlagg(xml) → xml</code> Concatenates the non-null XML input values (see Section 9.15.1.7).	No

It should be noted that except for `count`, these functions return a null value when no rows are selected. In particular, `sum` of no rows returns null, not zero as one might expect, and `array_agg` returns null rather than an empty array when there are no input rows. The `coalesce` function can be used to substitute zero or an empty array for null when necessary.

The aggregate functions `array_agg`, `json_agg`, `jsonb_agg`, `json_object_agg`, `jsonb_object_agg`, `string_agg`, and `xmlagg`, as well as similar user-defined aggregate functions, produce meaningfully different result values depending on the order of the input values. This ordering is unspecified by default, but can be controlled by writing an `ORDER BY` clause within the aggregate call, as shown in Section 4.2.7. Alternatively, supplying the input values from a sorted subquery will usually work. For example:

```
SELECT xmlagg(x) FROM (SELECT x FROM test ORDER BY y DESC) AS tab;
```

Beware that this approach can fail if the outer query level contains additional processing, such as a join, because that might cause the subquery's output to be reordered before the aggregate is computed.

### Note

The boolean aggregates `bool_and` and `bool_or` correspond to the standard SQL aggregates `every` and `any` or `some`. LightDB supports `every`, but not `any` or `some`, because there is an ambiguity built into the standard syntax:

```
SELECT b1 = ANY((SELECT b2 FROM t2 ...)) FROM t1 ...;
```

Here ANY can be considered either as introducing a subquery, or as being an aggregate function, if the subquery returns one row with a Boolean value. Thus the standard name cannot be given to these aggregates.

### Note

Users accustomed to working with other SQL database management systems might be disappointed by the performance of the `count` aggregate when it is applied to the entire table. A query like:

```
SELECT count(*) FROM sometable;
```

will require effort proportional to the size of the table: LightDB will need to scan either the entire table or the entirety of an index that includes all rows in the table.

### Note

When you use the SharedJDBC framework, it may resolve the aggregate function parameter names. But the LightDB output function call column name has no arguments by default.

```
select max(a) from agg_table;
max
-----
  10
(1 row)
```

If you have this problem, you can turn on the switch `lightdb_aggcolumn_rename`, when trun on this switch, LightDB will output column name with argument list, when you call `count`, `avg`, `min`, `max`, `sum` with column references.

```
set lightdb_aggcolumn_rename=on;
select max(a) from agg_table;
MAX(A)
-----
  10
(1 row)
```

This renaming works when simple referring to column, but not when function calls, expressions, etc.

```
set lightdb_aggcolumn_rename=on;
select max(a + 1) from agg_table;
max
-----
  11
(1 row)
```

Table 9.57 shows aggregate functions typically used in statistical analysis. (These are separated out merely to avoid cluttering the listing of more-commonly-used aggregates.) Functions shown as accepting *numeric\_type* are available for all the types *smallint*, *integer*, *bigint*, *numeric*, *real*, and *double precision*. Where the description mentions *N*, it means the number of input rows for which all the input expressions are non-null. In all cases, null is returned if the computation is meaningless, for example when *N* is zero.

**Table 9.57. Aggregate Functions for Statistics**

Function Description	Partial Mode
<code>corr ( Y double precision, X double precision ) → double precision</code> Computes the correlation coefficient.	Yes
<code>covar_pop ( Y double precision, X double precision ) → double precision</code> Computes the population covariance.	Yes
<code>covar_samp ( Y double precision, X double precision ) → double precision</code> Computes the sample covariance.	Yes
<code>regr_avgx ( Y double precision, X double precision ) → double precision</code> Computes the average of the independent variable, $\text{sum}(X) / N$ .	Yes
<code>regr_avgy ( Y double precision, X double precision ) → double precision</code> Computes the average of the dependent variable, $\text{sum}(Y) / N$ .	Yes
<code>regr_count ( Y double precision, X double precision ) → bigint</code> Computes the number of rows in which both inputs are non-null.	Yes
<code>regr_intercept ( Y double precision, X double precision ) → double precision</code> Computes the y-intercept of the least-squares-fit linear equation determined by the (X, Y) pairs.	Yes
<code>regr_r2 ( Y double precision, X double precision ) → double precision</code> Computes the square of the correlation coefficient.	Yes
<code>regr_slope ( Y double precision, X double precision ) → double precision</code> Computes the slope of the least-squares-fit linear equation determined by the (X, Y) pairs.	Yes
<code>regr_sxx ( Y double precision, X double precision ) → double precision</code> Computes the “sum of squares” of the independent variable, $\text{sum}(X^2) - \text{sum}(X)^2 / N$ .	Yes
<code>regr_sxy ( Y double precision, X double precision ) → double precision</code> Computes the “sum of products” of independent times dependent variables, $\text{sum}(X*Y) - \text{sum}(X) * \text{sum}(Y) / N$ .	Yes
<code>regr_syy ( Y double precision, X double precision ) → double precision</code>	Yes

Function Description	Partial Mode
Computes the “sum of squares” of the dependent variable, $\text{sum}(Y^2) - \text{sum}(Y)^2/N$ .	
<code>stddev( numeric_type )</code> → double precision for real or double precision, otherwise numeric This is a historical alias for <code>stddev_samp</code> .	Yes
<code>stddev_pop( numeric_type )</code> → double precision for real or double precision, otherwise numeric Computes the population standard deviation of the input values.	Yes
<code>stddev_samp( numeric_type )</code> → double precision for real or double precision, otherwise numeric Computes the sample standard deviation of the input values.	Yes
<code>variance( numeric_type )</code> → double precision for real or double precision, otherwise numeric This is a historical alias for <code>var_samp</code> .	Yes
<code>var_pop( numeric_type )</code> → double precision for real or double precision, otherwise numeric Computes the population variance of the input values (square of the population standard deviation).	Yes
<code>var_samp( numeric_type )</code> → double precision for real or double precision, otherwise numeric Computes the sample variance of the input values (square of the sample standard deviation).	Yes

Table 9.58 shows some aggregate functions that use the *ordered-set aggregate* syntax. These functions are sometimes referred to as “inverse distribution” functions. Their aggregated input is introduced by `ORDER BY`, and they may also take a *direct argument* that is not aggregated, but is computed only once. All these functions ignore null values in their aggregated input. For those that take a *fraction* parameter, the fraction value must be between 0 and 1; an error is thrown if not. However, a null *fraction* value simply produces a null result.

**Table 9.58. Ordered-Set Aggregate Functions**

Function Description	Partial Mode
<code>mode() WITHIN GROUP ( ORDER BY anyelement )</code> → anyelement Computes the <i>mode</i> , the most frequent value of the aggregated argument (arbitrarily choosing the first one if there are multiple equally-frequent values). The aggregated argument must be of a sortable type.	No
<code>percentile_cont( fraction double precision ) WITHIN GROUP ( ORDER BY double precision )</code> → double precision <code>percentile_cont( fraction double precision ) WITHIN GROUP ( ORDER BY interval )</code> → interval Computes the <i>continuous percentile</i> , a value corresponding to the specified <i>fraction</i> within the ordered set of aggregated argument values. This will interpolate between adjacent input items if needed.	No
<code>percentile_cont( fractions double precision[] ) WITHIN GROUP ( ORDER BY double precision )</code> → double precision[]	No

Function Description	Partial Mode
<code>percentile_cont ( fractions double precision[] ) WITHIN GROUP ( ORDER BY interval ) → interval[]</code> Computes multiple continuous percentiles. The result is an array of the same dimensions as the <i>fractions</i> parameter, with each non-null element replaced by the (possibly interpolated) value corresponding to that percentile.	
<code>percentile_disc ( fraction double precision ) WITHIN GROUP ( ORDER BY anyelement ) → anyelement</code> Computes the <i>discrete percentile</i> , the first value within the ordered set of aggregated argument values whose position in the ordering equals or exceeds the specified <i>fraction</i> . The aggregated argument must be of a sortable type.	No
<code>percentile_disc ( fractions double precision[] ) WITHIN GROUP ( ORDER BY anyelement ) → anyarray</code> Computes multiple discrete percentiles. The result is an array of the same dimensions as the <i>fractions</i> parameter, with each non-null element replaced by the input value corresponding to that percentile. The aggregated argument must be of a sortable type.	No

Each of the “hypothetical-set” aggregates listed in Table 9.59 is associated with a window function of the same name defined in Section 9.22. In each case, the aggregate's result is the value that the associated window function would have returned for the “hypothetical” row constructed from *args*, if such a row had been added to the sorted group of rows represented by the *sorted\_args*. For each of these functions, the list of direct arguments given in *args* must match the number and types of the aggregated arguments given in *sorted\_args*. Unlike most built-in aggregates, these aggregates are not strict, that is they do not drop input rows containing nulls. Null values sort according to the rule specified in the `ORDER BY` clause.

**Table 9.59. Hypothetical-Set Aggregate Functions**

Function Description	Partial Mode
<code>rank ( args ) WITHIN GROUP ( ORDER BY sorted_args ) → bigint</code> Computes the rank of the hypothetical row, with gaps; that is, the row number of the first row in its peer group.	No
<code>dense_rank ( args ) WITHIN GROUP ( ORDER BY sorted_args ) → bigint</code> Computes the rank of the hypothetical row, without gaps; this function effectively counts peer groups.	No
<code>percent_rank ( args ) WITHIN GROUP ( ORDER BY sorted_args ) → double precision</code> Computes the relative rank of the hypothetical row, that is $(rank - 1) / (total\ rows - 1)$ . The value thus ranges from 0 to 1 inclusive.	No
<code>cume_dist ( args ) WITHIN GROUP ( ORDER BY sorted_args ) → double precision</code> Computes the cumulative distribution, that is $(number\ of\ rows\ preceding\ or\ peers\ with\ hypothetical\ row) / (total\ rows)$ . The value thus ranges from $1/N$ to 1.	No

**Table 9.60. Grouping Operations**

Function Description
<code>GROUPING ( group_by_expression(s) ) → integer</code>



Function	Description
	Returns a bit mask indicating which GROUP BY expressions are not included in the current grouping set. Bits are assigned with the rightmost argument corresponding to the least-significant bit; each bit is 0 if the corresponding expression is included in the grouping criteria of the grouping set generating the current result row, and 1 if it is not included.

The grouping operations shown in Table 9.60 are used in conjunction with grouping sets (see Section 7.2.4) to distinguish result rows. The arguments to the GROUPING function are not actually evaluated, but they must exactly match expressions given in the GROUP BY clause of the associated query level. For example:

```
=> SELECT * FROM items_sold;
make | model | sales
-----+-----+-----
Foo   | GT    | 10
Foo   | Tour  | 20
Bar   | City  | 15
Bar   | Sport | 5
(4 rows)
```

```
=> SELECT make, model, GROUPING(make,model), sum(sales) FROM
items_sold GROUP BY ROLLUP(make,model);
make | model | grouping | sum
-----+-----+-----+-----
Foo   | GT    |          0 | 10
Foo   | Tour  |          0 | 20
Bar   | City  |          0 | 15
Bar   | Sport |          0 | 5
Foo   |       |          1 | 30
Bar   |       |          1 | 20
      |       |          3 | 50
(7 rows)
```

Here, the grouping value 0 in the first four rows shows that those have been grouped normally, over both the grouping columns. The value 1 indicates that model was not grouped by in the next-to-last two rows, and the value 3 indicates that neither make nor model was grouped by in the last row (which therefore is an aggregate over all the input rows).

## 9.22. Window Functions

*Window functions* provide the ability to perform calculations across sets of rows that are related to the current query row. See Section 3.5 for an introduction to this feature, and Section 4.2.8 for syntax details.

The built-in window functions are listed in Table 9.61. Note that these functions *must* be invoked using window function syntax, i.e., an OVER clause is required.

In addition to these functions, any built-in or user-defined ordinary aggregate (i.e., not ordered-set or hypothetical-set aggregates) can be used as a window function; see Section 9.21 for a list of the built-in aggregates. Aggregate functions act as window functions only when an OVER clause follows the call; otherwise they act as plain aggregates and return a single row for the entire set.

**Table 9.61. General-Purpose Window Functions**

Function	Description
<code>row_number ()</code> → <code>bigint</code>	Returns the number of the current row within its partition, counting from 1.
<code>rank ()</code> → <code>bigint</code>	Returns the rank of the current row, with gaps; that is, the <code>row_number</code> of the first row in its peer group.
<code>dense_rank ()</code> → <code>bigint</code>	Returns the rank of the current row, without gaps; this function effectively counts peer groups.
<code>percent_rank ()</code> → <code>double precision</code>	Returns the relative rank of the current row, that is $(rank - 1) / (total\ partition\ rows - 1)$ . The value thus ranges from 0 to 1 inclusive.
<code>cume_dist ()</code> → <code>double precision</code>	Returns the cumulative distribution, that is $(number\ of\ partition\ rows\ preceding\ or\ peers\ with\ current\ row) / (total\ partition\ rows)$ . The value thus ranges from $1/N$ to 1.
<code>ntile ( num_buckets integer )</code> → <code>integer</code>	Returns an integer ranging from 1 to the argument value, dividing the partition as equally as possible.
<code>lag ( value anyelement [, offset integer [, default anyelement ] ] )</code> → <code>anyelement</code>	Returns <i>value</i> evaluated at the row that is <i>offset</i> rows before the current row within the partition; if there is no such row, instead returns <i>default</i> (which must be of the same type as <i>value</i> ). Both <i>offset</i> and <i>default</i> are evaluated with respect to the current row. If omitted, <i>offset</i> defaults to 1 and <i>default</i> to NULL.
<code>lead ( value anyelement [, offset integer [, default anyelement ] ] )</code> → <code>anyelement</code>	Returns <i>value</i> evaluated at the row that is <i>offset</i> rows after the current row within the partition; if there is no such row, instead returns <i>default</i> (which must be of the same type as <i>value</i> ). Both <i>offset</i> and <i>default</i> are evaluated with respect to the current row. If omitted, <i>offset</i> defaults to 1 and <i>default</i> to NULL.
<code>first_value ( value anyelement )</code> → <code>anyelement</code>	Returns <i>value</i> evaluated at the row that is the first row of the window frame.
<code>last_value ( value anyelement )</code> → <code>anyelement</code>	Returns <i>value</i> evaluated at the row that is the last row of the window frame.
<code>nth_value ( value anyelement, n integer )</code> → <code>anyelement</code>	Returns <i>value</i> evaluated at the row that is the <i>n</i> 'th row of the window frame (counting from 1); returns NULL if there is no such row.

All of the functions listed in Table 9.61 depend on the sort ordering specified by the `ORDER BY` clause of the associated window definition. Rows that are not distinct when considering only the `ORDER BY` columns are said to be *peers*. The four ranking functions (including `cume_dist`) are defined so that they give the same answer for all rows of a peer group.

Note that `first_value`, `last_value`, and `nth_value` consider only the rows within the “window frame”, which by default contains the rows from the start of the partition through the last peer of the current row. This is likely to give unhelpful results for `last_value` and sometimes also `nth_value`. You can redefine the frame by adding a suitable frame specification (`RANGE`, `ROWS` or `GROUPS`) to the `OVER` clause. See Section 4.2.8 for more information about frame specifications.

When an aggregate function is used as a window function, it aggregates over the rows within the current row's window frame. An aggregate used with `ORDER BY` and the default window frame definition produces a “running sum” type of behavior, which may or may not be what's wanted. To obtain aggregation over the whole partition, omit `ORDER BY` or use `ROWS BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING`. Other frame specifications can be used to obtain other effects.

### Note

The SQL standard defines a `RESPECT NULLS` or `IGNORE NULLS` option for `lead`, `lag`, `first_value`, `last_value`, and `nth_value`. This is not implemented in LightDB: the behavior is always the same as the standard's default, namely `RESPECT NULLS`. Likewise, the standard's `FROM FIRST` or `FROM LAST` option for `nth_value` is not implemented: only the default `FROM FIRST` behavior is supported. (You can achieve the result of `FROM LAST` by reversing the `ORDER BY` ordering.)

## 9.23. Subquery Expressions

This section describes the SQL-compliant subquery expressions available in LightDB. All of the expression forms documented in this section return Boolean (true/false) results.

### 9.23.1. EXISTS

`EXISTS (subquery)`

The argument of `EXISTS` is an arbitrary `SELECT` statement, or *subquery*. The subquery is evaluated to determine whether it returns any rows. If it returns at least one row, the result of `EXISTS` is “true”; if the subquery returns no rows, the result of `EXISTS` is “false”.

The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery.

The subquery will generally only be executed long enough to determine whether at least one row is returned, not all the way to completion. It is unwise to write a subquery that has side effects (such as calling sequence functions); whether the side effects occur might be unpredictable.

Since the result depends only on whether any rows are returned, and not on the contents of those rows, the output list of the subquery is normally unimportant. A common coding convention is to write all `EXISTS` tests in the form `EXISTS (SELECT 1 WHERE ...)`. There are exceptions to this rule however, such as subqueries that use `INTERSECT`.

This simple example is like an inner join on `col2`, but it produces at most one output row for each `tab1` row, even if there are several matching `tab2` rows:

```
SELECT col1
FROM tab1
WHERE EXISTS (SELECT 1 FROM tab2 WHERE col2 = tab1.col2);
```

### 9.23.2. IN

`expression IN (subquery)`

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of `IN` is “true”

if any equal subquery row is found. The result is “false” if no equal row is found (including the case where the subquery returns no rows).

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the `IN` construct will be null, not false. This is in accordance with SQL’s normal rules for Boolean combinations of null values.

As with `EXISTS`, it’s unwise to assume that the subquery will be evaluated completely.

*row\_constructor* `IN` (*subquery*)

The left-hand side of this form of `IN` is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of `IN` is “true” if any equal subquery row is found. The result is “false” if no equal row is found (including the case where the subquery returns no rows).

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of `IN` is null.

### 9.23.3. NOT IN

*expression* `NOT IN` (*subquery*)

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of `NOT IN` is “true” if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is “false” if any equal row is found.

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the `NOT IN` construct will be null, not true. This is in accordance with SQL’s normal rules for Boolean combinations of null values.

As with `EXISTS`, it’s unwise to assume that the subquery will be evaluated completely.

*row\_constructor* `NOT IN` (*subquery*)

The left-hand side of this form of `NOT IN` is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of `NOT IN` is “true” if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is “false” if any equal row is found.

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of `NOT IN` is null.

### 9.23.4. ANY/SOME

*expression operator* `ANY` (*subquery*)  
*expression operator* `SOME` (*subquery*)

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of ANY is “true” if any true result is obtained. The result is “false” if no true result is found (including the case where the subquery returns no rows).

SOME is a synonym for ANY. IN is equivalent to = ANY.

Note that if there are no successes and at least one right-hand row yields null for the operator's result, the result of the ANY construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ANY (subquery)
row_constructor operator SOME (subquery)
```

The left-hand side of this form of ANY is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result, using the given *operator*. The result of ANY is “true” if the comparison returns true for any subquery row. The result is “false” if the comparison returns false for every subquery row (including the case where the subquery returns no rows). The result is NULL if no comparison with a subquery row returns true, and at least one comparison returns NULL.

See Section 9.24.5 for details about the meaning of a row constructor comparison.

## 9.23.5. ALL

```
expression operator ALL (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of ALL is “true” if all rows yield true (including the case where the subquery returns no rows). The result is “false” if any false result is found. The result is NULL if no comparison with a subquery row returns false, and at least one comparison returns NULL.

NOT IN is equivalent to <> ALL.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ALL (subquery)
```

The left-hand side of this form of ALL is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result, using the given *operator*. The result of ALL is “true” if the comparison returns true for all subquery rows (including the case where the subquery returns no rows). The result is “false” if the comparison returns false for any subquery row. The result is NULL if no comparison with a subquery row returns false, and at least one comparison returns NULL.

See Section 9.24.5 for details about the meaning of a row constructor comparison.

## 9.23.6. Single-Row Comparison

```
row_constructor operator (subquery)
```

The left-hand side is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the

left-hand row. Furthermore, the subquery cannot return more than one row. (If it returns zero rows, the result is taken to be null.) The left-hand side is evaluated and compared row-wise to the single subquery result row.

See Section 9.24.5 for details about the meaning of a row constructor comparison.

## 9.24. Row and Array Comparisons

This section describes several specialized constructs for making multiple comparisons between groups of values. These forms are syntactically related to the subquery forms of the previous section, but do not involve subqueries. The forms involving array subexpressions are LightDB extensions; the rest are SQL-compliant. All of the expression forms documented in this section return Boolean (true/false) results.

### 9.24.1. IN

```
expression IN (value [, ...])
```

The right-hand side is a parenthesized list of scalar expressions. The result is “true” if the left-hand expression's result is equal to any of the right-hand expressions. This is a shorthand notation for

```
expression = value1
OR
expression = value2
OR
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the IN construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

### 9.24.2. NOT IN

```
expression NOT IN (value [, ...])
```

The right-hand side is a parenthesized list of scalar expressions. The result is “true” if the left-hand expression's result is unequal to all of the right-hand expressions. This is a shorthand notation for

```
expression <> value1
AND
expression <> value2
AND
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the NOT IN construct will be null, not true as one might naively expect. This is in accordance with SQL's normal rules for Boolean combinations of null values.

#### Tip

$x$  NOT IN  $y$  is equivalent to NOT ( $x$  IN  $y$ ) in all cases. However, null values are much more likely to trip up the novice when working with NOT IN than when working with IN. It is best to express your condition positively if possible.

### 9.24.3. ANY/SOME (array)

*expression operator ANY (array expression)*  
*expression operator SOME (array expression)*

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of ANY is “true” if any true result is obtained. The result is “false” if no true result is found (including the case where the array has zero elements).

If the array expression yields a null array, the result of ANY will be null. If the left-hand expression yields null, the result of ANY is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no true comparison result is obtained, the result of ANY will be null, not false (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

SOME is a synonym for ANY.

### 9.24.4. ALL (array)

*expression operator ALL (array expression)*

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of ALL is “true” if all comparisons yield true (including the case where the array has zero elements). The result is “false” if any false result is found.

If the array expression yields a null array, the result of ALL will be null. If the left-hand expression yields null, the result of ALL is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no false comparison result is obtained, the result of ALL will be null, not true (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

### 9.24.5. Row Constructor Comparison

*row\_constructor operator row\_constructor*

Each side is a row constructor, as described in Section 4.2.13. The two row values must have the same number of fields. Each side is evaluated and they are compared row-wise. Row constructor comparisons are allowed when the *operator* is =, <>, <, <=, > or >=. Every row element must be of a type which has a default B-tree operator class or the attempted comparison may generate an error.

<p style="text-align: center;"><b>Note</b></p> <p>Errors related to the number or types of elements might not occur if the comparison is resolved using earlier columns.</p>
--

The = and <> cases work slightly differently from the others. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of the row comparison is unknown (null).

For the <, <=, > and >= cases, the row elements are compared left-to-right, stopping as soon as an unequal or null pair of elements is found. If either of this pair of elements is null, the result of the row

comparison is unknown (null); otherwise comparison of this pair of elements determines the result. For example, `ROW(1, 2, NULL) < ROW(1, 3, 0)` yields true, not null, because the third pair of elements are not considered.

**Note**

Prior to LightDB 8.2, the `<`, `<=`, `>` and `>=` cases were not handled per SQL specification. A comparison like `ROW(a, b) < ROW(c, d)` was implemented as `a < c AND b < d` whereas the correct behavior is equivalent to `a < c OR (a = c AND b < d)`.

`row_constructor IS DISTINCT FROM row_constructor`

This construct is similar to a `<>` row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will either be true or false, never null.

`row_constructor IS NOT DISTINCT FROM row_constructor`

This construct is similar to a `=` row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will always be either true or false, never null.

## 9.24.6. Composite Type Comparison

`record operator record`

The SQL specification requires row-wise comparison to return NULL if the result depends on comparing two NULL values or a NULL and a non-NULL. LightDB does this only when comparing the results of two row constructors (as in Section 9.24.5) or comparing a row constructor to the output of a subquery (as in Section 9.23). In other contexts where two composite-type values are compared, two NULL field values are considered equal, and a NULL is considered larger than a non-NULL. This is necessary in order to have consistent sorting and indexing behavior for composite types.

Each side is evaluated and they are compared row-wise. Composite type comparisons are allowed when the `operator` is `=`, `<>`, `<`, `<=`, `>` or `>=`, or has semantics similar to one of these. (To be specific, an operator can be a row comparison operator if it is a member of a B-tree operator class, or is the negator of the = member of a B-tree operator class.) The default behavior of the above operators is the same as for `IS [ NOT ] DISTINCT FROM` for row constructors (see Section 9.24.5).

To support matching of rows which include elements without a default B-tree operator class, the following operators are defined for composite type comparison: `*=`, `*<>`, `*<`, `*<=`, `*>`, and `*>=`. These operators compare the internal binary representation of the two rows. Two rows might have a different binary representation even though comparisons of the two rows with the equality operator is true. The ordering of rows under these comparison operators is deterministic but not otherwise meaningful. These operators are used internally for materialized views and might be useful for other specialized purposes such as replication and B-Tree deduplication (see Section 60.4.2). They are not intended to be generally useful for writing queries, though.

## 9.25. Set Returning Functions

This section describes functions that possibly return more than one row. The most widely used functions in this class are series generating functions, as detailed in Table 9.62 and Table 9.63. Other,



more specialized set-returning functions are described elsewhere in this manual. See Section 7.2.1.4 for ways to combine multiple set-returning functions.

**Table 9.62. Series Generating Functions**

Function	Description
<code>generate_series ( start integer, stop integer [, step integer ] )</code>	<code>→ setof integer</code>
<code>generate_series ( start bigint, stop bigint [, step bigint ] )</code>	<code>→ setof bigint</code>
<code>generate_series ( start numeric, stop numeric [, step numeric ] )</code>	<code>→ setof numeric</code> Generates a series of values from <i>start</i> to <i>stop</i> , with a step size of <i>step</i> . <i>step</i> defaults to 1.
<code>generate_series ( start timestamp, stop timestamp, step interval )</code>	<code>→ setof timestamp</code>
<code>generate_series ( start timestamp with time zone, stop timestamp with time zone, step interval )</code>	<code>→ setof timestamp with time zone</code> Generates a series of values from <i>start</i> to <i>stop</i> , with a step size of <i>step</i> .

When *step* is positive, zero rows are returned if *start* is greater than *stop*. Conversely, when *step* is negative, zero rows are returned if *start* is less than *stop*. Zero rows are also returned if any input is NULL. It is an error for *step* to be zero. Some examples follow:

```
SELECT * FROM generate_series(2,4);
generate_series
-----
                2
                3
                4
(3 rows)
```

```
SELECT * FROM generate_series(5,1,-2);
generate_series
-----
                5
                3
                1
(3 rows)
```

```
SELECT * FROM generate_series(4,3);
generate_series
-----
(0 rows)
```

```
SELECT generate_series(1.1, 4, 1.3);
generate_series
-----
                1.1
                2.4
                3.7
(3 rows)
```

-- this example relies on the date-plus-integer operator:

```

SELECT current_date + s.a AS dates FROM generate_series(0,14,7) AS
s(a);
  dates
-----
2004-02-05
2004-02-12
2004-02-19
(3 rows)

SELECT * FROM generate_series('2008-03-01 00:00'::timestamp,
                              '2008-03-04 12:00', '10 hours');
  generate_series
-----
2008-03-01 00:00:00
2008-03-01 10:00:00
2008-03-01 20:00:00
2008-03-02 06:00:00
2008-03-02 16:00:00
2008-03-03 02:00:00
2008-03-03 12:00:00
2008-03-03 22:00:00
2008-03-04 08:00:00
(9 rows)

```

**Table 9.63. Subscript Generating Functions**

Function	Description
<code>generate_subscripts ( array anyarray, dim integer ) → setof integer</code>	Generates a series comprising the valid subscripts of the <i>dim</i> 'th dimension of the given array.
<code>generate_subscripts ( array anyarray, dim integer, reverse boolean ) → setof integer</code>	Generates a series comprising the valid subscripts of the <i>dim</i> 'th dimension of the given array. When <i>reverse</i> is true, returns the series in reverse order.

`generate_subscripts` is a convenience function that generates the set of valid subscripts for the specified dimension of the given array. Zero rows are returned for arrays that do not have the requested dimension, or if any input is `NULL`. Some examples follow:

```

-- basic usage:
SELECT generate_subscripts( '{NULL,1,NULL,2}'::int[], 1) AS s;
 s
---
 1
 2
 3
 4
(4 rows)

-- presenting an array, the subscript and the subscripted
-- value requires a subquery:
SELECT * FROM arrays;
  a
-----
{-1,-2}

```

```
{100,200,300}
(2 rows)
```

```
SELECT a AS array, s AS subscript, a[s] AS value
FROM (SELECT generate_subscripts(a, 1) AS s, a FROM arrays) foo;
```

array	subscript	value
{-1,-2}	1	-1
{-1,-2}	2	-2
{100,200,300}	1	100
{100,200,300}	2	200
{100,200,300}	3	300

(5 rows)

```
-- unnest a 2D array:
CREATE OR REPLACE FUNCTION unnest2(anyarray)
RETURNS SETOF anyelement AS $$
select $1[i][j]
    from generate_subscripts($1,1) g1(i),
         generate_subscripts($1,2) g2(j);
$$ LANGUAGE sql IMMUTABLE;
CREATE FUNCTION
SELECT * FROM unnest2(ARRAY[[1,2],[3,4]]);
unnest2
```

```
-----
      1
      2
      3
      4
(4 rows)
```

When a function in the FROM clause is suffixed by WITH ORDINALITY, a bigint column is appended to the function's output column(s), which starts from 1 and increments by 1 for each row of the function's output. This is most useful in the case of set returning functions such as unnest().

```
-- set returning function WITH ORDINALITY:
SELECT * FROM pg_ls_dir('.') WITH ORDINALITY AS t(ls,n);
```

ls	n
lt_serial	1
lt_twophase	2
lightdb.opts	3
lt_notify	4
lightdb.conf	5
lt_tblspc	6
logfile	7
base	8
lightdb.pid	9
lt_ident.conf	10
global	11
lt_xact	12
lt_snapshots	13
lt_multixact	14
PG_VERSION	15
lt_wal	16
lt_hba.conf	17
lt_stat_tmp	18

lt\_subtrans | 19  
(19 rows)

## 9.26. System Information Functions and Operators

Table 9.64 shows several functions that extract session and system information.

In addition to the functions listed in this section, there are a number of functions related to the statistics system that also provide system information. See Section 25.2.2 for more information.

### 9.26.1. Session Information Functions

**Table 9.64. Session Information Functions**

Function	Description
<code>current_catalog</code> → name <code>current_database()</code> → name	Returns the name of the current database. (Databases are called “catalogs” in the SQL standard, so <code>current_catalog</code> is the standard's spelling.)
<code>current_query()</code> → text	Returns the text of the currently executing query, as submitted by the client (which might contain more than one statement).
<code>current_role</code> → name	This is equivalent to <code>current_user</code> .
<code>current_schema</code> → name <code>current_schema()</code> → name	Returns the name of the schema that is first in the search path (or a null value if the search path is empty). This is the schema that will be used for any tables or other named objects that are created without specifying a target schema.
<code>current_schemas(include_implicit boolean)</code> → name [ ]	Returns an array of the names of all schemas presently in the effective search path, in their priority order. (Items in the <code>current_search_path</code> setting that do not correspond to existing, searchable schemas are omitted.) If the Boolean argument is <code>true</code> , then implicitly-searched system schemas such as <code>pg_catalog</code> are included in the result.
<code>current_user</code> → name	Returns the user name of the current execution context.
<code>inet_client_addr()</code> → inet	Returns the IP address of the current client, or <code>NULL</code> if the current connection is via a Unix-domain socket.
<code>inet_client_port()</code> → integer	Returns the IP port number of the current client, or <code>NULL</code> if the current connection is via a Unix-domain socket.
<code>inet_server_addr()</code> → inet	Returns the IP address on which the server accepted the current connection, or <code>NULL</code> if the current connection is via a Unix-domain socket.
<code>inet_server_port()</code> → integer	

Function	Description
	Returns the IP port number on which the server accepted the current connection, or NULL if the current connection is via a Unix-domain socket.
<code>pg_backend_pid ()</code> → integer	Returns the process ID of the server process attached to the current session.
<code>pg_blocking_pids ( integer )</code> → integer[ ]	<p>Returns an array of the process ID(s) of the sessions that are blocking the server process with the specified process ID from acquiring a lock, or an empty array if there is no such server process or it is not blocked.</p> <p>One server process blocks another if it either holds a lock that conflicts with the blocked process's lock request (hard block), or is waiting for a lock that would conflict with the blocked process's lock request and is ahead of it in the wait queue (soft block).</p> <p>When using parallel queries the result always lists client-visible process IDs (that is, <code>pg_backend_pid</code> results) even if the actual lock is held or awaited by a child worker process. As a result of that, there may be duplicated PIDs in the result. Also note that when a prepared transaction holds a conflicting lock, it will be represented by a zero process ID.</p> <p>Frequent calls to this function could have some impact on database performance, because it needs exclusive access to the lock manager's shared state for a short time.</p>
<code>pg_conf_load_time ()</code> → timestamp with time zone	Returns the time when the server configuration files were last loaded. If the current session was alive at the time, this will be the time when the session itself re-read the configuration files (so the reading will vary a little in different sessions). Otherwise it is the time when the postmaster process re-read the configuration files.
<code>pg_current_logfile ( [ text ] )</code> → text	Returns the path name of the log file currently in use by the logging collector. The path includes the <code>log_directory</code> directory and the individual log file name. The result is NULL if the logging collector is disabled. When multiple log files exist, each in a different format, <code>pg_current_logfile</code> without an argument returns the path of the file having the first format found in the ordered list: <code>stderr</code> , <code>csvlog</code> . NULL is returned if no log file has any of these formats. To request information about a specific log file format, supply either <code>csvlog</code> or <code>stderr</code> as the value of the optional parameter. The result is NULL if the log format requested is not configured in <code>log_destination</code> . The result reflects the contents of the <code>current_logfiles</code> file.
<code>pg_my_temp_schema ()</code> → oid	Returns the OID of the current session's temporary schema, or zero if it has none (because it has not created any temporary tables).
<code>pg_is_other_temp_schema ( oid )</code> → boolean	Returns true if the given OID is the OID of another session's temporary schema. (This can be useful, for example, to exclude other sessions' temporary tables from a catalog display.)
<code>pg_jit_available ()</code> → boolean	Returns true if a JIT compiler extension is available (see Chapter 29) and the <code>jit</code> configuration parameter is set to on.
<code>pg_listening_channels ()</code> → setof text	Returns the set of names of asynchronous notification channels that the current session is listening to.
<code>pg_notification_queue_usage ()</code> → double precision	

Function	Description
	Returns the fraction (0–1) of the asynchronous notification queue's maximum size that is currently occupied by notifications that are waiting to be processed. See <code>LISTEN</code> and <code>NOTIFY</code> for more information.
<code>pg_postmaster_start_time ()</code> → timestamp with time zone	Returns the time when the server started.
<code>pg_safe_snapshot_blocking_pids ( integer )</code> → integer[ ]	Returns an array of the process ID(s) of the sessions that are blocking the server process with the specified process ID from acquiring a safe snapshot, or an empty array if there is no such server process or it is not blocked. A session running a <code>SERIALIZABLE</code> transaction blocks a <code>SERIALIZABLE READ ONLY DEFERRABLE</code> transaction from acquiring a snapshot until the latter determines that it is safe to avoid taking any predicate locks. See Section 13.2.3 for more information about serializable and deferrable transactions. Frequent calls to this function could have some impact on database performance, because it needs access to the predicate lock manager's shared state for a short time.
<code>pg_trigger_depth ()</code> → integer	Returns the current nesting level of LightDB triggers (0 if not called, directly or indirectly, from inside a trigger).
<code>session_user</code> → name	Returns the session user's name.
<code>user</code> → name	This is equivalent to <code>current_user</code> .
<code>version ()</code> → text	Returns a string describing the LightDB server's version. You can also get this information from <code>server_version</code> , or for a machine-readable version use <code>server_version_num</code> . Software developers should use <code>server_version_num</code> (available since 8.2) or <code>PQserverVersion</code> instead of parsing the text version.

**Note**

`current_catalog`, `current_role`, `current_schema`, `current_user`, `session_user`, and `user` have special syntactic status in SQL: they must be called without trailing parentheses. In LightDB, parentheses can optionally be used with `current_schema`, but not with the others.

The `session_user` is normally the user who initiated the current database connection; but superusers can change this setting with `SET SESSION AUTHORIZATION`. The `current_user` is the user identifier that is applicable for permission checking. Normally it is equal to the session user, but it can be changed with `SET ROLE`. It also changes during the execution of functions with the attribute `SECURITY DEFINER`. In Unix parlance, the session user is the “real user” and the current user is the “effective user”. `current_role` and `user` are synonyms for `current_user`. (The SQL standard draws a distinction between `current_role` and `current_user`, but LightDB does not, since it unifies users and roles into a single kind of entity.)

Table 9.65 lists functions that allow querying object access privileges programmatically. (See Section 5.7 for more information about privileges.) In these functions, the user whose privileges are being inquired about can be specified by name or by OID (`pg_authid.oid`), or if the name is given as `public` then the privileges of the `PUBLIC` pseudo-role are checked. Also, the `user` argument can

be omitted entirely, in which case the `current_user` is assumed. The object that is being inquired about can be specified either by name or by OID, too. When specifying by name, a schema name can be included if relevant. The access privilege of interest is specified by a text string, which must evaluate to one of the appropriate privilege keywords for the object's type (e.g., `SELECT`). Optionally, `WITH GRANT OPTION` can be added to a privilege type to test whether the privilege is held with grant option. Also, multiple privilege types can be listed separated by commas, in which case the result will be true if any of the listed privileges is held. (Case of the privilege string is not significant, and extra whitespace is allowed between but not within privilege names.) Some examples:

```
SELECT has_table_privilege('myschema.mytable', 'select');
SELECT has_table_privilege('joe', 'mytable', 'INSERT, SELECT WITH
GRANT OPTION');
```

## 9.26.2. Access Privilege Inquiry Functions

**Table 9.65. Access Privilege Inquiry Functions**

Function	Description
<code>has_any_column_privilege</code>	<p><code>( [ user name or oid, ] table text or oid, privilege text ) → boolean</code></p> <p>Does user have privilege for any column of table? This succeeds either if the privilege is held for the whole table, or if there is a column-level grant of the privilege for at least one column. Allowable privilege types are <code>SELECT</code>, <code>INSERT</code>, <code>UPDATE</code>, and <code>REFERENCES</code>.</p>
<code>has_column_privilege</code>	<p><code>( [ user name or oid, ] table text or oid, column text or smallint, privilege text ) → boolean</code></p> <p>Does user have privilege for the specified table column? This succeeds either if the privilege is held for the whole table, or if there is a column-level grant of the privilege for the column. The column can be specified by name or by attribute number (<code>pg_attribute.attnum</code>). Allowable privilege types are <code>SELECT</code>, <code>INSERT</code>, <code>UPDATE</code>, and <code>REFERENCES</code>.</p>
<code>has_database_privilege</code>	<p><code>( [ user name or oid, ] database text or oid, privilege text ) → boolean</code></p> <p>Does user have privilege for database? Allowable privilege types are <code>CREATE</code>, <code>CONNECT</code>, <code>TEMPORARY</code>, and <code>TEMP</code> (which is equivalent to <code>TEMPORARY</code>).</p>
<code>has_foreign_data_wrapper_privilege</code>	<p><code>( [ user name or oid, ] fdw text or oid, privilege text ) → boolean</code></p> <p>Does user have privilege for foreign-data wrapper? The only allowable privilege type is <code>USAGE</code>.</p>
<code>has_function_privilege</code>	<p><code>( [ user name or oid, ] function text or oid, privilege text ) → boolean</code></p> <p>Does user have privilege for function? The only allowable privilege type is <code>EXECUTE</code>. When specifying a function by name rather than by OID, the allowed input is the same as for the <code>regprocedure</code> data type (see Section 8.19). An example is:</p> <pre>SELECT has_function_privilege('joeuser', 'myfunc(int, text)', 'execute');</pre>
<code>has_language_privilege</code>	<p><code>( [ user name or oid, ] language text or oid, privilege text ) → boolean</code></p> <p>Does user have privilege for language? The only allowable privilege type is <code>USAGE</code>.</p>

Function	Description
<code>has_schema_privilege ( [ user name or oid, ] schema text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for schema? Allowable privilege types are CREATE and USAGE.
<code>has_sequence_privilege ( [ user name or oid, ] sequence text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for sequence? Allowable privilege types are USAGE, SELECT, and UPDATE.
<code>has_server_privilege ( [ user name or oid, ] server text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for foreign server? The only allowable privilege type is USAGE.
<code>has_table_privilege ( [ user name or oid, ] table text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for table? Allowable privilege types are SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, and TRIGGER.
<code>has_tablespace_privilege ( [ user name or oid, ] tablespace text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for tablespace? The only allowable privilege type is CREATE.
<code>has_type_privilege ( [ user name or oid, ] type text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for data type? The only allowable privilege type is USAGE. When specifying a type by name rather than by OID, the allowed input is the same as for the regtype data type (see Section 8.19).
<code>pg_has_role ( [ user name or oid, ] role text or oid, privilege text )</code>	<code>→ boolean</code> Does user have privilege for role? Allowable privilege types are MEMBER and USAGE. MEMBER denotes direct or indirect membership in the role (that is, the right to do SET ROLE), while USAGE denotes whether the privileges of the role are immediately available without doing SET ROLE. This function does not allow the special case of setting <code>user</code> to <code>public</code> , because the PUBLIC pseudo-role can never be a member of real roles.
<code>row_security_active ( table text or oid )</code>	<code>→ boolean</code> Is row-level security active for the specified table in the context of the current user and current environment?

### 9.26.3. aclitem Operators

Table 9.66 shows the operators available for the `aclitem` type, which is the catalog representation of access privileges. See Section 5.7 for information about how to read access privilege values.

**Table 9.66. `aclitem` Operators**

Operator	Description
<code>aclitem = aclitem</code>	<code>→ boolean</code> Are <code>aclitems</code> equal? (Notice that type <code>aclitem</code> lacks the usual set of comparison operators; it has only equality. In turn, <code>aclitem</code> arrays can only be compared for equality.)



Operator	Description
	<b>Example(s)</b> <code>'calvin=r*w/hobbes'::aclitem = 'calvin=r*w*/hobbes'::aclitem → f</code>
<code>aclitem[] @&gt; aclitem</code>	<code>→ boolean</code> Does array contain the specified privileges? (This is true if there is an array entry that matches the aclitem's grantee and grantor, and has at least the specified set of privileges.) <code>'{calvin=r*w/hobbes,hobbes=r*w*/postgres}'::aclitem[] @&gt; 'calvin=r*/hobbes'::aclitem → t</code>
<code>aclitem[] ~ aclitem</code>	<code>→ boolean</code> This is a deprecated alias for @>. <code>'{calvin=r*w/hobbes,hobbes=r*w*/postgres}'::aclitem[] ~ 'calvin=r*/hobbes'::aclitem → t</code>

Table 9.67 shows some additional functions to manage the `aclitem` type.

**Table 9.67. `aclitem` Functions**

Function	Description
<code>acldefault ( type "char", ownerId oid )</code>	<code>→ aclitem[]</code> Constructs an <code>aclitem</code> array holding the default access privileges for an object of type <code>type</code> belonging to the role with OID <code>ownerId</code> . This represents the access privileges that will be assumed when an object's ACL entry is null. (The default access privileges are described in Section 5.7.) The <code>type</code> parameter must be one of 'c' for COLUMN, 'r' for TABLE and table-like objects, 's' for SEQUENCE, 'd' for DATABASE, 'f' for FUNCTION or PROCEDURE, 'l' for LANGUAGE, 'L' for LARGE OBJECT, 'n' for SCHEMA, 't' for TABLESPACE, 'F' for FOREIGN DATA WRAPPER, 'S' for FOREIGN SERVER, or 'T' for TYPE or DOMAIN.
<code>aclexplode ( aclitem[] )</code>	<code>→ setof record ( grantor oid, grantee oid, privilege_type text, is_grantable boolean )</code> Returns the <code>aclitem</code> array as a set of rows. If the grantee is the pseudo-role PUBLIC, it is represented by zero in the <code>grantee</code> column. Each granted privilege is represented as SELECT, INSERT, etc. Note that each privilege is broken out as a separate row, so only one keyword appears in the <code>privilege_type</code> column.
<code>makeaclitem ( grantee oid, grantor oid, privileges text, is_grantable boolean )</code>	<code>→ aclitem</code> Constructs an <code>aclitem</code> with the given properties.

## 9.26.4. Schema Visibility Inquiry Functions

Table 9.68 shows functions that determine whether a certain object is *visible* in the current schema search path. For example, a table is said to be visible if its containing schema is in the search path and no table of the same name appears earlier in the search path. This is equivalent to the statement that the table can be referenced by name without explicit schema qualification. Thus, to list the names of all visible tables:

```
SELECT relname FROM pg_class WHERE pg_table_is_visible(oid);
```

For functions and operators, an object in the search path is said to be visible if there is no object of the same name *and argument data type(s)* earlier in the path. For operator classes and families, both the name and the associated index access method are considered.

**Table 9.68. Schema Visibility Inquiry Functions**

Function	Description
<code>pg_collation_is_visible ( collation oid )</code>	→ boolean Is collation visible in search path?
<code>pg_conversion_is_visible ( conversion oid )</code>	→ boolean Is conversion visible in search path?
<code>pg_function_is_visible ( function oid )</code>	→ boolean Is function visible in search path? (This also works for procedures and aggregates.)
<code>pg_opclass_is_visible ( opclass oid )</code>	→ boolean Is operator class visible in search path?
<code>pg_operator_is_visible ( operator oid )</code>	→ boolean Is operator visible in search path?
<code>pg_opfamily_is_visible ( opclass oid )</code>	→ boolean Is operator family visible in search path?
<code>pg_statistics_obj_is_visible ( stat oid )</code>	→ boolean Is statistics object visible in search path?
<code>pg_table_is_visible ( table oid )</code>	→ boolean Is table visible in search path? (This works for all types of relations, including views, materialized views, indexes, sequences and foreign tables.)
<code>pg_ts_config_is_visible ( config oid )</code>	→ boolean Is text search configuration visible in search path?
<code>pg_ts_dict_is_visible ( dict oid )</code>	→ boolean Is text search dictionary visible in search path?
<code>pg_ts_parser_is_visible ( parser oid )</code>	→ boolean Is text search parser visible in search path?
<code>pg_ts_template_is_visible ( template oid )</code>	→ boolean Is text search template visible in search path?
<code>pg_type_is_visible ( type oid )</code>	→ boolean Is type (or domain) visible in search path?

All these functions require object OIDs to identify the object to be checked. If you want to test an object by name, it is convenient to use the OID alias types (`regclass`, `regtype`, `regprocedure`, `regoperator`, `regconfig`, or `regdictionary`), for example:

```
SELECT pg_type_is_visible( 'myschema.widget'::regtype );
```

Note that it would not make much sense to test a non-schema-qualified type name in this way — if the name can be recognized at all, it must be visible.

## 9.26.5. System Catalog Information Functions

Table 9.69 lists functions that extract information from the system catalogs.

**Table 9.69. System Catalog Information Functions**

Function	Description
<code>format_type ( type oid, typemod integer ) → text</code>	Returns the SQL name for a data type that is identified by its type OID and possibly a type modifier. Pass NULL for the type modifier if no specific modifier is known.
<code>pg_get_constraintdef ( constraint oid [, pretty boolean ] ) → text</code>	Reconstructs the creating command for a constraint. (This is a decompiled reconstruction, not the original text of the command.)
<code>pg_get_expr ( expr pg_node_tree, relation oid [, pretty boolean ] ) → text</code>	Decompiles the internal form of an expression stored in the system catalogs, such as the default value for a column. If the expression might contain Vars, specify the OID of the relation they refer to as the second parameter; if no Vars are expected, passing zero is sufficient.
<code>pg_get_functiondef ( func oid ) → text</code>	Reconstructs the creating command for a function or procedure. (This is a decompiled reconstruction, not the original text of the command.) The result is a complete CREATE OR REPLACE FUNCTION or CREATE OR REPLACE PROCEDURE statement.
<code>pg_get_function_arguments ( func oid ) → text</code>	Reconstructs the argument list of a function or procedure, in the form it would need to appear in within CREATE FUNCTION (including default values).
<code>pg_get_function_identity_arguments ( func oid ) → text</code>	Reconstructs the argument list necessary to identify a function or procedure, in the form it would need to appear in within commands such as ALTER FUNCTION. This form omits default values.
<code>pg_get_function_result ( func oid ) → text</code>	Reconstructs the RETURNS clause of a function, in the form it would need to appear in within CREATE FUNCTION. Returns NULL for a procedure.
<code>pg_get_indexdef ( index oid [, column integer, pretty boolean ] ) → text</code>	Reconstructs the creating command for an index. (This is a decompiled reconstruction, not the original text of the command.) If <i>column</i> is supplied and is not zero, only the definition of that column is reconstructed.
<code>pg_get_keywords () → setof record ( word text, catcode "char", catdesc text )</code>	Returns a set of records describing the SQL keywords recognized by the server. The <i>word</i> column contains the keyword. The <i>catcode</i> column contains a category code: U for an unreserved keyword, C for a keyword that can be a column name, T for a keyword that can be a type or function name, or R for a fully reserved keyword. The <i>catdesc</i> column contains a possibly-localized string describing the category.
<code>pg_get_ruledef ( rule oid [, pretty boolean ] ) → text</code>	Reconstructs the creating command for a rule. (This is a decompiled reconstruction, not the original text of the command.)
<code>pg_get_serial_sequence ( table text, column text ) → text</code>	Returns the name of the sequence associated with a column, or NULL if no sequence is associated with the column. If the column is an identity column, the associated sequence is the sequence internally created for that column. For columns created using one of the serial types ( <i>serial</i> , <i>smallserial</i> , <i>bigserial</i> ), it is the sequence created for that serial column definition. In the latter case, the association can be modified or removed with ALTER SEQUENCE OWNED BY. (This function probably should have

Function	Description
	<p>been called <code>pg_get_owned_sequence</code>; its current name reflects the fact that it has historically been used with serial-type columns.) The first parameter is a table name with optional schema, and the second parameter is a column name. Because the first parameter potentially contains both schema and table names, it is parsed per usual SQL rules, meaning it is lower-cased by default. The second parameter, being just a column name, is treated literally and so has its case preserved. The result is suitably formatted for passing to the sequence functions (see Section 9.17). A typical use is in reading the current value of the sequence for an identity or serial column, for example:</p> <pre>SELECT currval(pg_get_serial_sequence('sometable', 'id'));</pre>
<code>pg_get_statisticsobjdef ( <i>statobj oid</i> )</code>	<code>→ text</code> Reconstructs the creating command for an extended statistics object. (This is a decompiled reconstruction, not the original text of the command.)
<code>pg_get_triggerdef ( <i>trigger oid</i> [, <i>pretty boolean</i> ] )</code>	<code>→ text</code> Reconstructs the creating command for a trigger. (This is a decompiled reconstruction, not the original text of the command.)
<code>pg_get_userbyid ( <i>role oid</i> )</code>	<code>→ name</code> Returns a role's name given its OID.
<code>pg_get_viewdef ( <i>view oid</i> [, <i>pretty boolean</i> ] )</code>	<code>→ text</code> Reconstructs the underlying <code>SELECT</code> command for a view or materialized view. (This is a decompiled reconstruction, not the original text of the command.)
<code>pg_get_viewdef ( <i>view oid</i>, <i>wrap_column integer</i> )</code>	<code>→ text</code> Reconstructs the underlying <code>SELECT</code> command for a view or materialized view. (This is a decompiled reconstruction, not the original text of the command.) In this form of the function, pretty-printing is always enabled, and long lines are wrapped to try to keep them shorter than the specified number of columns.
<code>pg_get_viewdef ( <i>view text</i> [, <i>pretty boolean</i> ] )</code>	<code>→ text</code> Reconstructs the underlying <code>SELECT</code> command for a view or materialized view, working from a textual name for the view rather than its OID. (This is deprecated; use the OID variant instead.)
<code>pg_index_column_has_property ( <i>index regclass</i>, <i>column integer</i>, <i>property text</i> )</code>	<code>→ boolean</code> Tests whether an index column has the named property. Common index column properties are listed in Table 9.70. (Note that extension access methods can define additional property names for their indexes.) <code>NULL</code> is returned if the property name is not known or does not apply to the particular object, or if the OID or column number does not identify a valid object.
<code>pg_index_has_property ( <i>index regclass</i>, <i>property text</i> )</code>	<code>→ boolean</code> Tests whether an index has the named property. Common index properties are listed in Table 9.71. (Note that extension access methods can define additional property names for their indexes.) <code>NULL</code> is returned if the property name is not known or does not apply to the particular object, or if the OID does not identify a valid object.
<code>pg_indexam_has_property ( <i>am oid</i>, <i>property text</i> )</code>	<code>→ boolean</code> Tests whether an index access method has the named property. Access method properties are listed in Table 9.72. <code>NULL</code> is returned if the property name is not known or does not apply to the particular object, or if the OID does not identify a valid object.

Function	Description
<code>pg_options_to_table ( options_array text[] ) → setof record ( option_name text, option_value text )</code>	Returns the set of storage options represented by a value from <code>pg_class.reloptions</code> or <code>pg_attribute.attoptions</code> .
<code>pg_tablespace_databases ( tablespace oid ) → setof oid</code>	Returns the set of OIDs of databases that have objects stored in the specified tablespace. If this function returns any rows, the tablespace is not empty and cannot be dropped. To identify the specific objects populating the tablespace, you will need to connect to the database(s) identified by <code>pg_tablespace_databases</code> and query their <code>pg_class</code> catalogs.
<code>pg_tablespace_location ( tablespace oid ) → text</code>	Returns the file system path that this tablespace is located in.
<code>pg_typeof ( "any" ) → regtype</code>	Returns the OID of the data type of the value that is passed to it. This can be helpful for troubleshooting or dynamically constructing SQL queries. The function is declared as returning <code>regtype</code> , which is an OID alias type (see Section 8.19); this means that it is the same as an OID for comparison purposes but displays as a type name. For example:
	<pre> SELECT pg_typeof(33);  pg_typeof -----  integer  SELECT typlen FROM pg_type WHERE oid = pg_typeof(33);  typlen -----       4 </pre>
<code>COLLATION FOR ( "any" ) → text</code>	Returns the name of the collation of the value that is passed to it. The value is quoted and schema-qualified if necessary. If no collation was derived for the argument expression, then NULL is returned. If the argument is not of a collatable data type, then an error is raised. For example:
	<pre> SELECT collation for (description) FROM pg_description  LIMIT 1;  pg_collation_for -----  "default"  SELECT collation for ('foo' COLLATE "de_DE");  pg_collation_for -----  "de_DE" </pre>
<code>to_regclass ( text ) → regclass</code>	Translates a textual relation name to its OID. A similar result is obtained by casting the string to type <code>regclass</code> (see Section 8.19); however, this function will return NULL

Function	Description
	rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regcollation ( text ) → regcollation</code>	Translates a textual collation name to its OID. A similar result is obtained by casting the string to type <code>regcollation</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regnamespace ( text ) → regnamespace</code>	Translates a textual schema name to its OID. A similar result is obtained by casting the string to type <code>regnamespace</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regoper ( text ) → regoper</code>	Translates a textual operator name to its OID. A similar result is obtained by casting the string to type <code>regoper</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found or is ambiguous. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regoperator ( text ) → regoperator</code>	Translates a textual operator name (with parameter types) to its OID. A similar result is obtained by casting the string to type <code>regoperator</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regproc ( text ) → regproc</code>	Translates a textual function or procedure name to its OID. A similar result is obtained by casting the string to type <code>regproc</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found or is ambiguous. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regprocedure ( text ) → regprocedure</code>	Translates a textual function or procedure name (with argument types) to its OID. A similar result is obtained by casting the string to type <code>regprocedure</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regrole ( text ) → regrole</code>	Translates a textual role name to its OID. A similar result is obtained by casting the string to type <code>regrole</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.
<code>to_regtype ( text ) → regtype</code>	Translates a textual type name to its OID. A similar result is obtained by casting the string to type <code>regtype</code> (see Section 8.19); however, this function will return <code>NULL</code> rather than throwing an error if the name is not found. Also unlike the cast, this does not accept a numeric OID as input.

Most of the functions that reconstruct (decompile) database objects have an optional `pretty` flag, which if `true` causes the result to be “pretty-printed”. Pretty-printing suppresses unnecessary parentheses and adds whitespace for legibility. The pretty-printed format is more readable, but the default format is more likely to be interpreted the same way by future versions of LightDB; so avoid using pretty-printed output for dump purposes. Passing `false` for the `pretty` parameter yields the same result as omitting the parameter.

## 9.26.6. Index Column Properties

**Table 9.70. Index Column Properties**

Name	Description
asc	Does the column sort in ascending order on a forward scan?
desc	Does the column sort in descending order on a forward scan?
nulls_first	Does the column sort with nulls first on a forward scan?
nulls_last	Does the column sort with nulls last on a forward scan?
orderable	Does the column possess any defined sort ordering?
distance_orderable	Can the column be scanned in order by a “distance” operator, for example ORDER BY col <-> constant ?
returnable	Can the column value be returned by an index-only scan?
search_array	Does the column natively support col = ANY(array) searches?
search_nulls	Does the column support IS NULL and IS NOT NULL searches?

## 9.26.7. Index Properties

**Table 9.71. Index Properties**

Name	Description
clusterable	Can the index be used in a CLUSTER command?
index_scan	Does the index support plain (non-bitmap) scans?
bitmap_scan	Does the index support bitmap scans?
backward_scan	Can the scan direction be changed in mid-scan (to support FETCH BACKWARD on a cursor without needing materialization)?

## 9.26.8. Index Access Method Properties

**Table 9.72. Index Access Method Properties**

Name	Description
can_order	Does the access method support ASC, DESC and related keywords in CREATE INDEX?
can_unique	Does the access method support unique indexes?
can_multi_col	Does the access method support indexes with multiple columns?
can_exclude	Does the access method support exclusion constraints?

Name	Description
can_include	Does the access method support the INCLUDE clause of CREATE INDEX?

## 9.26.9. Object Information and Addressing Functions

Table 9.73 lists functions related to database object identification and addressing.

**Table 9.73. Object Information and Addressing Functions**

Function	Description
<code>pg_describe_object ( classid oid, objid oid, objsubid integer ) → text</code>	Returns a textual description of a database object identified by catalog OID, object OID, and sub-object ID (such as a column number within a table; the sub-object ID is zero when referring to a whole object). This description is intended to be human-readable, and might be translated, depending on server configuration. This is especially useful to determine the identity of an object referenced in the <code>pg_depend</code> catalog.
<code>pg_identify_object ( classid oid, objid oid, objsubid integer ) → record ( type text, schema text, name text, identity text )</code>	Returns a row containing enough information to uniquely identify the database object specified by catalog OID, object OID and sub-object ID. This information is intended to be machine-readable, and is never translated. <i>type</i> identifies the type of database object; <i>schema</i> is the schema name that the object belongs in, or NULL for object types that do not belong to schemas; <i>name</i> is the name of the object, quoted if necessary, if the name (along with schema name, if pertinent) is sufficient to uniquely identify the object, otherwise NULL; <i>identity</i> is the complete object identity, with the precise format depending on object type, and each name within the format being schema-qualified and quoted as necessary.
<code>pg_identify_object_as_address ( classid oid, objid oid, objsubid integer ) → record ( type text, object_names text[], object_args text[] )</code>	Returns a row containing enough information to uniquely identify the database object specified by catalog OID, object OID and sub-object ID. The returned information is independent of the current server, that is, it could be used to identify an identically named object in another server. <i>type</i> identifies the type of database object; <i>object_names</i> and <i>object_args</i> are text arrays that together form a reference to the object. These three values can be passed to <code>pg_get_object_address</code> to obtain the internal address of the object.
<code>pg_get_object_address ( type text, object_names text[], object_args text[] ) → record ( classid oid, objid oid, objsubid integer )</code>	Returns a row containing enough information to uniquely identify the database object specified by a type code and object name and argument arrays. The returned values are the ones that would be used in system catalogs such as <code>pg_depend</code> ; they can be passed to other system functions such as <code>pg_describe_object</code> or <code>pg_identify_object</code> . <i>classid</i> is the OID of the system catalog containing the object; <i>objid</i> is the OID of the object itself, and <i>objsubid</i> is the sub-object ID, or zero if none. This function is the inverse of <code>pg_identify_object_as_address</code> .

## 9.26.10. Comment Information Functions

The functions shown in Table 9.74 extract comments previously stored with the COMMENT command. A null value is returned if no comment could be found for the specified parameters.



**Table 9.74. Comment Information Functions**

Function	Description
<code>col_description ( table oid, column integer ) → text</code>	Returns the comment for a table column, which is specified by the OID of its table and its column number. ( <code>obj_description</code> cannot be used for table columns, since columns do not have OIDs of their own.)
<code>obj_description ( object oid, catalog name ) → text</code>	Returns the comment for a database object specified by its OID and the name of the containing system catalog. For example, <code>obj_description(123456, 'pg_class')</code> would retrieve the comment for the table with OID 123456.
<code>obj_description ( object oid ) → text</code>	Returns the comment for a database object specified by its OID alone. This is <i>deprecated</i> since there is no guarantee that OIDs are unique across different system catalogs; therefore, the wrong comment might be returned.
<code>shobj_description ( object oid, catalog name ) → text</code>	Returns the comment for a shared database object specified by its OID and the name of the containing system catalog. This is just like <code>obj_description</code> except that it is used for retrieving comments on shared objects (that is, databases, roles, and tablespaces). Some system catalogs are global to all databases within each cluster, and the descriptions for objects in them are stored globally as well.

## 9.26.11. Transaction ID and Snapshot Information Functions

The functions shown in Table 9.75 provide server transaction information in an exportable form. The main use of these functions is to determine which transactions were committed between two snapshots.

**Table 9.75. Transaction ID and Snapshot Information Functions**

Function	Description
<code>pg_current_xact_id () → xid8</code>	Returns the current transaction's ID. It will assign a new one if the current transaction does not have one already (because it has not performed any database updates).
<code>pg_current_xact_id_if_assigned () → xid8</code>	Returns the current transaction's ID, or NULL if no ID is assigned yet. (It's best to use this variant if the transaction might otherwise be read-only, to avoid unnecessary consumption of an XID.)
<code>pg_xact_status ( xid8 ) → text</code>	Reports the commit status of a recent transaction. The result is one of <code>in progress</code> , <code>committed</code> , or <code>aborted</code> , provided that the transaction is recent enough that the system retains the commit status of that transaction. If it is old enough that no references to the transaction survive in the system and the commit status information has been discarded, the result is NULL. Applications might use this function, for example, to determine whether their transaction committed or aborted after the application and database server become disconnected while a COMMIT is in progress. Note that prepared transactions are reported as <code>in progress</code> ; applications must check <code>pg_prepared_xacts</code> if they need to determine whether a transaction ID belongs to a prepared transaction.

Function	Description
<code>pg_current_snapshot ()</code> → <code>pg_snapshot</code>	Returns a current <i>snapshot</i> , a data structure showing which transaction IDs are now in-progress.
<code>pg_snapshot_xip (pg_snapshot)</code> → <code>setof xid8</code>	Returns the set of in-progress transaction IDs contained in a snapshot.
<code>pg_snapshot_xmax (pg_snapshot)</code> → <code>xid8</code>	Returns the <code>xmax</code> of a snapshot.
<code>pg_snapshot_xmin (pg_snapshot)</code> → <code>xid8</code>	Returns the <code>xmin</code> of a snapshot.
<code>pg_visible_in_snapshot (xid8, pg_snapshot)</code> → <code>boolean</code>	Is the given transaction ID <i>visible</i> according to this snapshot (that is, was it completed before the snapshot was taken)? Note that this function will not give the correct answer for a subtransaction ID.

The internal transaction ID type `xid` is 32 bits wide and wraps around every 4 billion transactions. However, the functions shown in Table 9.75 use a 64-bit type `xid8` that does not wrap around during the life of an installation, and can be converted to `xid` by casting if required. The data type `pg_snapshot` stores information about transaction ID visibility at a particular moment in time. Its components are described in Table 9.76. `pg_snapshot`'s textual representation is `xmin:xmax:xip_list`. For example `10:20:10,14,15` means `xmin=10`, `xmax=20`, `xip_list=10, 14, 15`.

**Table 9.76. Snapshot Components**

Name	Description
<code>xmin</code>	Lowest transaction ID that was still active. All transaction IDs less than <code>xmin</code> are either committed and visible, or rolled back and dead.
<code>xmax</code>	One past the highest completed transaction ID. All transaction IDs greater than or equal to <code>xmax</code> had not yet completed as of the time of the snapshot, and thus are invisible.
<code>xip_list</code>	Transactions in progress at the time of the snapshot. A transaction ID that is <code>xmin &lt;= X &lt; xmax</code> and not in this list was already completed at the time of the snapshot, and thus is either visible or dead according to its commit status. This list does not include the transaction IDs of subtransactions.

In releases of LightDB before 13 there was no `xid8` type, so variants of these functions were provided that used `bigint` to represent a 64-bit `XID`, with a correspondingly distinct snapshot data type `txid_snapshot`. These older functions have `txid` in their names. They are still supported for backward compatibility, but may be removed from a future release. See Table 9.77.

**Table 9.77. Deprecated Transaction ID and Snapshot Information Functions**

Function	Description
<code>txid_current ()</code> → <code>bigint</code>	See <code>pg_current_xact_id()</code> .

Function	Description
<code>txid_current_if_assigned()</code>	<code>→ bigint</code> See <code>pg_current_xact_id_if_assigned()</code> .
<code>txid_current_snapshot()</code>	<code>→ txid_snapshot</code> See <code>pg_current_snapshot()</code> .
<code>txid_snapshot_xip(txid_snapshot)</code>	<code>→ setof bigint</code> See <code>pg_snapshot_xip()</code> .
<code>txid_snapshot_xmax(txid_snapshot)</code>	<code>→ bigint</code> See <code>pg_snapshot_xmax()</code> .
<code>txid_snapshot_xmin(txid_snapshot)</code>	<code>→ bigint</code> See <code>pg_snapshot_xmin()</code> .
<code>txid_visible_in_snapshot(bigint, txid_snapshot)</code>	<code>→ boolean</code> See <code>pg_visible_in_snapshot()</code> .
<code>txid_status(bigint)</code>	<code>→ text</code> See <code>pg_xact_status()</code> .

The functions shown in Table 9.78 provide information about when past transactions were committed. They only provide useful data when the `track_commit_timestamp` configuration option is enabled, and only for transactions that were committed after it was enabled.

**Table 9.78. Committed Transaction Information Functions**

Function	Description
<code>pg_xact_commit_timestamp(xid)</code>	<code>→ timestamp with time zone</code> Returns the commit timestamp of a transaction.
<code>pg_last_committed_xact()</code>	<code>→ record(xid xid, timestamp timestamp with time zone)</code> Returns the transaction ID and commit timestamp of the latest committed transaction.

## 9.26.12. Control File Data Functions

The functions shown in Table 9.79 print information initialized during `initdb`, such as the catalog version. They also show information about write-ahead logging and checkpoint processing. This information is cluster-wide, not specific to any one database. These functions provide most of the same information, from the same source, as the `lt_controldata` application.

**Table 9.79. Control File Data Functions**

Function	Description
<code>pg_control_checkpoint()</code>	<code>→ record</code> Returns information about current checkpoint state, as shown in Table 9.80.
<code>pg_control_system()</code>	<code>→ record</code> Returns information about current control file state, as shown in Table 9.81.
<code>pg_control_init()</code>	<code>→ record</code> Returns information about cluster initialization state, as shown in Table 9.82.
<code>pg_control_recovery()</code>	<code>→ record</code>

Function
<b>Description</b>
Returns information about recovery state, as shown in Table 9.83.

**Table 9.80. pg\_control\_checkpoint Output Columns**

Column Name	Data Type
checkpoint_lsn	pg_lsn
redo_lsn	pg_lsn
redo_wal_file	text
timeline_id	integer
prev_timeline_id	integer
full_page_writes	boolean
next_xid	text
next_oid	oid
next_multixact_id	xid
next_multi_offset	xid
oldest_xid	xid
oldest_xid_dbid	oid
oldest_active_xid	xid
oldest_multi_xid	xid
oldest_multi_dbid	oid
oldest_commit_ts_xid	xid
newest_commit_ts_xid	xid
checkpoint_time	timestamp with time zone

**Table 9.81. pg\_control\_system Output Columns**

Column Name	Data Type
pg_control_version	integer
catalog_version_no	integer
system_identifier	bigint
pg_control_last_modified	timestamp with time zone

**Table 9.82. pg\_control\_init Output Columns**

Column Name	Data Type
max_data_alignment	integer
database_block_size	integer
blocks_per_segment	integer
wal_block_size	integer
bytes_per_wal_segment	integer
max_identifier_length	integer
max_index_columns	integer
max_toast_chunk_size	integer
large_object_chunk_size	integer

Column Name	Data Type
<code>float8_pass_by_value</code>	boolean
<code>data_page_checksum_version</code>	integer

**Table 9.83. `pg_control_recovery` Output Columns**

Column Name	Data Type
<code>min_recovery_end_lsn</code>	<code>pg_lsn</code>
<code>min_recovery_end_timeline</code>	integer
<code>backup_start_lsn</code>	<code>pg_lsn</code>
<code>backup_end_lsn</code>	<code>pg_lsn</code>
<code>end_of_backup_record_required</code>	boolean

## 9.27. System Administration Functions

The functions described in this section are used to control and monitor a LightDB installation.

### 9.27.1. Configuration Settings Functions

Table 9.84 shows the functions available to query and alter run-time configuration parameters.

**Table 9.84. Configuration Settings Functions**

Function	Description	Example(s)
<code>current_setting</code>	<code>current_setting(setting_name text [, missing_ok boolean]) → text</code> Returns the current value of the setting <code>setting_name</code> . If there is no such setting, <code>current_setting</code> throws an error unless <code>missing_ok</code> is supplied and is <code>true</code> (in which case <code>NULL</code> is returned). This function corresponds to the SQL command <code>SHOW</code> .	<code>current_setting('datestyle') → ISO, MDY</code>
<code>set_config</code>	<code>set_config(setting_name text, new_value text, is_local boolean) → text</code> Sets the parameter <code>setting_name</code> to <code>new_value</code> , and returns that value. If <code>is_local</code> is <code>true</code> , the new value will only apply during the current transaction. If you want the new value to apply for the rest of the current session, use <code>false</code> instead. This function corresponds to the SQL command <code>SET</code> .	<code>set_config('log_statement_stats', 'off', false) → off</code>

### 9.27.2. Server Signaling Functions

The functions shown in Table 9.85 send control signals to other server processes. Use of these functions is restricted to superusers by default but access may be granted to others using `GRANT`, with noted exceptions.

Each of these functions returns `true` if successful and `false` otherwise.

**Table 9.85. Server Signaling Functions**

Function	Description
<code>pg_cancel_backend</code>	<code>pg_cancel_backend(pid integer) → boolean</code>

Function	Description
	Cancels the current query of the session whose backend process has the specified process ID. This is also allowed if the calling role is a member of the role whose backend is being canceled or the calling role has been granted <code>pg_signal_backend</code> , however only superusers can cancel superuser backends.
<code>pg_reload_conf ()</code> → boolean	Causes all processes of the LightDB server to reload their configuration files. (This is initiated by sending a <code>SIGHUP</code> signal to the postmaster process, which in turn sends <code>SIGHUP</code> to each of its children.)
<code>pg_rotate_logfile ()</code> → boolean	Signals the log-file manager to switch to a new output file immediately. This works only when the built-in log collector is running, since otherwise there is no log-file manager subprocess.
<code>pg_terminate_backend ( pid integer )</code> → boolean	Terminates the session whose backend process has the specified process ID. This is also allowed if the calling role is a member of the role whose backend is being terminated or the calling role has been granted <code>pg_signal_backend</code> , however only superusers can terminate superuser backends.

`pg_cancel_backend` and `pg_terminate_backend` send signals (`SIGINT` or `SIGTERM` respectively) to backend processes identified by process ID. The process ID of an active backend can be found from the `pid` column of the `pg_stat_activity` view, or by listing the `lightdb` processes on the server (using `ps` on Unix or the Task Manager on Windows). The role of an active backend can be found from the `username` column of the `pg_stat_activity` view.

### 9.27.3. Backup Control Functions

The functions shown in Table 9.86 assist in making on-line backups. These functions cannot be executed during recovery (except non-exclusive `pg_start_backup`, non-exclusive `pg_stop_backup`, `pg_is_in_backup`, `pg_backup_start_time` and `pg_wal_lsn_diff`).

For details about proper usage of these functions, see Section 23.3.

**Table 9.86. Backup Control Functions**

Function	Description
<code>pg_create_restore_point ( name text )</code> → <code>pg_lsn</code>	Creates a named marker record in the write-ahead log that can later be used as a recovery target, and returns the corresponding write-ahead log location. The given name can then be used with <code>recovery_target_name</code> to specify the point up to which recovery will proceed. Avoid creating multiple restore points with the same name, since recovery will stop at the first one whose name matches the recovery target. This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.
<code>pg_current_wal_flush_lsn ()</code> → <code>pg_lsn</code>	Returns the current write-ahead log flush location (see notes below).
<code>pg_current_wal_insert_lsn ()</code> → <code>pg_lsn</code>	Returns the current write-ahead log insert location (see notes below).
<code>pg_current_wal_lsn ()</code> → <code>pg_lsn</code>	Returns the current write-ahead log write location (see notes below).

Function
<p><b>Description</b></p> <p><code>pg_start_backup ( label text [, fast boolean [, exclusive boolean ] ] ) → pg_lsn</code>  Prepares the server to begin an on-line backup. The only required parameter is an arbitrary user-defined label for the backup. (Typically this would be the name under which the backup dump file will be stored.) If the optional second parameter is given as <code>true</code>, it specifies executing <code>pg_start_backup</code> as quickly as possible. This forces an immediate checkpoint which will cause a spike in I/O operations, slowing any concurrently executing queries. The optional third parameter specifies whether to perform an exclusive or non-exclusive backup (default is exclusive).  When used in exclusive mode, this function writes a backup label file (<code>backup_label</code>) and, if there are any links in the <code>lt_tbsp/</code> directory, a tablespace map file (<code>tablespace_map</code>) into the database cluster's data directory, then performs a checkpoint, and then returns the backup's starting write-ahead log location. (The user can ignore this result value, but it is provided in case it is useful.)  When used in non-exclusive mode, the contents of these files are instead returned by the <code>pg_stop_backup</code> function, and should be copied to the backup area by the user. This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.</p>
<p><code>pg_stop_backup ( exclusive boolean [, wait_for_archive boolean ] ) → setof record ( lsn pg_lsn, labelfile text, spcmapfile text )</code>  Finishes performing an exclusive or non-exclusive on-line backup. The <code>exclusive</code> parameter must match the previous <code>pg_start_backup</code> call. In an exclusive backup, <code>pg_stop_backup</code> removes the backup label file and, if it exists, the tablespace map file created by <code>pg_start_backup</code>. In a non-exclusive backup, the desired contents of these files are returned as part of the result of the function, and should be written to files in the backup area (not in the data directory).  There is an optional second parameter of type <code>boolean</code>. If false, the function will return immediately after the backup is completed, without waiting for WAL to be archived. This behavior is only useful with backup software that independently monitors WAL archiving. Otherwise, WAL required to make the backup consistent might be missing and make the backup useless. By default or when this parameter is true, <code>pg_stop_backup</code> will wait for WAL to be archived when archiving is enabled. (On a standby, this means that it will wait only when <code>archive_mode = always</code>. If write activity on the primary is low, it may be useful to run <code>pg_switch_wal</code> on the primary in order to trigger an immediate segment switch.)  When executed on a primary, this function also creates a backup history file in the write-ahead log archive area. The history file includes the label given to <code>pg_start_backup</code>, the starting and ending write-ahead log locations for the backup, and the starting and ending times of the backup. After recording the ending location, the current write-ahead log insertion point is automatically advanced to the next write-ahead log file, so that the ending write-ahead log file can be archived immediately to complete the backup.  The result of the function is a single record. The <code>lsn</code> column holds the backup's ending write-ahead log location (which again can be ignored). The second and third columns are NULL when ending an exclusive backup; after a non-exclusive backup they hold the desired contents of the label and tablespace map files.  This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.</p>
<p><code>pg_stop_backup () → pg_lsn</code>  Finishes performing an exclusive on-line backup. This simplified version is equivalent to <code>pg_stop_backup ( true, true )</code>, except that it only returns the <code>pg_lsn</code> result. This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.</p>

Function	Description
<code>pg_is_in_backup()</code> → boolean	Returns true if an on-line exclusive backup is in progress.
<code>pg_backup_start_time()</code> → timestamp with time zone	Returns the start time of the current on-line exclusive backup if one is in progress, otherwise NULL.
<code>pg_switch_wal()</code> → pg_lsn	Forces the server to switch to a new write-ahead log file, which allows the current file to be archived (assuming you are using continuous archiving). The result is the ending write-ahead log location plus 1 within the just-completed write-ahead log file. If there has been no write-ahead log activity since the last write-ahead log switch, <code>pg_switch_wal</code> does nothing and returns the start location of the write-ahead log file currently in use. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_walfile_name(lsn pg_lsn)</code> → text	Converts a write-ahead log location to the name of the WAL file holding that location.
<code>pg_walfile_name_offset(lsn pg_lsn)</code> → record( <i>file_name</i> text, <i>file_offset</i> integer)	Converts a write-ahead log location to a WAL file name and byte offset within that file.
<code>pg_wal_lsn_diff(lsn1 pg_lsn, lsn2 pg_lsn)</code> → numeric	Calculates the difference in bytes ( <i>lsn1</i> - <i>lsn2</i> ) between two write-ahead log locations. This can be used with <code>pg_stat_replication</code> or some of the functions shown in Table 9.86 to get the replication lag.

`pg_current_wal_lsn` displays the current write-ahead log write location in the same format used by the above functions. Similarly, `pg_current_wal_insert_lsn` displays the current write-ahead log insertion location and `pg_current_wal_flush_lsn` displays the current write-ahead log flush location. The insertion location is the “logical” end of the write-ahead log at any instant, while the write location is the end of what has actually been written out from the server’s internal buffers, and the flush location is the last location known to be written to durable storage. The write location is the end of what can be examined from outside the server, and is usually what you want if you are interested in archiving partially-complete write-ahead log files. The insertion and flush locations are made available primarily for server debugging purposes. These are all read-only operations and do not require superuser permissions.

You can use `pg_walfile_name_offset` to extract the corresponding write-ahead log file name and byte offset from a `pg_lsn` value. For example:

```
lightdb@postgres=# SELECT * FROM
  pg_walfile_name_offset(pg_stop_backup());
   file_name          | file_offset
-----+-----
 00000001000000000000000D |      4039624
(1 row)
```

Similarly, `pg_walfile_name` extracts just the write-ahead log file name. When the given write-ahead log location is exactly at a write-ahead log file boundary, both these functions return the name of the preceding write-ahead log file. This is usually the desired behavior for managing write-ahead log archiving behavior, since the preceding file is the last one that currently needs to be archived.



## 9.27.4. Recovery Control Functions

The functions shown in Table 9.87 provide information about the current status of a standby server. These functions may be executed both during recovery and in normal running.

**Table 9.87. Recovery Information Functions**

Function	Description
<code>pg_is_in_recovery ()</code> → boolean	Returns true if recovery is still in progress.
<code>pg_last_wal_receive_lsn ()</code> → pg_lsn	Returns the last write-ahead log location that has been received and synced to disk by streaming replication. While streaming replication is in progress this will increase monotonically. If recovery has completed then this will remain static at the location of the last WAL record received and synced to disk during recovery. If streaming replication is disabled, or if it has not yet started, the function returns NULL.
<code>pg_last_wal_replay_lsn ()</code> → pg_lsn	Returns the last write-ahead log location that has been replayed during recovery. If recovery is still in progress this will increase monotonically. If recovery has completed then this will remain static at the location of the last WAL record applied during recovery. When the server has been started normally without recovery, the function returns NULL.
<code>pg_last_xact_replay_timestamp ()</code> → timestamp with time zone	Returns the time stamp of the last transaction replayed during recovery. This is the time at which the commit or abort WAL record for that transaction was generated on the primary. If no transactions have been replayed during recovery, the function returns NULL. Otherwise, if recovery is still in progress this will increase monotonically. If recovery has completed then this will remain static at the time of the last transaction applied during recovery. When the server has been started normally without recovery, the function returns NULL.

The functions shown in Table 9.88 control the progress of recovery. These functions may be executed only during recovery.

**Table 9.88. Recovery Control Functions**

Function	Description
<code>pg_is_wal_replay_paused ()</code> → boolean	Returns true if recovery is paused.
<code>pg_promote (wait boolean DEFAULT true, wait_seconds integer DEFAULT 60)</code> → boolean	Promotes a standby server to primary status. With <i>wait</i> set to <i>true</i> (the default), the function waits until promotion is completed or <i>wait_seconds</i> seconds have passed, and returns <i>true</i> if promotion is successful and <i>false</i> otherwise. If <i>wait</i> is set to <i>false</i> , the function returns <i>true</i> immediately after sending a SIGUSR1 signal to the postmaster to trigger promotion. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_wal_replay_pause ()</code> → void	

Function	Description
	Pauses recovery. While recovery is paused, no further database changes are applied. If hot standby is active, all new queries will see the same consistent snapshot of the database, and no further query conflicts will be generated until recovery is resumed. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_wal_replay_resume () → void</code>	Restarts recovery if it was paused. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

`pg_wal_replay_pause` and `pg_wal_replay_resume` cannot be executed while a promotion is ongoing. If a promotion is triggered while recovery is paused, the paused state ends and promotion continues.

If streaming replication is disabled, the paused state may continue indefinitely without a problem. If streaming replication is in progress then WAL records will continue to be received, which will eventually fill available disk space, depending upon the duration of the pause, the rate of WAL generation and available disk space.

## 9.27.5. Snapshot Synchronization Functions

LightDB allows database sessions to synchronize their snapshots. A *snapshot* determines which data is visible to the transaction that is using the snapshot. Synchronized snapshots are necessary when two or more sessions need to see identical content in the database. If two sessions just start their transactions independently, there is always a possibility that some third transaction commits between the executions of the two `START TRANSACTION` commands, so that one session sees the effects of that transaction and the other does not.

To solve this problem, LightDB allows a transaction to *export* the snapshot it is using. As long as the exporting transaction remains open, other transactions can *import* its snapshot, and thereby be guaranteed that they see exactly the same view of the database that the first transaction sees. But note that any database changes made by any one of these transactions remain invisible to the other transactions, as is usual for changes made by uncommitted transactions. So the transactions are synchronized with respect to pre-existing data, but act normally for changes they make themselves.

Snapshots are exported with the `pg_export_snapshot` function, shown in Table 9.89, and imported with the `SET TRANSACTION` command.

**Table 9.89. Snapshot Synchronization Functions**

Function	Description
<code>pg_export_snapshot () → text</code>	Saves the transaction's current snapshot and returns a <code>text</code> string identifying the snapshot. This string must be passed (outside the database) to clients that want to import the snapshot. The snapshot is available for import only until the end of the transaction that exported it.  A transaction can export more than one snapshot, if needed. Note that doing so is only useful in <code>READ COMMITTED</code> transactions, since in <code>REPEATABLE READ</code> and higher isolation levels, transactions use the same snapshot throughout their lifetime. Once a transaction has exported any snapshots, it cannot be prepared with <code>PREPARE TRANSACTION</code> .

## 9.27.6. Replication Management Functions

The functions shown in Table 9.90 are for controlling and interacting with replication features. See Section 24.2.5, Section 24.2.6, and Chapter 46 for information about the underlying features. Use of functions for replication origin is restricted to superusers. Use of functions for replication slots is restricted to superusers and users having REPLICATION privilege.

Many of these functions have equivalent commands in the replication protocol; see Section 49.4.

The functions described in Section 9.27.3, Section 9.27.4, and Section 9.27.5 are also relevant for replication.

**Table 9.90. Replication Management Functions**

Function	Description
<code>pg_create_physical_replication_slot ( slot_name name [, immediately_reserve boolean, temporary boolean ] ) → record ( slot_name name, lsn pg_lsn )</code>	Creates a new physical replication slot named <i>slot_name</i> . The optional second parameter, when <code>true</code> , specifies that the LSN for this replication slot be reserved immediately; otherwise the LSN is reserved on first connection from a streaming replication client. Streaming changes from a physical slot is only possible with the streaming-replication protocol — see Section 49.4. The optional third parameter, <i>temporary</i> , when set to <code>true</code> , specifies that the slot should not be permanently stored to disk and is only meant for use by the current session. Temporary slots are also released upon any error. This function corresponds to the replication protocol command <code>CREATE_REPLICATION_SLOT ... PHYSICAL</code> .
<code>pg_drop_replication_slot ( slot_name name ) → void</code>	Drops the physical or logical replication slot named <i>slot_name</i> . Same as replication protocol command <code>DROP_REPLICATION_SLOT</code> . For logical slots, this must be called while connected to the same database the slot was created on.
<code>pg_create_logical_replication_slot ( slot_name name, plugin name [, temporary boolean ] ) → record ( slot_name name, lsn pg_lsn )</code>	Creates a new logical (decoding) replication slot named <i>slot_name</i> using the output plugin <i>plugin</i> . The optional third parameter, <i>temporary</i> , when set to <code>true</code> , specifies that the slot should not be permanently stored to disk and is only meant for use by the current session. Temporary slots are also released upon any error. A call to this function has the same effect as the replication protocol command <code>CREATE_REPLICATION_SLOT ... LOGICAL</code> .
<code>pg_copy_physical_replication_slot ( src_slot_name name, dst_slot_name name [, temporary boolean ] ) → record ( slot_name name, lsn pg_lsn )</code>	Copies an existing physical replication slot named <i>src_slot_name</i> to a physical replication slot named <i>dst_slot_name</i> . The copied physical slot starts to reserve WAL from the same LSN as the source slot. <i>temporary</i> is optional. If <i>temporary</i> is omitted, the same value as the source slot is used.
<code>pg_copy_logical_replication_slot ( src_slot_name name, dst_slot_name name [, temporary boolean [, plugin name ] ] ) → record ( slot_name name, lsn pg_lsn )</code>	Copies an existing logical replication slot named <i>src_slot_name</i> to a logical replication slot named <i>dst_slot_name</i> , optionally changing the output plugin and persistence. The copied logical slot starts from the same LSN as the source logical slot. Both <i>temporary</i> and <i>plugin</i> are optional; if they are omitted, the values of the source slot are used.

Function	Description
<code>pg_logical_slot_get_changes ( slot_name name, upto_lsn pg_lsn, upto_nchanges integer, VARIADIC options text[] )</code>	<code>→ setof record ( lsn pg_lsn, xid xid, data text )</code> Returns changes in the slot <i>slot_name</i> , starting from the point from which changes have been consumed last. If <i>upto_lsn</i> and <i>upto_nchanges</i> are NULL, logical decoding will continue until end of WAL. If <i>upto_lsn</i> is non-NULL, decoding will include only those transactions which commit prior to the specified LSN. If <i>upto_nchanges</i> is non-NULL, decoding will stop when the number of rows produced by decoding exceeds the specified value. Note, however, that the actual number of rows returned may be larger, since this limit is only checked after adding the rows produced when decoding each new transaction commit.
<code>pg_logical_slot_peek_changes ( slot_name name, upto_lsn pg_lsn, upto_nchanges integer, VARIADIC options text[] )</code>	<code>→ setof record ( lsn pg_lsn, xid xid, data text )</code> Behaves just like the <code>pg_logical_slot_get_changes ( )</code> function, except that changes are not consumed; that is, they will be returned again on future calls.
<code>pg_logical_slot_get_binary_changes ( slot_name name, upto_lsn pg_lsn, upto_nchanges integer, VARIADIC options text[] )</code>	<code>→ setof record ( lsn pg_lsn, xid xid, data bytea )</code> Behaves just like the <code>pg_logical_slot_get_changes ( )</code> function, except that changes are returned as <code>bytea</code> .
<code>pg_logical_slot_peek_binary_changes ( slot_name name, upto_lsn pg_lsn, upto_nchanges integer, VARIADIC options text[] )</code>	<code>→ setof record ( lsn pg_lsn, xid xid, data bytea )</code> Behaves just like the <code>pg_logical_slot_peek_changes ( )</code> function, except that changes are returned as <code>bytea</code> .
<code>pg_replication_slot_advance ( slot_name name, upto_lsn pg_lsn )</code>	<code>→ record ( slot_name name, end_lsn pg_lsn )</code> Advances the current confirmed position of a replication slot named <i>slot_name</i> . The slot will not be moved backwards, and it will not be moved beyond the current insert location. Returns the name of the slot and the actual position that it was advanced to. The updated slot position information is written out at the next checkpoint if any advancing is done. So in the event of a crash, the slot may return to an earlier position.
<code>pg_replication_origin_create ( node_name text )</code>	<code>→ oid</code> Creates a replication origin with the given external name, and returns the internal ID assigned to it.
<code>pg_replication_origin_drop ( node_name text )</code>	<code>→ void</code> Deletes a previously-created replication origin, including any associated replay progress.
<code>pg_replication_origin_oid ( node_name text )</code>	<code>→ oid</code> Looks up a replication origin by name and returns the internal ID. If no such replication origin is found, NULL is returned.
<code>pg_replication_origin_session_setup ( node_name text )</code>	<code>→ void</code> Marks the current session as replaying from the given origin, allowing replay progress to be tracked. Can only be used if no origin is currently selected. Use <code>pg_replication_origin_session_reset</code> to undo.
<code>pg_replication_origin_session_reset ( )</code>	<code>→ void</code> Cancels the effects of <code>pg_replication_origin_session_setup ( )</code> .
<code>pg_replication_origin_session_is_setup ( )</code>	<code>→ boolean</code>

Function	Description
	Returns true if a replication origin has been selected in the current session.
<code>pg_replication_origin_session_progress ( flush boolean ) → pg_lsn</code>	Returns the replay location for the replication origin selected in the current session. The parameter <i>flush</i> determines whether the corresponding local transaction will be guaranteed to have been flushed to disk or not.
<code>pg_replication_origin_xact_setup ( origin_lsn pg_lsn, origin_timestamp timestamp with time zone ) → void</code>	Marks the current transaction as replaying a transaction that has committed at the given LSN and timestamp. Can only be called when a replication origin has been selected using <code>pg_replication_origin_session_setup</code> .
<code>pg_replication_origin_xact_reset () → void</code>	Cancels the effects of <code>pg_replication_origin_xact_setup()</code> .
<code>pg_replication_origin_advance ( node_name text, lsn pg_lsn ) → void</code>	Sets replication progress for the given node to the given location. This is primarily useful for setting up the initial location, or setting a new location after configuration changes and similar. Be aware that careless use of this function can lead to inconsistently replicated data.
<code>pg_replication_origin_progress ( node_name text, flush boolean ) → pg_lsn</code>	Returns the replay location for the given replication origin. The parameter <i>flush</i> determines whether the corresponding local transaction will be guaranteed to have been flushed to disk or not.
<code>pg_logical_emit_message ( transactional boolean, prefix text, content text ) → pg_lsn</code> <code>pg_logical_emit_message ( transactional boolean, prefix text, content bytea ) → pg_lsn</code>	Emits a logical decoding message. This can be used to pass generic messages to logical decoding plugins through WAL. The <i>transactional</i> parameter specifies if the message should be part of the current transaction, or if it should be written immediately and decoded as soon as the logical decoder reads the record. The <i>prefix</i> parameter is a textual prefix that can be used by logical decoding plugins to easily recognize messages that are interesting for them. The <i>content</i> parameter is the content of the message, given either in text or binary form.

## 9.27.7. Database Object Management Functions

The functions shown in Table 9.91 calculate the disk space usage of database objects, or assist in presentation of usage results. All these functions return sizes measured in bytes. If an OID that does not represent an existing object is passed to one of these functions, NULL is returned.

**Table 9.91. Database Object Size Functions**

Function	Description
<code>pg_column_size ( "any" ) → integer</code>	Shows the number of bytes used to store any individual data value. If applied directly to a table column value, this reflects any compression that was done.
<code>pg_database_size ( name ) → bigint</code> <code>pg_database_size ( oid ) → bigint</code>	

Function	Description
	Computes the total disk space used by the database with the specified name or OID. To use this function, you must have <code>CONNECT</code> privilege on the specified database (which is granted by default) or be a member of the <code>pg_read_all_stats</code> role.
<code>pg_indexes_size ( regclass ) → bigint</code>	Computes the total disk space used by indexes attached to the specified table.
<code>pg_relation_size ( relation regclass [, fork text ] ) → bigint</code>	Computes the disk space used by one “fork” of the specified relation. (Note that for most purposes it is more convenient to use the higher-level functions <code>pg_total_relation_size</code> or <code>pg_table_size</code> , which sum the sizes of all forks.) With one argument, this returns the size of the main data fork of the relation. The second argument can be provided to specify which fork to examine: <ul style="list-style-type: none"> <li>• <code>main</code> returns the size of the main data fork of the relation.</li> <li>• <code>fsm</code> returns the size of the Free Space Map (see Section 64.3) associated with the relation.</li> <li>• <code>vm</code> returns the size of the Visibility Map (see Section 64.4) associated with the relation.</li> <li>• <code>init</code> returns the size of the initialization fork, if any, associated with the relation.</li> </ul>
<code>pg_size_bytes ( text ) → bigint</code>	Converts a size in human-readable format (as returned by <code>pg_size_pretty</code> ) into bytes.
<code>pg_size_pretty ( bigint ) → text</code> <code>pg_size_pretty ( numeric ) → text</code>	Converts a size in bytes into a more easily human-readable format with size units (bytes, kB, MB, GB or TB as appropriate). Note that the units are powers of 2 rather than powers of 10, so 1kB is 1024 bytes, 1MB is $1024^2 = 1048576$ bytes, and so on.
<code>pg_table_size ( regclass ) → bigint</code>	Computes the disk space used by the specified table, excluding indexes (but including its TOAST table if any, free space map, and visibility map).
<code>pg_tablespace_size ( name ) → bigint</code> <code>pg_tablespace_size ( oid ) → bigint</code>	Computes the total disk space used in the tablespace with the specified name or OID. To use this function, you must have <code>CREATE</code> privilege on the specified tablespace or be a member of the <code>pg_read_all_stats</code> role, unless it is the default tablespace for the current database.
<code>pg_total_relation_size ( regclass ) → bigint</code>	Computes the total disk space used by the specified table, including all indexes and TOAST data. The result is equivalent to <code>pg_table_size + pg_indexes_size</code> .

The functions above that operate on tables or indexes accept a `regclass` argument, which is simply the OID of the table or index in the `pg_class` system catalog. You do not have to look up the OID by hand, however, since the `regclass` data type's input converter will do the work for you. Just write the table name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the table name.

The functions shown in Table 9.92 assist in identifying the specific disk files associated with database objects.

**Table 9.92. Database Object Location Functions**

Function	Description
<code>pg_relation_filenum ( relation regclass ) → oid</code>	Returns the “filenum” number currently assigned to the specified relation. The filenum is the base component of the file name(s) used for the relation (see Section 64.1 for more information). For most relations the result is the same as <code>pg_class.relfilenum</code> , but for certain system catalogs <code>relfilenum</code> is zero and this function must be used to get the correct value. The function returns NULL if passed a relation that does not have storage, such as a view.
<code>pg_relation_filepath ( relation regclass ) → text</code>	Returns the entire file path name (relative to the database cluster's data directory, <code>LTDATA</code> ) of the relation.
<code>pg_filenum_relation ( tablespace oid, filenum oid ) → regclass</code>	Returns a relation's OID given the tablespace OID and filenum it is stored under. This is essentially the inverse mapping of <code>pg_relation_filepath</code> . For a relation in the database's default tablespace, the tablespace can be specified as zero. Returns NULL if no relation in the current database is associated with the given values.

Table 9.93 lists functions used to manage collations.

**Table 9.93. Collation Management Functions**

Function	Description
<code>pg_collation_actual_version ( oid ) → text</code>	Returns the actual version of the collation object as it is currently installed in the operating system. If this is different from the value in <code>pg_collation.collversion</code> , then objects depending on the collation might need to be rebuilt. See also <code>ALTER COLLATION</code> .
<code>pg_import_system_collations ( schema regnamespace ) → integer</code>	Adds collations to the system catalog <code>pg_collation</code> based on all the locales it finds in the operating system. This is what <code>initdb</code> uses; see Section 21.2.2 for more details. If additional locales are installed into the operating system later on, this function can be run again to add collations for the new locales. Locales that match existing entries in <code>pg_collation</code> will be skipped. (But collation objects based on locales that are no longer present in the operating system are not removed by this function.) The <code>schema</code> parameter would typically be <code>pg_catalog</code> , but that is not a requirement; the collations could be installed into some other schema as well. The function returns the number of new collation objects it created. Use of this function is restricted to superusers.

Table 9.94 lists functions that provide information about the structure of partitioned tables.

**Table 9.94. Partitioning Information Functions**

Function	Description
<code>pg_partition_tree ( regclass ) → setof record ( relid regclass, parentrelid regclass, isleaf boolean, level integer )</code>	Lists the tables or indexes in the partition tree of the given partitioned table or partitioned index, with one row for each partition. Information provided includes the OID of the partition, the OID of its immediate parent, a boolean value telling if the partition is a leaf,

Function	Description
	and an integer telling its level in the hierarchy. The level value is 0 for the input table or index, 1 for its immediate child partitions, 2 for their partitions, and so on. Returns no rows if the relation does not exist or is not a partition or partitioned table.
<code>pg_partition_ancestors ( regclass ) → setof regclass</code>	Lists the ancestor relations of the given partition, including the relation itself. Returns no rows if the relation does not exist or is not a partition or partitioned table.
<code>pg_partition_root ( regclass ) → regclass</code>	Returns the top-most parent of the partition tree to which the given relation belongs. Returns NULL if the relation does not exist or is not a partition or partitioned table.

For example, to check the total size of the data contained in a partitioned table `measurement`, one could use the following query:

```
SELECT pg_size_pretty(sum(pg_relation_size(releid))) AS total_size
FROM pg_partition_tree('measurement');
```

## 9.27.8. Index Maintenance Functions

Table 9.95 shows the functions available for index maintenance tasks. (Note that these maintenance tasks are normally done automatically by autovacuum; use of these functions is only required in special cases.) These functions cannot be executed during recovery. Use of these functions is restricted to superusers and the owner of the given index.

**Table 9.95. Index Maintenance Functions**

Function	Description
<code>gin_clean_pending_list ( index regclass ) → bigint</code>	Cleans up the “pending” list of the specified GIN index by moving entries in it, in bulk, to the main GIN data structure. Returns the number of pages removed from the pending list. If the argument is a GIN index built with the <code>fastupdate</code> option disabled, no cleanup happens and the result is zero, because the index doesn't have a pending list. See Section 62.4.1 and Section 62.5 for details about the pending list and <code>fastupdate</code> option.

## 9.27.9. Generic File Access Functions

The functions shown in Table 9.96 provide native access to files on the machine hosting the server. Only files within the database cluster directory and the `log_directory` can be accessed, unless the user is a superuser or is granted the role `pg_read_server_files`. Use a relative path for files in the cluster directory, and a path matching the `log_directory` configuration setting for log files.

Note that granting users the `EXECUTE` privilege on `pg_read_file()`, or related functions, allows them the ability to read any file on the server that the database server process can read; these functions bypass all in-database privilege checks. This means that, for example, a user with such access is able to read the contents of the `pg_authid` table where authentication information is stored, as well as read any table data in the database. Therefore, granting access to these functions should be carefully considered.

Some of these functions take an optional `missing_ok` parameter, which specifies the behavior when the file or directory does not exist. If `true`, the function returns NULL or an empty result set, as appropriate. If `false`, an error is raised. The default is `false`.



**Table 9.96. Generic File Access Functions**

Function	Description
<code>pg_ls_dir (dirname text [, missing_ok boolean, include_dot_dirs boolean]) → setof text</code>	<p>Returns the names of all files (and directories and other special files) in the specified directory. The <code>include_dot_dirs</code> parameter indicates whether “.” and “..” are to be included in the result set; the default is to exclude them. Including them can be useful when <code>missing_ok</code> is true, to distinguish an empty directory from a non-existent directory.</p> <p>This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_ls_logdir () → setof record (name text, size bigint, modification timestamp with time zone)</code>	<p>Returns the name, size, and last modification time (mtime) of each ordinary file in the server's log directory. Filenames beginning with a dot, directories, and other special files are excluded.</p> <p>This function is restricted to superusers and members of the <code>pg_monitor</code> role by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_ls_waldir () → setof record (name text, size bigint, modification timestamp with time zone)</code>	<p>Returns the name, size, and last modification time (mtime) of each ordinary file in the server's write-ahead log (WAL) directory. Filenames beginning with a dot, directories, and other special files are excluded.</p> <p>This function is restricted to superusers and members of the <code>pg_monitor</code> role by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_ls_archive_statusdir () → setof record (name text, size bigint, modification timestamp with time zone)</code>	<p>Returns the name, size, and last modification time (mtime) of each ordinary file in the server's WAL archive status directory (<code>lt_wal/archive_status</code>). Filenames beginning with a dot, directories, and other special files are excluded.</p> <p>This function is restricted to superusers and members of the <code>pg_monitor</code> role by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_ls_tmpdir ([tablespace oid]) → setof record (name text, size bigint, modification timestamp with time zone)</code>	<p>Returns the name, size, and last modification time (mtime) of each ordinary file in the temporary file directory for the specified <code>tablespace</code>. If <code>tablespace</code> is not provided, the <code>pg_default</code> tablespace is examined. Filenames beginning with a dot, directories, and other special files are excluded.</p> <p>This function is restricted to superusers and members of the <code>pg_monitor</code> role by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_read_file (filename text [, offset bigint, length bigint [, missing_ok boolean]]) → text</code>	<p>Returns all or part of a text file, starting at the given byte <code>offset</code>, returning at most <code>length</code> bytes (less if the end of file is reached first). If <code>offset</code> is negative, it is relative to the end of the file. If <code>offset</code> and <code>length</code> are omitted, the entire file is returned. The bytes read from the file are interpreted as a string in the database's encoding; an error is thrown if they are not valid in that encoding.</p> <p>This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.</p>
<code>pg_read_binary_file (filename text [, offset bigint, length bigint [, missing_ok boolean]]) → bytea</code>	

Function	Description
	<p>Returns all or part of a file. This function is identical to <code>pg_read_file</code> except that it can read arbitrary binary data, returning the result as <code>bytea</code> not <code>text</code>; accordingly, no encoding checks are performed.</p> <p>This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.</p> <p>In combination with the <code>convert_from</code> function, this function can be used to read a text file in a specified encoding and convert to the database's encoding:</p> <pre>SELECT   convert_from(pg_read_binary_file('file_in_utf8.txt'),     'UTF8');</pre>
	<pre>pg_stat_file(filename text [,missing_ok boolean]) → record(size   bigint,access timestamp with time zone,modification timestamp   with time zone,change timestamp with time zone,creation   timestamp with time zone,isdir boolean)</pre> <p>Returns a record containing the file's size, last access time stamp, last modification time stamp, last file status change time stamp (Unix platforms only), file creation time stamp (Windows only), and a flag indicating if it is a directory.</p> <p>This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.</p>

## 9.27.10. Advisory Lock Functions

The functions shown in Table 9.97 manage advisory locks. For details about proper use of these functions, see Section 13.3.5.

All these functions are intended to be used to lock application-defined resources, which can be identified either by a single 64-bit key value or two 32-bit key values (note that these two key spaces do not overlap). If another session already holds a conflicting lock on the same resource identifier, the functions will either wait until the resource becomes available, or return a `false` result, as appropriate for the function. Locks can be either shared or exclusive: a shared lock does not conflict with other shared locks on the same resource, only with exclusive locks. Locks can be taken at session level (so that they are held until released or the session ends) or at transaction level (so that they are held until the current transaction ends; there is no provision for manual release). Multiple session-level lock requests stack, so that if the same resource identifier is locked three times there must then be three unlock requests to release the resource in advance of session end.

**Table 9.97. Advisory Lock Functions**

Function	Description
<code>pg_advisory_lock(key bigint) → void</code> <code>pg_advisory_lock(key1 integer, key2 integer) → void</code>	Obtains an exclusive session-level advisory lock, waiting if necessary.
<code>pg_advisory_lock_shared(key bigint) → void</code> <code>pg_advisory_lock_shared(key1 integer, key2 integer) → void</code>	Obtains a shared session-level advisory lock, waiting if necessary.
<code>pg_advisory_unlock(key bigint) → boolean</code> <code>pg_advisory_unlock(key1 integer, key2 integer) → boolean</code>	

Function	Description
	Releases a previously-acquired exclusive session-level advisory lock. Returns <code>true</code> if the lock is successfully released. If the lock was not held, <code>false</code> is returned, and in addition, an SQL warning will be reported by the server.
<code>pg_advisory_unlock_all ()</code> → void	Releases all session-level advisory locks held by the current session. (This function is implicitly invoked at session end, even if the client disconnects ungracefully.)
<code>pg_advisory_unlock_shared (key bigint)</code> → boolean <code>pg_advisory_unlock_shared (key1 integer, key2 integer)</code> → boolean	Releases a previously-acquired shared session-level advisory lock. Returns <code>true</code> if the lock is successfully released. If the lock was not held, <code>false</code> is returned, and in addition, an SQL warning will be reported by the server.
<code>pg_advisory_xact_lock (key bigint)</code> → void <code>pg_advisory_xact_lock (key1 integer, key2 integer)</code> → void	Obtains an exclusive transaction-level advisory lock, waiting if necessary.
<code>pg_advisory_xact_lock_shared (key bigint)</code> → void <code>pg_advisory_xact_lock_shared (key1 integer, key2 integer)</code> → void	Obtains a shared transaction-level advisory lock, waiting if necessary.
<code>pg_try_advisory_lock (key bigint)</code> → boolean <code>pg_try_advisory_lock (key1 integer, key2 integer)</code> → boolean	Obtains an exclusive session-level advisory lock if available. This will either obtain the lock immediately and return <code>true</code> , or return <code>false</code> without waiting if the lock cannot be acquired immediately.
<code>pg_try_advisory_lock_shared (key bigint)</code> → boolean <code>pg_try_advisory_lock_shared (key1 integer, key2 integer)</code> → boolean	Obtains a shared session-level advisory lock if available. This will either obtain the lock immediately and return <code>true</code> , or return <code>false</code> without waiting if the lock cannot be acquired immediately.
<code>pg_try_advisory_xact_lock (key bigint)</code> → boolean <code>pg_try_advisory_xact_lock (key1 integer, key2 integer)</code> → boolean	Obtains an exclusive transaction-level advisory lock if available. This will either obtain the lock immediately and return <code>true</code> , or return <code>false</code> without waiting if the lock cannot be acquired immediately.
<code>pg_try_advisory_xact_lock_shared (key bigint)</code> → boolean <code>pg_try_advisory_xact_lock_shared (key1 integer, key2 integer)</code> → boolean	Obtains a shared transaction-level advisory lock if available. This will either obtain the lock immediately and return <code>true</code> , or return <code>false</code> without waiting if the lock cannot be acquired immediately.

## 9.28. Trigger Functions

While many uses of triggers involve user-written trigger functions, LightDB provides a few built-in trigger functions that can be used directly in user-defined triggers. These are summarized in Table 9.98. (Additional built-in trigger functions exist, which implement foreign key constraints and deferred index constraints. Those are not documented here since users need not use them directly.)

For more information about creating triggers, see `CREATE TRIGGER`.

**Table 9.98. Built-In Trigger Functions**

Function	Description	Example Usage
<code>suppress_redundant_updates_trigger()</code>	Suppresses do-nothing update operations. See below for details.	<code>CREATE TRIGGER ... suppress_redundant_updates_trigger()</code>
<code>tsvector_update_trigger()</code>	Automatically updates a <code>tsvector</code> column from associated plain-text document column(s). The text search configuration to use is specified by name as a trigger argument. See Section 12.4.3 for details.	<code>CREATE TRIGGER ... tsvector_update_trigger(tsvcol, 'pg_catalog.swedish', title, body)</code>
<code>tsvector_update_trigger_column()</code>	Automatically updates a <code>tsvector</code> column from associated plain-text document column(s). The text search configuration to use is taken from a <code>regconfig</code> column of the table. See Section 12.4.3 for details.	<code>CREATE TRIGGER ... tsvector_update_trigger_column(tsvcol, tsconfigcol, title, body)</code>

The `suppress_redundant_updates_trigger` function, when applied as a row-level `BEFORE UPDATE` trigger, will prevent any update that does not actually change the data in the row from taking place. This overrides the normal behavior which always performs a physical row update regardless of whether or not the data has changed. (This normal behavior makes updates run faster, since no checking is required, and is also useful in certain cases.)

Ideally, you should avoid running updates that don't actually change the data in the record. Redundant updates can cost considerable unnecessary time, especially if there are lots of indexes to alter, and space in dead rows that will eventually have to be vacuumed. However, detecting such situations in client code is not always easy, or even possible, and writing expressions to detect them can be error-prone. An alternative is to use `suppress_redundant_updates_trigger`, which will skip updates that don't change the data. You should use this with care, however. The trigger takes a small but non-trivial time for each record, so if most of the records affected by updates do actually change, use of this trigger will make updates run slower on average.

The `suppress_redundant_updates_trigger` function can be added to a table like this:

```
CREATE TRIGGER z_min_update
BEFORE UPDATE ON tablename
FOR EACH ROW EXECUTE FUNCTION suppress_redundant_updates_trigger();
```

In most cases, you need to fire this trigger last for each row, so that it does not override other triggers that might wish to alter the row. Bearing in mind that triggers fire in name order, you would therefore choose a trigger name that comes after the name of any other trigger you might have on the table. (Hence the “z” prefix in the example.)

## 9.29. Event Trigger Functions

LightDB provides these helper functions to retrieve information from event triggers.

For more information about event triggers, see Chapter 38.

### 9.29.1. Capturing Changes at Command End

`pg_event_trigger_ddl_commands () → setof record`

`pg_event_trigger_ddl_commands` returns a list of DDL commands executed by each user action, when invoked in a function attached to a `ddl_command_end` event trigger. If called in any other context, an error is raised. `pg_event_trigger_ddl_commands` returns one row for each base command executed; some commands that are a single SQL sentence may return more than one row. This function returns the following columns:

Name	Type	Description
<code>classid</code>	<code>oid</code>	OID of catalog the object belongs in
<code>objid</code>	<code>oid</code>	OID of the object itself
<code>objsubid</code>	<code>integer</code>	Sub-object ID (e.g., attribute number for a column)
<code>command_tag</code>	<code>text</code>	Command tag
<code>object_type</code>	<code>text</code>	Type of the object
<code>schema_name</code>	<code>text</code>	Name of the schema the object belongs in, if any; otherwise NULL. No quoting is applied.
<code>object_identity</code>	<code>text</code>	Text rendering of the object identity, schema-qualified. Each identifier included in the identity is quoted if necessary.
<code>in_extension</code>	<code>boolean</code>	True if the command is part of an extension script
<code>command</code>	<code>pg_ddl_command</code>	A complete representation of the command, in internal format. This cannot be output directly, but it can be passed to other functions to obtain different pieces of information about the command.

## 9.29.2. Processing Objects Dropped by a DDL Command

`pg_event_trigger_dropped_objects () → setof record`

`pg_event_trigger_dropped_objects` returns a list of all objects dropped by the command in whose `sql_drop` event it is called. If called in any other context, an error is raised. This function returns the following columns:

Name	Type	Description
<code>classid</code>	<code>oid</code>	OID of catalog the object belonged in
<code>objid</code>	<code>oid</code>	OID of the object itself
<code>objsubid</code>	<code>integer</code>	Sub-object ID (e.g., attribute number for a column)
<code>original</code>	<code>boolean</code>	True if this was one of the root object(s) of the deletion

Name	Type	Description
normal	boolean	True if there was a normal dependency relationship in the dependency graph leading to this object
is_temporary	boolean	True if this was a temporary object
object_type	text	Type of the object
schema_name	text	Name of the schema the object belonged in, if any; otherwise NULL. No quoting is applied.
object_name	text	Name of the object, if the combination of schema and name can be used as a unique identifier for the object; otherwise NULL. No quoting is applied, and name is never schema-qualified.
object_identity	text	Text rendering of the object identity, schema-qualified. Each identifier included in the identity is quoted if necessary.
address_names	text[]	An array that, together with object_type and address_args, can be used by the pg_get_object_address function to recreate the object address in a remote server containing an identically named object of the same kind.
address_args	text[]	Complement for address_names

The `pg_event_trigger_dropped_objects` function can be used in an event trigger like this:

```
CREATE FUNCTION test_event_trigger_for_drops()
    RETURNS event_trigger LANGUAGE plpgsql AS $$
DECLARE
    obj record;
BEGIN
    FOR obj IN SELECT * FROM pg_event_trigger_dropped_objects()
    LOOP
        RAISE NOTICE '% dropped object: % %.% %',
            tg_tag,
            obj.object_type,
            obj.schema_name,
            obj.object_name,
            obj.object_identity;
    END LOOP;
END;
$$;
CREATE EVENT TRIGGER test_event_trigger_for_drops
    ON sql_drop
```

```
EXECUTE FUNCTION test_event_trigger_for_drops();
```

### 9.29.3. Handling a Table Rewrite Event

The functions shown in Table 9.99 provide information about a table for which a `table_rewrite` event has just been called. If called in any other context, an error is raised.

**Table 9.99. Table Rewrite Information Functions**

Function	Description
<code>pg_event_trigger_table_rewrite_oid() → oid</code>	Returns the OID of the table about to be rewritten.
<code>pg_event_trigger_table_rewrite_reason() → integer</code>	Returns a code explaining the reason(s) for rewriting. The exact meaning of the codes is release dependent.

These functions can be used in an event trigger like this:

```
CREATE FUNCTION test_event_trigger_table_rewrite_oid()
  RETURNS event_trigger
  LANGUAGE plpgsql AS
$$
BEGIN
  RAISE NOTICE 'rewriting table % for reason %',
    pg_event_trigger_table_rewrite_oid()::regclass,
    pg_event_trigger_table_rewrite_reason();
END;
$$;

CREATE EVENT TRIGGER test_table_rewrite_oid
  ON table_rewrite
  EXECUTE FUNCTION test_event_trigger_table_rewrite_oid();
```

## 9.30. Statistics Information Functions

LightDB provides a function to inspect complex statistics defined using the `CREATE STATISTICS` command.

### 9.30.1. Inspecting MCV Lists

```
pg_mcv_list_items ( pg_mcv_list ) → setof record
```

`pg_mcv_list_items` returns a set of records describing all items stored in a multi-column MCV list. It returns the following columns:

Name	Type	Description
<code>index</code>	<code>integer</code>	index of the item in the MCV list
<code>values</code>	<code>text[]</code>	values stored in the MCV item
<code>nulls</code>	<code>boolean[]</code>	flags identifying NULL values
<code>frequency</code>	<code>double precision</code>	frequency of this MCV item

Name	Type	Description
base_frequency	double precision	base frequency of this MCV item

The `pg_mcv_list_items` function can be used like this:

```
SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
           pg_mcv_list_items(stxdmcv) m WHERE stxname =
'stts';
```

Values of the `pg_mcv_list` type can be obtained only from the `pg_statistic_ext_data.stxdmcv` column.



---

# Chapter 10. Type Conversion

SQL statements can, intentionally or not, require the mixing of different data types in the same expression. LightDB has extensive facilities for evaluating mixed-type expressions.

In many cases a user does not need to understand the details of the type conversion mechanism. However, implicit conversions done by LightDB can affect the results of a query. When necessary, these results can be tailored by using *explicit* type conversion.

This chapter introduces the LightDB type conversion mechanisms and conventions. Refer to the relevant sections in Chapter 8 and Chapter 9 for more information on specific data types and allowed functions and operators.

## 10.1. Overview

SQL is a strongly typed language. That is, every data item has an associated data type which determines its behavior and allowed usage. LightDB has an extensible type system that is more general and flexible than other SQL implementations. Hence, most type conversion behavior in LightDB is governed by general rules rather than by *ad hoc* heuristics. This allows the use of mixed-type expressions even with user-defined types.

The LightDB scanner/parser divides lexical elements into five fundamental categories: integers, non-integer numbers, strings, identifiers, and key words. Constants of most non-numeric types are first classified as strings. The SQL language definition allows specifying type names with strings, and this mechanism can be used in LightDB to start the parser down the correct path. For example, the query:

```
SELECT text 'Origin' AS "label", point '(0,0)' AS "value";
```

```
label | value
-----+-----
Origin | (0,0)
(1 row)
```

has two literal constants, of type `text` and `point`. If a type is not specified for a string literal, then the placeholder type `unknown` is assigned initially, to be resolved in later stages as described below.

There are four fundamental SQL constructs requiring distinct type conversion rules in the LightDB parser:

### Function calls

Much of the LightDB type system is built around a rich set of functions. Functions can have one or more arguments. Since LightDB permits function overloading, the function name alone does not uniquely identify the function to be called; the parser must select the right function based on the data types of the supplied arguments.

### Operators

LightDB allows expressions with prefix and postfix unary (one-argument) operators, as well as binary (two-argument) operators. Like functions, operators can be overloaded, so the same problem of selecting the right operator exists.

### Value Storage

SQL `INSERT` and `UPDATE` statements place the results of expressions into a table. The expressions in the statement must be matched up with, and perhaps converted to, the types of the target columns.

## UNION, CASE, and related constructs

Since all query results from a unionized `SELECT` statement must appear in a single set of columns, the types of the results of each `SELECT` clause must be matched up and converted to a uniform set. Similarly, the result expressions of a `CASE` construct must be converted to a common type so that the `CASE` expression as a whole has a known output type. Some other constructs, such as `ARRAY[ ]` and the `GREATEST` and `LEAST` functions, likewise require determination of a common type for several subexpressions.

The system catalogs store information about which conversions, or *casts*, exist between which data types, and how to perform those conversions. Additional casts can be added by the user with the `CREATE CAST` command. (This is usually done in conjunction with defining new data types. The set of casts between built-in types has been carefully crafted and is best not altered.)

An additional heuristic provided by the parser allows improved determination of the proper casting behavior among groups of types that have implicit casts. Data types are divided into several basic *type categories*, including `boolean`, `numeric`, `string`, `bitstring`, `datetime`, `timespan`, `geometric`, `network`, and `user-defined`. (For a list see Table 48.71; but note it is also possible to create custom type categories.) Within each category there can be one or more *preferred types*, which are preferred when there is a choice of possible types. With careful selection of preferred types and available implicit casts, it is possible to ensure that ambiguous expressions (those with multiple candidate parsing solutions) can be resolved in a useful way.

All type conversion rules are designed with several principles in mind:

- Implicit conversions should never have surprising or unpredictable outcomes.
- There should be no extra overhead in the parser or executor if a query does not need implicit type conversion. That is, if a query is well-formed and the types already match, then the query should execute without spending extra time in the parser and without introducing unnecessary implicit conversion calls in the query.
- Additionally, if a query usually requires an implicit conversion for a function, and if then the user defines a new function with the correct argument types, the parser should use this new function and no longer do implicit conversion to use the old function.

## 10.2. Operators

The specific operator that is referenced by an operator expression is determined using the following procedure. Note that this procedure is indirectly affected by the precedence of the operators involved, since that will determine which sub-expressions are taken to be the inputs of which operators. See Section 4.1.6 for more information.

### Operator Type Resolution

1. Select the operators to be considered from the `pg_operator` system catalog. If a non-schema-qualified operator name was used (the usual case), the operators considered are those with the matching name and argument count that are visible in the current search path (see Section 5.9.3). If a qualified operator name was given, only operators in the specified schema are considered.
  - (Optional) If the search path finds multiple operators with identical argument types, only the one appearing earliest in the path is considered. Operators with different argument types are considered on an equal footing regardless of search path position.
2. Check for an operator accepting exactly the input argument types. If one exists (there can be only one exact match in the set of operators considered), use it. Lack of an exact match creates a security hazard when calling, via qualified name<sup>1</sup> (not typical), any operator found in a schema

---

<sup>1</sup> The hazard does not arise with a non-schema-qualified name, because a search path containing schemas that permit untrusted users to create objects is not a secure schema usage pattern.

that permits untrusted users to create objects. In such situations, cast arguments to force an exact match.

- a. (Optional) In Oracle or MySQL compatible type (see `lightdb_syntax_compatible_type`), if one argument of a binary operator invocation is of the `unknown` type, and another is number type (`int2`, `int4`, `int8`, `float4`, `float8`), then assume the `unknown` type is `text` type. If there is an operator accepting exactly match the `text` type and number type, use it.
  - b. (Optional) If one argument of a binary operator invocation is of the `unknown` type, then assume it is the same type as the other argument for this check. Invocations involving two `unknown` inputs, or a unary operator with an `unknown` input, will never find a match at this step.
  - c. (Optional) If one argument of a binary operator invocation is of the `unknown` type and the other is of a domain type, next check to see if there is an operator accepting exactly the domain's base type on both sides; if so, use it.
3. Look for the best match.
- a. Discard candidate operators for which the input types do not match and cannot be converted (using an implicit conversion) to match. `unknown` literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.
  - b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-operator resolution.
  - c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.
  - d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.
  - e. If any input arguments are `unknown`, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an `unknown`-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.
  - f. If there are both `unknown` and known-type arguments, and all the known-type arguments have the same type, assume that the `unknown` arguments are also of that type, and check which candidates can accept that type at the `unknown`-argument positions. If exactly one candidate passes this test, use it; else continue to the next step.
  - g. Try type compatible match describe at Section 10.7.

Some examples follow.

### **Example 10.1. Square Root Operator Type Resolution**

There is only one square root operator (prefix `|/`) defined in the standard catalog, and it takes an argument of type `double precision`. The scanner assigns an initial type of `integer` to the argument in this query expression:

```
SELECT |/ 40 AS "square root of 40";
   square root of 40
-----
   6.324555320336759
(1 row)
```

So the parser does a type conversion on the operand and the query is equivalent to:

```
SELECT |/ CAST(40 AS double precision) AS "square root of 40";
```

### Example 10.2. String Concatenation Operator Type Resolution

A string-like syntax is used for working with string types and for working with complex extension types. Strings with unspecified type are matched with likely operator candidates.

An example with one unspecified argument:

```
SELECT text 'abc' || 'def' AS "text and unknown";

   text and unknown
-----
   abcdef
(1 row)
```

In this case the parser looks to see if there is an operator taking `text` for both arguments. Since there is, it assumes that the second argument should be interpreted as type `text`.

Here is a concatenation of two values of unspecified types:

```
SELECT 'abc' || 'def' AS "unspecified";

   unspecified
-----
   abcdef
(1 row)
```

In this case there is no initial hint for which type to use, since no types are specified in the query. So, the parser looks for all candidate operators and finds that there are candidates accepting both string-category and bit-string-category inputs. Since string category is preferred when available, that category is selected, and then the preferred type for strings, `text`, is used as the specific type to resolve the unknown-type literals as.

### Example 10.3. Absolute-Value and Negation Operator Type Resolution

The LightDB operator catalog has several entries for the prefix operator `@`, all of which implement absolute-value operations for various numeric data types. One of these entries is for type `float8`, which is the preferred type in the numeric category. Therefore, LightDB will use that entry when faced with an unknown input:

```
SELECT @ '-4.5' AS "abs";
   abs
-----
   4.5
(1 row)
```

Here the system has implicitly resolved the unknown-type literal as type `float8` before applying the chosen operator. We can verify that `float8` and not some other type was used:

```
SELECT @ '-4.5e500' AS "abs";

ERROR:  "-4.5e500" is out of range for type double precision
```

#### Example 10.4. Array Inclusion Operator Type Resolution

Here is another example of resolving an operator with one known and one unknown input:

```
SELECT array[1,2] <@ '{1,2,3}' as "is subset";

 is subset
-----
 t
(1 row)
```

The LightDB operator catalog has several entries for the infix operator `<@`, but the only two that could possibly accept an integer array on the left-hand side are array inclusion (`anyarray <@ anyarray`) and range inclusion (`anyelement <@ anyrange`). Since none of these polymorphic pseudo-types (see Section 8.21) are considered preferred, the parser cannot resolve the ambiguity on that basis. However, Step 3.f tells it to assume that the unknown-type literal is of the same type as the other input, that is, integer array. Now only one of the two operators can match, so array inclusion is selected. (Had range inclusion been selected, we would have gotten an error, because the string does not have the right format to be a range literal.)

#### Example 10.5. Custom Operator on a Domain Type

Users sometimes try to declare operators applying just to a domain type. This is possible but is not nearly as useful as it might seem, because the operator resolution rules are designed to select operators applying to the domain's base type. As an example consider

```
CREATE DOMAIN mytext AS text CHECK(...);
CREATE FUNCTION mytext_eq_text (mytext, text) RETURNS boolean
AS ...;
CREATE OPERATOR = (procedure=mytext_eq_text, leftarg=mytext,
rightarg=text);
CREATE TABLE mytable (val mytext);

SELECT * FROM mytable WHERE val = 'foo';
```

This query will not use the custom operator. The parser will first see if there is a `mytext = mytext` operator (Step 2.b), which there is not; then it will consider the domain's base type `text`, and see if there is a `text = text` operator (Step 2.c), which there is; so it resolves the unknown-type literal as `text` and uses the `text = text` operator. The only way to get the custom operator to be used is to explicitly cast the literal:

```
SELECT * FROM mytable WHERE val = text 'foo';
```

so that the `mytext = text` operator is found immediately according to the exact-match rule. If the best-match rules are reached, they actively discriminate against operators on domain types. If they did not, such an operator would create too many ambiguous-operator failures, because the casting rules always consider a domain as castable to or from its base type, and so the domain operator would be considered usable in all the same cases as a similarly-named operator on the base type.

## 10.3. Functions

The specific function that is referenced by a function call is determined using the following procedure.

### Function Type Resolution

1. Select the functions to be considered from the `pg_proc` system catalog. If a non-schema-qualified function name was used, the functions considered are those with the matching name and argument count that are visible in the current search path (see Section 5.9.3). If a qualified function name was given, only functions in the specified schema are considered.
  - a. (Optional) If the search path finds multiple functions of identical argument types, only the one appearing earliest in the path is considered. Functions of different argument types are considered on an equal footing regardless of search path position.
  - b. (Optional) If a function is declared with a `VARIADIC` array parameter, and the call does not use the `VARIADIC` keyword, then the function is treated as if the array parameter were replaced by one or more occurrences of its element type, as needed to match the call. After such expansion the function might have effective argument types identical to some non-variadic function. In that case the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

This creates a security hazard when calling, via qualified name<sup>2</sup>, a variadic function found in a schema that permits untrusted users to create objects. A malicious user can take control and execute arbitrary SQL functions as though you executed them. Substitute a call bearing the `VARIADIC` keyword, which bypasses this hazard. Calls populating `VARIADIC` "any" parameters often have no equivalent formulation containing the `VARIADIC` keyword. To issue those calls safely, the function's schema must permit only trusted users to create objects.

- c. (Optional) Functions that have default values for parameters are considered to match any call that omits zero or more of the defaultable parameter positions. If more than one such function matches a call, the one appearing earliest in the search path is used. If there are two or more such functions in the same schema with identical parameter types in the non-defaulted positions (which is possible if they have different sets of defaultable parameters), the system will not be able to determine which to prefer, and so an "ambiguous function call" error will result if no better match to the call can be found.

This creates an availability hazard when calling, via qualified name<sup>2</sup>, any function found in a schema that permits untrusted users to create objects. A malicious user can create a function with the name of an existing function, replicating that function's parameters and appending novel parameters having default values. This precludes new calls to the original function. To forestall this hazard, place functions in schemas that permit only trusted users to create objects.

2. Check for a function accepting exactly the input argument types. If one exists (there can be only one exact match in the set of functions considered), use it. Lack of an exact match creates a security hazard when calling, via qualified name<sup>2</sup>, a function found in a schema that permits untrusted users to create objects. In such situations, cast arguments to force an exact match. (Cases involving unknown will never find a match at this step.)
3. If no exact match is found, see if the function call appears to be a special type conversion request. This happens if the function call has just one argument and the function name is the same as the (internal) name of some data type. Furthermore, the function argument must be either an unknown-type literal, or a type that is binary-coercible to the named data type, or a type that could be converted to the named data type by applying that type's I/O functions (that is, the conversion

<sup>2</sup> The hazard does not arise with a non-schema-qualified name, because a search path containing schemas that permit untrusted users to create objects is not a secure schema usage pattern.

is either to or from one of the standard string types). When these conditions are met, the function call is treated as a form of `CAST` specification.<sup>3</sup>

4. Look for the best match.
  - a. Discard candidate functions for which the input types do not match and cannot be converted (using an implicit conversion) to match. `unknown` literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.
  - b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-function resolution.
  - c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.
  - d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.
  - e. If any input arguments are `unknown`, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an `unknown`-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.
  - f. If there are both `unknown` and known-type arguments, and all the known-type arguments have the same type, assume that the `unknown` arguments are also of that type, and check which candidates can accept that type at the `unknown`-argument positions. If exactly one candidate passes this test, use it; else continue to the next step.
  - g. Try type compatible match describe at Section 10.7.

Note that the “best match” rules are identical for operator and function type resolution. Some examples follow.

### Example 10.6. Rounding Function Argument Type Resolution

There is only one `round` function that takes two arguments; it takes a first argument of type `numeric` and a second argument of type `integer`. So the following query automatically converts the first argument of type `integer` to `numeric`:

```
SELECT round(4, 4);
```

```
round
-----
4.0000
(1 row)
```

That query is actually transformed by the parser to:

<sup>3</sup> The reason for this step is to support function-style cast specifications in cases where there is not an actual cast function. If there is a cast function, it is conventionally named after its output type, and so there is no need to have a special case. See `CREATE CAST` for additional commentary.

```
SELECT round(CAST (4 AS numeric), 4);
```

Since numeric constants with decimal points are initially assigned the type `numeric`, the following query will require no type conversion and therefore might be slightly more efficient:

```
SELECT round(4.0, 4);
```

### Example 10.7. Variadic Function Resolution

```
CREATE FUNCTION public.variadic_example(VARIADIC numeric[]) RETURNS
  int
  LANGUAGE sql AS 'SELECT 1';
CREATE FUNCTION
```

This function accepts, but does not require, the `VARIADIC` keyword. It tolerates both integer and numeric arguments:

```
SELECT public.variadic_example(0),
       public.variadic_example(0.0),
       public.variadic_example(VARIADIC array[0.0]);
 variadic_example | variadic_example | variadic_example
-----+-----+-----
                1 |                  1 |                  1
(1 row)
```

However, the first and second calls will prefer more-specific functions, if available:

```
CREATE FUNCTION public.variadic_example(numeric) RETURNS int
  LANGUAGE sql AS 'SELECT 2';
CREATE FUNCTION

CREATE FUNCTION public.variadic_example(int) RETURNS int
  LANGUAGE sql AS 'SELECT 3';
CREATE FUNCTION

SELECT public.variadic_example(0),
       public.variadic_example(0.0),
       public.variadic_example(VARIADIC array[0.0]);
 variadic_example | variadic_example | variadic_example
-----+-----+-----
                3 |                  2 |                  1
(1 row)
```

Given the default configuration and only the first function existing, the first and second calls are insecure. Any user could intercept them by creating the second or third function. By matching the argument type exactly and using the `VARIADIC` keyword, the third call is secure.

### Example 10.8. Substring Function Type Resolution

There are several `substr` functions, one of which takes types `text` and `integer`. If called with a string constant of unspecified type, the system chooses the candidate function that accepts an argument of the preferred category `string` (namely of type `text`).

```
SELECT substr('1234', 3);
```



```

substr
-----
      34
(1 row)

```

If the string is declared to be of type `varchar`, as might be the case if it comes from a table, then the parser will try to convert it to become `text`:

```
SELECT substr(vvarchar '1234', 3);
```

```

substr
-----
      34
(1 row)

```

This is transformed by the parser to effectively become:

```
SELECT substr(CAST (varchar '1234' AS text), 3);
```

### Note

The parser learns from the `pg_cast` catalog that `text` and `varchar` are binary-compatible, meaning that one can be passed to a function that accepts the other without doing any physical conversion. Therefore, no type conversion call is really inserted in this case.

### Example 10.9. Add Months Function Type Resolution

The Oracle extension provides two versions of function `add_months`, one under schema `pg_catalog` and the other under schema `oracle`.

There are some slight differences between the two functions: `pg_catalog.add_months` accepts `date` and `int`, returns `date`; `oracle.add_months` accepts `timestamp with time zone` and `int`, returns `timestamp`.

```
CREATE FUNCTION pg_catalog.add_months(day date, value int)
RETURNS date ...
```

```
select pg_catalog.add_months('2021-12-23', 4);
 add_months
-----
 2022-04-23
(1 row)
```

```
CREATE FUNCTION oracle.add_months(TIMESTAMP WITH TIME ZONE, INTEGER)
RETURNS TIMESTAMP ...
```

```
select oracle.add_months('2021-12-23', 4);
 add_months
-----
 2022-04-23 00:00:00
(1 row)
```

When the `add_months` function is called with the unknown type, different functions are matched depending on the `search_path`.

When schema `oracle` is not in `search_path`, it only looks for `add_months` in schema `pg_catalog` by default.

When schema `oracle` is in `search_path`, there are two versions of `add_months` functions available. However, the `oracle.add_months` argument type `timestamp with time zone` is preferred type, so `oracle.add_months` will be selected.

```
select add_months('2021-12-23', 4);
 add_months
-----
 2022-04-23
(1 row)

set search_path="$user",public,oracle;

select add_months('2021-12-23', 4);
 add_months
-----
 2022-04-23 00:00:00
(1 row)
```

## 10.4. Value Storage

Values to be inserted into a table are converted to the destination column's data type according to the following steps.

### Value Storage Type Conversion

1. Check for an exact match with the target.
2. Otherwise, try to convert the expression to the target type. This is possible if an *assignment cast* between the two types is registered in the `pg_cast` catalog (see `CREATE CAST`). Alternatively, if the expression is an unknown-type literal, the contents of the literal string will be fed to the input conversion routine for the target type.
3. Check to see if there is a sizing cast for the target type. A sizing cast is a cast from that type to itself. If one is found in the `pg_cast` catalog, apply it to the expression before storing into the destination column. The implementation function for such a cast always takes an extra parameter of type `integer`, which receives the destination column's `atttypmod` value (typically its declared length, although the interpretation of `atttypmod` varies for different data types), and it may take a third `boolean` parameter that says whether the cast is explicit or implicit. The cast function is responsible for applying any length-dependent semantics such as size checking or truncation.

### Example 10.10. character Storage Type Conversion

For a target column declared as `character(20)` the following statement shows that the stored value is sized correctly:

```
CREATE TABLE vv (v character(20));
INSERT INTO vv SELECT 'abc' || 'def';
SELECT v, octet_length(v) FROM vv;
```

v	octet_length
abcdef	20

(1 row)

What has really happened here is that the two unknown literals are resolved to `text` by default, allowing the `||` operator to be resolved as `text` concatenation. Then the `text` result of the operator is converted to `bpchar` (“blank-padded char”, the internal name of the character data type) to match the target column type. (Since the conversion from `text` to `bpchar` is binary-coercible, this conversion does not insert any real function call.) Finally, the sizing function `bpchar(bpchar, integer, boolean)` is found in the system catalog and applied to the operator's result and the stored column length. This type-specific function performs the required length check and addition of padding spaces.

## 10.5. UNION, CASE, and Related Constructs

SQL `UNION` constructs must match up possibly dissimilar types to become a single result set. The resolution algorithm is applied separately to each output column of a union query. The `INTERSECT` and `EXCEPT` constructs resolve dissimilar types in the same way as `UNION`. Some other constructs, including `CASE`, `ARRAY`, `VALUES`, and the `GREATEST` and `LEAST` functions, use the identical algorithm to match up their component expressions and select a result data type.

### Type Resolution for UNION, CASE, and Related Constructs

1. If all inputs are of the same type, and it is not unknown, resolve as that type.
2. If any input is of a domain type, treat it as being of the domain's base type for all subsequent steps.<sup>4</sup>
3. If all inputs are of type `unknown`, resolve as type `text` (the preferred type of the string category). Otherwise, unknown inputs are ignored for the purposes of the remaining rules.
4. If the non-unknown inputs are not all of the same type category, fail.
5. Select the first non-unknown input type as the candidate type, then consider each other non-unknown input type, left to right.<sup>5</sup> If the candidate type can be implicitly converted to the other type, but not vice-versa, select the other type as the new candidate type. Then continue considering the remaining inputs. If, at any stage of this process, a preferred type is selected, stop considering additional inputs.
6. Convert all inputs to the final candidate type. Fail if there is not an implicit conversion from a given input type to the candidate type.

Some examples follow.

#### Example 10.11. Type Resolution with Underspecified Types in a Union

```
SELECT text 'a' AS "text" UNION SELECT 'b';
```

```
text
-----
a
b
```

<sup>4</sup> Somewhat like the treatment of domain inputs for operators and functions, this behavior allows a domain type to be preserved through a `UNION` or similar construct, so long as the user is careful to ensure that all inputs are implicitly or explicitly of that exact type. Otherwise the domain's base type will be used.

<sup>5</sup> For historical reasons, `CASE` treats its `ELSE` clause (if any) as the “first” input, with the `THEN` clauses(s) considered after that. In all other cases, “left to right” means the order in which the expressions appear in the query text.

(2 rows)

Here, the unknown-type literal 'b' will be resolved to type text.

### Example 10.12. Type Resolution in a Simple Union

```
SELECT 1.2 AS "numeric" UNION SELECT 1;
```

```
numeric
-----
      1
     1.2
(2 rows)
```

The literal 1.2 is of type numeric, and the integer value 1 can be cast implicitly to numeric, so that type is used.

### Example 10.13. Type Resolution in a Transposed Union

```
SELECT 1 AS "real" UNION SELECT CAST('2.2' AS REAL);
```

```
real
-----
      1
     2.2
(2 rows)
```

Here, since type real cannot be implicitly cast to integer, but integer can be implicitly cast to real, the union result type is resolved as real.

### Example 10.14. Type Resolution in a Nested Union

```
SELECT NULL UNION SELECT NULL UNION SELECT 1;
```

```
ERROR:  UNION types text and integer cannot be matched
```

This failure occurs because LightDB treats multiple UNIONS as a nest of pairwise operations; that is, this input is the same as

```
(SELECT NULL UNION SELECT NULL) UNION SELECT 1;
```

The inner UNION is resolved as emitting type text, according to the rules given above. Then the outer UNION has inputs of types text and integer, leading to the observed error. The problem can be fixed by ensuring that the leftmost UNION has at least one input of the desired result type.

INTERSECT and EXCEPT operations are likewise resolved pairwise. However, the other constructs described in this section consider all of their inputs in one resolution step.

## 10.6. SELECT Output Columns

The rules given in the preceding sections will result in assignment of non-unknown data types to all expressions in a SQL query, except for unspecified-type literals that appear as simple output columns of a SELECT command. For example, in

```
SELECT 'Hello World';
```

there is nothing to identify what type the string literal should be taken as. In this situation LightDB will fall back to resolving the literal's type as `text`.

When the `SELECT` is one arm of a `UNION` (or `INTERSECT` or `EXCEPT`) construct, or when it appears within `INSERT ... SELECT`, this rule is not applied since rules given in preceding sections take precedence. The type of an unspecified-type literal can be taken from the other `UNION` arm in the first case, or from the destination column in the second case.

`RETURNING` lists are treated the same as `SELECT` output lists for this purpose.

## 10.7. Type Compatibility

LightDB supports special compatibility between string and numeric types. When implicit casting rules cannot find suitable operators or functions((Section 10.2,Section 10.3)), explicit type casts will be applied automatically and type priority will be applied to select the appropriate operator or function.

This special compatibility feature for 9 types with priority by default. Consider each of these types supports implicit casts to the other.

Here are the default 9 types(in descending order of priority):

```
numeric > double precision > real > bigint > integer > smallint >
text > varchar > char
```

You can use `ALTER TYPE` to modify or add priority of type, built-in type is cannot modify, see `ALTER TYPE`.

### Note

The value of priority must be positive.

### Example 10.15. Alter or add type priority

```
ALTER TYPE varchar2 set (priority=200)
```

### Type Resolution for Compatibility

1. Execute the following flow after the rules described in Section 10.2 and Section 10.3.
2. Ignore all candidates have Pseudo-Types argument.
3. All unknown-type will be considered as `text` type.
4. Run through all candidates and keep those with the least explicit cast on input types. If only one candidate remains, use it; else keep all the remaining candidates and continue to the next step.
5. Run through all remain candidates, if all the explicit cast positions have the same argument type, the candidate's priority will be the same as the argument type's priority. If candidate's explicit cast positions have more than one argument type, the priority will be lower than all types. In operator, if one argument is number and another is string, the number type's priority will be higher than all types.
6. Run through all remaining candidates, keep those at the most positions where is exact match. If only one candidate remains, then use it; else continue to the next step.

- Run through all remaining candidates, compare candidate's argument type priority at the same position from left to right, keep the candidate that have the highest priority.

### Example 10.16. Automatically Apply Explicit Cast

```
select |/'20'::text;

      ?column?
-----
 4.47213595499958
(1 row)
```

In this example, the type `text` cannot be implicitly cast to `double precision`, but by the type compatible rules, explicit cast can be applied automatically between number and string types.

### Example 10.17. Type priority

```
select ~ '20';

      ?column?
-----
      -21
(1 row)
```

In this example, the input type is `unknown-type`, so consider the input type as `text`, and select the candidate has the highest priority argument, and use `~ bigint`.

If input value cannot convert to `bigint`, a type convert error will be reported.

```
select ~ 'a';

ERROR:  invalid input syntax for type bigint: "a"
LINE 1: select ~ 'a';
```

### Example 10.18. Substring Function Type Resolution

If `substr` function is called with an argument of type `integer`, LightDB will try to convert that to `text`:

```
SELECT substr(1234, 3);
 substr
-----
     34
(1 row)
```

### Example 10.19. Argument List Priority

```
create function testfun(text,integer)
  returns text as $$ select 'text,integer' $$ language sql;

create function testfun(integer,text)
  returns text as $$ select 'integer,text' $$ language sql;

select testfun('1'::text, '1'::text);
```

None of them are more suitable, so compare argument priority from left to right. Now the first argument is integer and text, integer is higher than text, use `testfun(integer, text)`.

### Example 10.20. Insert and Update

```
create table tb(name varchar, age int);

insert into tb(name,age) values(1223, '23'::varchar);
INSERT 0 1

update tb set name=1343,age='24'::text;
UPDATE 1

select * from tb;
 name | age
-----+-----
 1343 |  24
(1 row)
```

Column type and value type is not matched and LightDB does not have implicit cast rule between value type and column type by default. But by the compatible rules, LightDB can use explicit cast rule on it.

#### Note

Type compatible works with operators, functions, insert and update. Does not work in SELECT UNION, CASE(Section 10.5).

---

# Chapter 11. Indexes

Indexes are a common way to enhance database performance. An index allows the database server to find and retrieve specific rows much faster than it could do without an index. But indexes also add overhead to the database system as a whole, so they should be used sensibly.

## 11.1. Introduction

Suppose we have a table similar to this:

```
CREATE TABLE test1 (  
    id integer,  
    content varchar  
);
```

and the application issues many queries of the form:

```
SELECT content FROM test1 WHERE id = constant;
```

With no advance preparation, the system would have to scan the entire `test1` table, row by row, to find all matching entries. If there are many rows in `test1` and only a few rows (perhaps zero or one) that would be returned by such a query, this is clearly an inefficient method. But if the system has been instructed to maintain an index on the `id` column, it can use a more efficient method for locating matching rows. For instance, it might only have to walk a few levels deep into a search tree.

A similar approach is used in most non-fiction books: terms and concepts that are frequently looked up by readers are collected in an alphabetic index at the end of the book. The interested reader can scan the index relatively quickly and flip to the appropriate page(s), rather than having to read the entire book to find the material of interest. Just as it is the task of the author to anticipate the items that readers are likely to look up, it is the task of the database programmer to foresee which indexes will be useful.

The following command can be used to create an index on the `id` column, as discussed:

```
CREATE INDEX test1_id_index ON test1 (id);
```

The name `test1_id_index` can be chosen freely, but you should pick something that enables you to remember later what the index was for.

To remove an index, use the `DROP INDEX` command. Indexes can be added to and removed from tables at any time.

Once an index is created, no further intervention is required: the system will update the index when the table is modified, and it will use the index in queries when it thinks doing so would be more efficient than a sequential table scan. But you might have to run the `ANALYZE` command regularly to update statistics to allow the query planner to make educated decisions. See Chapter 14 for information about how to find out whether an index is used and when and why the planner might choose *not* to use an index.

Indexes can also benefit `UPDATE` and `DELETE` commands with search conditions. Indexes can moreover be used in join searches. Thus, an index defined on a column that is part of a join condition can also significantly speed up queries with joins.

Creating an index on a large table can take a long time. By default, LightDB allows reads (`SELECT` statements) to occur on the table in parallel with index creation, but writes (`INSERT`, `UPDATE`, `DELETE`) are blocked until the index build is finished. In production environments this is often



unacceptable. It is possible to allow writes to occur in parallel with index creation, but there are several caveats to be aware of — for more information see [Building Indexes Concurrently](#).

After an index is created, the system has to keep it synchronized with the table. This adds overhead to data manipulation operations. Therefore indexes that are seldom or never used in queries should be removed.

## 11.2. Index Types

LightDB provides several index types: B-tree, Hash, GiST and GIN. Each index type uses a different algorithm that is best suited to different types of queries. By default, the `CREATE INDEX` command creates B-tree indexes, which fit the most common situations.

B-trees can handle equality and range queries on data that can be sorted into some ordering. In particular, the LightDB query planner will consider using a B-tree index whenever an indexed column is involved in a comparison using one of these operators:

```
<
<=
=
>=
>
```

Constructs equivalent to combinations of these operators, such as `BETWEEN` and `IN`, can also be implemented with a B-tree index search. Also, an `IS NULL` or `IS NOT NULL` condition on an index column can be used with a B-tree index.

The optimizer can also use a B-tree index for queries involving the pattern matching operators `LIKE` and `~` if the pattern is a constant and is anchored to the beginning of the string — for example, `col LIKE 'foo%'` or `col ~ '^foo'`, but not `col LIKE '%bar'`. However, if your database does not use the C locale you will need to create the index with a special operator class to support indexing of pattern-matching queries; see Section 11.10 below. It is also possible to use B-tree indexes for `ILIKE` and `~*`, but only if the pattern starts with non-alphabetic characters, i.e., characters that are not affected by upper/lower case conversion.

B-tree indexes can also be used to retrieve data in sorted order. This is not always faster than a simple scan and sort, but it is often helpful.

Hash indexes can only handle simple equality comparisons. The query planner will consider using a hash index whenever an indexed column is involved in a comparison using the `=` operator. The following command is used to create a hash index:

```
CREATE INDEX name ON table USING HASH (column);
```

GiST indexes are not a single kind of index, but rather an infrastructure within which many different indexing strategies can be implemented. Accordingly, the particular operators with which a GiST index can be used vary depending on the indexing strategy (the *operator class*). As an example, the standard distribution of LightDB includes GiST operator classes for several two-dimensional geometric data types, which support indexed queries using these operators:

```
<<
&<
&>
>>
<< |
&< |
| &>
| >>
```

```
@>
<@
~=
&&
```

(See Section 9.11 for the meaning of these operators.) The GiST operator classes included in the standard distribution are documented in Table 61.1. Many other GiST operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 61.

GIN indexes are “inverted indexes” which are appropriate for data values that contain multiple component values, such as arrays. An inverted index contains a separate entry for each component value, and can efficiently handle queries that test for the presence of specific component values.

GIN can support many different user-defined indexing strategies, and the particular operators with which a GIN index can be used vary depending on the indexing strategy. As an example, the standard distribution of LightDB includes a GIN operator class for arrays, which supports indexed queries using these operators:

```
<@
@>
=
&&
```

(See Section 9.19 for the meaning of these operators.) The GIN operator classes included in the standard distribution are documented in Table 62.1. Many other GIN operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 62.

## 11.3. Multicolumn Indexes

An index can be defined on more than one column of a table. For example, if you have a table of this form:

```
CREATE TABLE test2 (
    major int,
    minor int,
    name varchar
);
```

(say, you keep your `/dev` directory in a database...) and you frequently issue queries like:

```
SELECT name FROM test2 WHERE major = constant AND minor = constant;
```

then it might be appropriate to define an index on the columns `major` and `minor` together, e.g.:

```
CREATE INDEX test2_mm_idx ON test2 (major, minor);
```

Currently, only the B-tree, GiST and GIN index types support multicolumn indexes. Up to 32 columns can be specified. (This limit can be altered when building LightDB; see the file `pg_config_manual.h`.)

A multicolumn B-tree index can be used with query conditions that involve any subset of the index's columns, but the index is most efficient when there are constraints on the leading (leftmost) columns. The exact rule is that equality constraints on leading columns, plus any inequality constraints on the first column that does not have an equality constraint, will be used to limit the portion of the index that is scanned. Constraints on columns to the right of these columns are checked in the index, so they save visits to the table proper, but they do not reduce the portion of the index that has to be scanned. For example, given an index on `(a, b, c)` and a query condition `WHERE a = 5 AND b >=`

42 AND  $c < 77$ , the index would have to be scanned from the first entry with  $a = 5$  and  $b = 42$  up through the last entry with  $a = 5$ . Index entries with  $c \geq 77$  would be skipped, but they'd still have to be scanned through. This index could in principle be used for queries that have constraints on  $b$  and/or  $c$  with no constraint on  $a$  — but the entire index would have to be scanned, so in most cases the planner would prefer a sequential table scan over using the index.

A multicolumn GiST index can be used with query conditions that involve any subset of the index's columns. Conditions on additional columns restrict the entries returned by the index, but the condition on the first column is the most important one for determining how much of the index needs to be scanned. A GiST index will be relatively ineffective if its first column has only a few distinct values, even if there are many distinct values in additional columns.

A multicolumn GIN index can be used with query conditions that involve any subset of the index's columns. Unlike B-tree or GiST, index search effectiveness is the same regardless of which index column(s) the query conditions use.

Of course, each column must be used with operators appropriate to the index type; clauses that involve other operators will not be considered.

Multicolumn indexes should be used sparingly. In most situations, an index on a single column is sufficient and saves space and time. Indexes with more than three columns are unlikely to be helpful unless the usage of the table is extremely stylized. See also Section 11.5 and Section 11.9 for some discussion of the merits of different index configurations.

## 11.4. Indexes and ORDER BY

In addition to simply finding the rows to be returned by a query, an index may be able to deliver them in a specific sorted order. This allows a query's ORDER BY specification to be honored without a separate sorting step. Of the index types currently supported by LightDB, only B-tree can produce sorted output — the other index types return matching rows in an unspecified, implementation-dependent order.

The planner will consider satisfying an ORDER BY specification either by scanning an available index that matches the specification, or by scanning the table in physical order and doing an explicit sort. For a query that requires scanning a large fraction of the table, an explicit sort is likely to be faster than using an index because it requires less disk I/O due to following a sequential access pattern. Indexes are more useful when only a few rows need be fetched. An important special case is ORDER BY in combination with LIMIT  $n$ : an explicit sort will have to process all the data to identify the first  $n$  rows, but if there is an index matching the ORDER BY, the first  $n$  rows can be retrieved directly, without scanning the remainder at all.

By default, B-tree indexes store their entries in ascending order with nulls last (table TID is treated as a tiebreaker column among otherwise equal entries). This means that a forward scan of an index on column  $x$  produces output satisfying ORDER BY  $x$  (or more verbosely, ORDER BY  $x$  ASC NULLS LAST). The index can also be scanned backward, producing output satisfying ORDER BY  $x$  DESC (or more verbosely, ORDER BY  $x$  DESC NULLS FIRST, since NULLS FIRST is the default for ORDER BY DESC).

You can adjust the ordering of a B-tree index by including the options ASC, DESC, NULLS FIRST, and/or NULLS LAST when creating the index; for example:

```
CREATE INDEX test2_info_nulls_low ON test2 (info NULLS FIRST);
CREATE INDEX test3_desc_index ON test3 (id DESC NULLS LAST);
```

An index stored in ascending order with nulls first can satisfy either ORDER BY  $x$  ASC NULLS FIRST or ORDER BY  $x$  DESC NULLS LAST depending on which direction it is scanned in.

You might wonder why bother providing all four options, when two options together with the possibility of backward scan would cover all the variants of ORDER BY. In single-column indexes the

options are indeed redundant, but in multicolumn indexes they can be useful. Consider a two-column index on  $(x, y)$ : this can satisfy `ORDER BY x, y` if we scan forward, or `ORDER BY x DESC, y DESC` if we scan backward. But it might be that the application frequently needs to use `ORDER BY x ASC, y DESC`. There is no way to get that ordering from a plain index, but it is possible if the index is defined as  $(x \text{ ASC}, y \text{ DESC})$  or  $(x \text{ DESC}, y \text{ ASC})$ .

Obviously, indexes with non-default sort orderings are a fairly specialized feature, but sometimes they can produce tremendous speedups for certain queries. Whether it's worth maintaining such an index depends on how often you use queries that require a special sort ordering.

## 11.5. Combining Multiple Indexes

A single index scan can only use query clauses that use the index's columns with operators of its operator class and are joined with `AND`. For example, given an index on  $(a, b)$  a query condition like `WHERE a = 5 AND b = 6` could use the index, but a query like `WHERE a = 5 OR b = 6` could not directly use the index.

Fortunately, LightDB has the ability to combine multiple indexes (including multiple uses of the same index) to handle cases that cannot be implemented by single index scans. The system can form `AND` and `OR` conditions across several index scans. For example, a query like `WHERE x = 42 OR x = 47 OR x = 53 OR x = 99` could be broken down into four separate scans of an index on  $x$ , each scan using one of the query clauses. The results of these scans are then `ORed` together to produce the result. Another example is that if we have separate indexes on  $x$  and  $y$ , one possible implementation of a query like `WHERE x = 5 AND y = 6` is to use each index with the appropriate query clause and then `AND` together the index results to identify the result rows.

To combine multiple indexes, the system scans each needed index and prepares a *bitmap* in memory giving the locations of table rows that are reported as matching that index's conditions. The bitmaps are then `ANDed` and `ORed` together as needed by the query. Finally, the actual table rows are visited and returned. The table rows are visited in physical order, because that is how the bitmap is laid out; this means that any ordering of the original indexes is lost, and so a separate sort step will be needed if the query has an `ORDER BY` clause. For this reason, and because each additional index scan adds extra time, the planner will sometimes choose to use a simple index scan even though additional indexes are available that could have been used as well.

In all but the simplest applications, there are various combinations of indexes that might be useful, and the database developer must make trade-offs to decide which indexes to provide. Sometimes multicolumn indexes are best, but sometimes it's better to create separate indexes and rely on the index-combination feature. For example, if your workload includes a mix of queries that sometimes involve only column  $x$ , sometimes only column  $y$ , and sometimes both columns, you might choose to create two separate indexes on  $x$  and  $y$ , relying on index combination to process the queries that use both columns. You could also create a multicolumn index on  $(x, y)$ . This index would typically be more efficient than index combination for queries involving both columns, but as discussed in Section 11.3, it would be almost useless for queries involving only  $y$ , so it should not be the only index. A combination of the multicolumn index and a separate index on  $y$  would serve reasonably well. For queries involving only  $x$ , the multicolumn index could be used, though it would be larger and hence slower than an index on  $x$  alone. The last alternative is to create all three indexes, but this is probably only reasonable if the table is searched much more often than it is updated and all three types of query are common. If one of the types of query is much less common than the others, you'd probably settle for creating just the two indexes that best match the common types.

## 11.6. Unique Indexes

Indexes can also be used to enforce uniqueness of a column's value, or the uniqueness of the combined values of more than one column.

```
CREATE UNIQUE INDEX name ON table (column [, ...]);
```

Currently, only B-tree indexes can be declared unique.

When an index is declared unique, multiple table rows with equal indexed values are not allowed. Null values are not considered equal. A multicolumn unique index will only reject cases where all indexed columns are equal in multiple rows.

LightDB automatically creates a unique index when a unique constraint or primary key is defined for a table. The index covers the columns that make up the primary key or unique constraint (a multicolumn index, if appropriate), and is the mechanism that enforces the constraint.

### Note

There's no need to manually create indexes on unique columns; doing so would just duplicate the automatically-created index.

## 11.7. Indexes on Expressions

An index column need not be just a column of the underlying table, but can be a function or scalar expression computed from one or more columns of the table. This feature is useful to obtain fast access to tables based on the results of computations.

For example, a common way to do case-insensitive comparisons is to use the `lower` function:

```
SELECT * FROM test1 WHERE lower(coll) = 'value';
```

This query can use an index if one has been defined on the result of the `lower(coll)` function:

```
CREATE INDEX test1_lower_coll_idx ON test1 (lower(coll));
```

If we were to declare this index `UNIQUE`, it would prevent creation of rows whose `coll` values differ only in case, as well as rows whose `coll` values are actually identical. Thus, indexes on expressions can be used to enforce constraints that are not definable as simple unique constraints.

As another example, if one often does queries like:

```
SELECT * FROM people WHERE (first_name || ' ' || last_name) = 'John  
Smith';
```

then it might be worth creating an index like this:

```
CREATE INDEX people_names ON people ((first_name || ' ' ||  
last_name));
```

The syntax of the `CREATE INDEX` command normally requires writing parentheses around index expressions, as shown in the second example. The parentheses can be omitted when the expression is just a function call, as in the first example.

Index expressions are relatively expensive to maintain, because the derived expression(s) must be computed for each row insertion and non-HOT update. However, the index expressions are *not* recomputed during an indexed search, since they are already stored in the index. In both examples above, the system sees the query as just `WHERE indexedcolumn = 'constant'` and so the speed of the search is equivalent to any other simple index query. Thus, indexes on expressions are useful when retrieval speed is more important than insertion and update speed.

## 11.8. Partial Indexes

A *partial index* is an index built over a subset of a table; the subset is defined by a conditional expression (called the *predicate* of the partial index). The index contains entries only for those table rows that satisfy the predicate. Partial indexes are a specialized feature, but there are several situations in which they are useful.

One major reason for using a partial index is to avoid indexing common values. Since a query searching for a common value (one that accounts for more than a few percent of all the table rows) will not use the index anyway, there is no point in keeping those rows in the index at all. This reduces the size of the index, which will speed up those queries that do use the index. It will also speed up many table update operations because the index does not need to be updated in all cases. Example 11.1 shows a possible application of this idea.

### Example 11.1. Setting up a Partial Index to Exclude Common Values

Suppose you are storing web server access logs in a database. Most accesses originate from the IP address range of your organization but some are from elsewhere (say, employees on dial-up connections). If your searches by IP are primarily for outside accesses, you probably do not need to index the IP range that corresponds to your organization's subnet.

Assume a table like this:

```
CREATE TABLE access_log (  
    url varchar,  
    client_ip inet,  
    ...  
);
```

To create a partial index that suits our example, use a command such as this:

```
CREATE INDEX access_log_client_ip_ix ON access_log (client_ip)  
WHERE NOT (client_ip > inet '192.168.100.0' AND  
          client_ip < inet '192.168.100.255');
```

A typical query that can use this index would be:

```
SELECT *  
FROM access_log  
WHERE url = '/index.html' AND client_ip = inet '212.78.10.32';
```

Here the query's IP address is covered by the partial index. The following query cannot use the partial index, as it uses an IP address that is excluded from the index:

```
SELECT *  
FROM access_log  
WHERE url = '/index.html' AND client_ip = inet '192.168.100.23';
```

Observe that this kind of partial index requires that the common values be predetermined, so such partial indexes are best used for data distributions that do not change. Such indexes can be recreated occasionally to adjust for new data distributions, but this adds maintenance effort.

Another possible use for a partial index is to exclude values from the index that the typical query workload is not interested in; this is shown in Example 11.2. This results in the same advantages as listed above, but it prevents the “uninteresting” values from being accessed via that index, even if

an index scan might be profitable in that case. Obviously, setting up partial indexes for this kind of scenario will require a lot of care and experimentation.

### Example 11.2. Setting up a Partial Index to Exclude Uninteresting Values

If you have a table that contains both billed and unbilled orders, where the unbilled orders take up a small fraction of the total table and yet those are the most-accessed rows, you can improve performance by creating an index on just the unbilled rows. The command to create the index would look like this:

```
CREATE INDEX orders_unbilled_index ON orders (order_nr)
  WHERE billed is not true;
```

A possible query to use this index would be:

```
SELECT * FROM orders WHERE billed is not true AND order_nr < 10000;
```

However, the index can also be used in queries that do not involve `order_nr` at all, e.g.:

```
SELECT * FROM orders WHERE billed is not true AND amount > 5000.00;
```

This is not as efficient as a partial index on the `amount` column would be, since the system has to scan the entire index. Yet, if there are relatively few unbilled orders, using this partial index just to find the unbilled orders could be a win.

Note that this query cannot use this index:

```
SELECT * FROM orders WHERE order_nr = 3501;
```

The order 3501 might be among the billed or unbilled orders.

Example 11.2 also illustrates that the indexed column and the column used in the predicate do not need to match. LightDB supports partial indexes with arbitrary predicates, so long as only columns of the table being indexed are involved. However, keep in mind that the predicate must match the conditions used in the queries that are supposed to benefit from the index. To be precise, a partial index can be used in a query only if the system can recognize that the `WHERE` condition of the query mathematically implies the predicate of the index. LightDB does not have a sophisticated theorem prover that can recognize mathematically equivalent expressions that are written in different forms. (Not only is such a general theorem prover extremely difficult to create, it would probably be too slow to be of any real use.) The system can recognize simple inequality implications, for example “ $x < 1$ ” implies “ $x < 2$ ”; otherwise the predicate condition must exactly match part of the query's `WHERE` condition or the index will not be recognized as usable. Matching takes place at query planning time, not at run time. As a result, parameterized query clauses do not work with a partial index. For example a prepared query with a parameter might specify “ $x < ?$ ” which will never imply “ $x < 2$ ” for all possible values of the parameter.

A third possible use for partial indexes does not require the index to be used in queries at all. The idea here is to create a unique index over a subset of a table, as in Example 11.3. This enforces uniqueness among the rows that satisfy the index predicate, without constraining those that do not.

### Example 11.3. Setting up a Partial Unique Index

Suppose that we have a table describing test outcomes. We wish to ensure that there is only one “successful” entry for a given subject and target combination, but there might be any number of “unsuccessful” entries. Here is one way to do it:

```
CREATE TABLE tests (
```

```

        subject text,
        target text,
        success boolean,
        ...
    );

CREATE UNIQUE INDEX tests_success_constraint ON tests (subject,
    target)
    WHERE success;

```

This is a particularly efficient approach when there are few successful tests and many unsuccessful ones. It is also possible to allow only one null in a column by creating a unique partial index with an `IS NULL` restriction.

Finally, a partial index can also be used to override the system's query plan choices. Also, data sets with peculiar distributions might cause the system to use an index when it really should not. In that case the index can be set up so that it is not available for the offending query. Normally, LightDB makes reasonable choices about index usage (e.g., it avoids them when retrieving common values, so the earlier example really only saves index size, it is not required to avoid index usage), and grossly incorrect plan choices are cause for a bug report.

Keep in mind that setting up a partial index indicates that you know at least as much as the query planner knows, in particular you know when an index might be profitable. Forming this knowledge requires experience and understanding of how indexes in LightDB work. In most cases, the advantage of a partial index over a regular index will be minimal. There are cases where they are quite counterproductive, as in Example 11.4.

#### Example 11.4. Do Not Use Partial Indexes as a Substitute for Partitioning

You might be tempted to create a large set of non-overlapping partial indexes, for example

```

CREATE INDEX mytable_cat_1 ON mytable (data) WHERE category = 1;
CREATE INDEX mytable_cat_2 ON mytable (data) WHERE category = 2;
CREATE INDEX mytable_cat_3 ON mytable (data) WHERE category = 3;
...
CREATE INDEX mytable_cat_N ON mytable (data) WHERE category = N;

```

This is a bad idea! Almost certainly, you'll be better off with a single non-partial index, declared like

```

CREATE INDEX mytable_cat_data ON mytable (category, data);

```

(Put the category column first, for the reasons described in Section 11.3.) While a search in this larger index might have to descend through a couple more tree levels than a search in a smaller index, that's almost certainly going to be cheaper than the planner effort needed to select the appropriate one of the partial indexes. The core of the problem is that the system does not understand the relationship among the partial indexes, and will laboriously test each one to see if it's applicable to the current query.

If your table is large enough that a single index really is a bad idea, you should look into using partitioning instead (see Section 5.11). With that mechanism, the system does understand that the tables and indexes are non-overlapping, so far better performance is possible.

More information about partial indexes can be found in [ston89b], [olson93], and [seshadri95].

## 11.9. Index-Only Scans and Covering Indexes

All indexes in LightDB are *secondary* indexes, meaning that each index is stored separately from the table's main data area (which is called the table's *heap* in LightDB terminology). This means that in an ordinary index scan, each row retrieval requires fetching data from both the index and the



heap. Furthermore, while the index entries that match a given indexable `WHERE` condition are usually close together in the index, the table rows they reference might be anywhere in the heap. The heap-access portion of an index scan thus involves a lot of random access into the heap, which can be slow, particularly on traditional rotating media. (As described in Section 11.5, bitmap scans try to alleviate this cost by doing the heap accesses in sorted order, but that only goes so far.)

To solve this performance problem, LightDB supports *index-only scans*, which can answer queries from an index alone without any heap access. The basic idea is to return values directly out of each index entry instead of consulting the associated heap entry. There are two fundamental restrictions on when this method can be used:

1. The index type must support index-only scans. B-tree indexes always do. GiST indexes support index-only scans for some operator classes but not others. Other index types have no support. The underlying requirement is that the index must physically store, or else be able to reconstruct, the original data value for each index entry. As a counterexample, GIN indexes cannot support index-only scans because each index entry typically holds only part of the original data value.
2. The query must reference only columns stored in the index. For example, given an index on columns `x` and `y` of a table that also has a column `z`, these queries could use index-only scans:

```
SELECT x, y FROM tab WHERE x = 'key';  
SELECT x FROM tab WHERE x = 'key' AND y < 42;
```

but these queries could not:

```
SELECT x, z FROM tab WHERE x = 'key';  
SELECT x FROM tab WHERE x = 'key' AND z < 42;
```

(Expression indexes and partial indexes complicate this rule, as discussed below.)

If these two fundamental requirements are met, then all the data values required by the query are available from the index, so an index-only scan is physically possible. But there is an additional requirement for any table scan in LightDB: it must verify that each retrieved row be “visible” to the query’s MVCC snapshot, as discussed in Chapter 13. Visibility information is not stored in index entries, only in heap entries; so at first glance it would seem that every row retrieval would require a heap access anyway. And this is indeed the case, if the table row has been modified recently. However, for seldom-changing data there is a way around this problem. LightDB tracks, for each page in a table’s heap, whether all rows stored in that page are old enough to be visible to all current and future transactions. This information is stored in a bit in the table’s *visibility map*. An index-only scan, after finding a candidate index entry, checks the visibility map bit for the corresponding heap page. If it’s set, the row is known visible and so the data can be returned with no further work. If it’s not set, the heap entry must be visited to find out whether it’s visible, so no performance advantage is gained over a standard index scan. Even in the successful case, this approach trades visibility map accesses for heap accesses; but since the visibility map is four orders of magnitude smaller than the heap it describes, far less physical I/O is needed to access it. In most situations the visibility map remains cached in memory all the time.

In short, while an index-only scan is possible given the two fundamental requirements, it will be a win only if a significant fraction of the table’s heap pages have their all-visible map bits set. But tables in which a large fraction of the rows are unchanging are common enough to make this type of scan very useful in practice.

To make effective use of the index-only scan feature, you might choose to create a *covering index*, which is an index specifically designed to include the columns needed by a particular type of query that you run frequently. Since queries typically need to retrieve more columns than just the ones they search on, LightDB allows you to create an index in which some columns are just “payload” and are not part of the search key. This is done by adding an `INCLUDE` clause listing the extra columns. For example, if you commonly run queries like

```
SELECT y FROM tab WHERE x = 'key';
```

the traditional approach to speeding up such queries would be to create an index on `x` only. However, an index defined as

```
CREATE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

could handle these queries as index-only scans, because `y` can be obtained from the index without visiting the heap.

Because column `y` is not part of the index's search key, it does not have to be of a data type that the index can handle; it's merely stored in the index and is not interpreted by the index machinery. Also, if the index is a unique index, that is

```
CREATE UNIQUE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

the uniqueness condition applies to just column `x`, not to the combination of `x` and `y`. (An `INCLUDE` clause can also be written in `UNIQUE` and `PRIMARY KEY` constraints, providing alternative syntax for setting up an index like this.)

It's wise to be conservative about adding non-key payload columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion will fail. In any case, non-key columns duplicate data from the index's table and bloat the size of the index, thus potentially slowing searches. And remember that there is little point in including payload columns in an index unless the table changes slowly enough that an index-only scan is likely to not need to access the heap. If the heap tuple must be visited anyway, it costs nothing more to get the column's value from there. Other restrictions are that expressions are not currently supported as included columns, and that only B-tree and GiST indexes currently support included columns.

Before LightDB had the `INCLUDE` feature, people sometimes made covering indexes by writing the payload columns as ordinary index columns, that is writing

```
CREATE INDEX tab_x_y ON tab(x, y);
```

even though they had no intention of ever using `y` as part of a `WHERE` clause. This works fine as long as the extra columns are trailing columns; making them be leading columns is unwise for the reasons explained in Section 11.3. However, this method doesn't support the case where you want the index to enforce uniqueness on the key column(s).

*Suffix truncation* always removes non-key columns from upper B-Tree levels. As payload columns, they are never used to guide index scans. The truncation process also removes one or more trailing key column(s) when the remaining prefix of key column(s) happens to be sufficient to describe tuples on the lowest B-Tree level. In practice, covering indexes without an `INCLUDE` clause often avoid storing columns that are effectively payload in the upper levels. However, explicitly defining payload columns as non-key columns *reliably* keeps the tuples in upper levels small.

In principle, index-only scans can be used with expression indexes. For example, given an index on `f(x)` where `x` is a table column, it should be possible to execute

```
SELECT f(x) FROM tab WHERE f(x) < 1;
```

as an index-only scan; and this is very attractive if `f()` is an expensive-to-compute function. However, LightDB's planner is currently not very smart about such cases. It considers a query to be potentially executable by index-only scan only when all *columns* needed by the query are available from the index. In this example, `x` is not needed except in the context `f(x)`, but the planner does not notice

that and concludes that an index-only scan is not possible. If an index-only scan seems sufficiently worthwhile, this can be worked around by adding  $x$  as an included column, for example

```
CREATE INDEX tab_f_x ON tab (f(x)) INCLUDE (x);
```

An additional caveat, if the goal is to avoid recalculating  $f(x)$ , is that the planner won't necessarily match uses of  $f(x)$  that aren't in indexable WHERE clauses to the index column. It will usually get this right in simple queries such as shown above, but not in queries that involve joins. These deficiencies may be remedied in future versions of LightDB.

Partial indexes also have interesting interactions with index-only scans. Consider the partial index shown in Example 11.3:

```
CREATE UNIQUE INDEX tests_success_constraint ON tests (subject,
  target)
  WHERE success;
```

In principle, we could do an index-only scan on this index to satisfy a query like

```
SELECT target FROM tests WHERE subject = 'some-subject' AND
  success;
```

But there's a problem: the WHERE clause refers to `success` which is not available as a result column of the index. Nonetheless, an index-only scan is possible because the plan does not need to recheck that part of the WHERE clause at run time: all entries found in the index necessarily have `success = true` so this need not be explicitly checked in the plan. LightDB versions 9.6 and later will recognize such cases and allow index-only scans to be generated, but older versions will not.

## 11.10. Operator Classes and Operator Families

An index definition can specify an *operator class* for each column of an index.

```
CREATE INDEX name ON table (column opclass [ ( opclass_options ) ]
  [sort options] [, ...]);
```

The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on the type `int4` would use the `int4_ops` class; this operator class includes comparison functions for values of type `int4`. In practice the default operator class for the column's data type is usually sufficient. The main reason for having operator classes is that for some data types, there could be more than one meaningful index behavior. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when making an index. The operator class determines the basic sort ordering (which can then be modified by adding sort options `COLLATE`, `ASC/DESC` and/or `NULLS FIRST/NULLS LAST`).

There are also some built-in operator classes besides the default ones:

- The operator classes `text_pattern_ops`, `varchar_pattern_ops`, and `bpchar_pattern_ops` support B-tree indexes on the types `text`, `varchar`, and `char` respectively. The difference from the default operator classes is that the values are compared strictly character by character rather than according to the locale-specific collation rules. This makes these operator classes suitable for use by queries involving pattern matching expressions (`LIKE` or `POSIX` regular expressions) when the database does not use the standard “C” locale. As an example, you might index a `varchar` column like this:

```
CREATE INDEX test_index ON test_table (col varchar_pattern_ops);
```

Note that you should also create an index with the default operator class if you want queries involving ordinary `<`, `<=`, `>`, or `>=` comparisons to use an index. Such queries cannot use the `xxx_pattern_ops` operator classes. (Ordinary equality comparisons can use these operator classes, however.) It is possible to create multiple indexes on the same column with different operator classes. If you do use the C locale, you do not need the `xxx_pattern_ops` operator classes, because an index with the default operator class is usable for pattern-matching queries in the C locale.

The following query shows all defined operator classes:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
FROM pg_am am, pg_opclass opc
WHERE opc.opcmethod = am.oid
ORDER BY index_method, opclass_name;
```

An operator class is actually just a subset of a larger structure called an *operator family*. In cases where several data types have similar behaviors, it is frequently useful to define cross-data-type operators and allow these to work with indexes. To do this, the operator classes for each of the types must be grouped into the same operator family. The cross-type operators are members of the family, but are not associated with any single class within the family.

This expanded version of the previous query shows the operator family each operator class belongs to:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opf.opfname AS opfamily_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
FROM pg_am am, pg_opclass opc, pg_opfamily opf
WHERE opc.opcmethod = am.oid AND
       opc.opcfamily = opf.oid
ORDER BY index_method, opclass_name;
```

This query shows all defined operator families and all the operators included in each family:

```
SELECT am.amname AS index_method,
       opf.opfname AS opfamily_name,
       amop.amopopr::regoperator AS opfamily_operator
FROM pg_am am, pg_opfamily opf, pg_amop amop
WHERE opf.opfmethod = am.oid AND
       amop.amopfamily = opf.oid
ORDER BY index_method, opfamily_name, opfamily_operator;
```

### Tip

Itsql has commands `\dAc`, `\dAf`, and `\dAo`, which provide slightly more sophisticated versions of these queries.

## 11.11. Indexes and Collations

An index can support only one collation per index column. If multiple collations are of interest, multiple indexes may be needed.

Consider these statements:

```
CREATE TABLE test1c (  
    id integer,  
    content varchar COLLATE "x"  
);
```

```
CREATE INDEX test1c_content_index ON test1c (content);
```

The index automatically uses the collation of the underlying column. So a query of the form

```
SELECT * FROM test1c WHERE content > constant;
```

could use the index, because the comparison will by default use the collation of the column. However, this index cannot accelerate queries that involve some other collation. So if queries of the form, say,

```
SELECT * FROM test1c WHERE content > constant COLLATE "y";
```

are also of interest, an additional index could be created that supports the "y" collation, like this:

```
CREATE INDEX test1c_content_y_index ON test1c (content COLLATE  
"y");
```

## 11.12. Examining Index Usage

Although indexes in LightDB do not need maintenance or tuning, it is still important to check which indexes are actually used by the real-life query workload. Examining index usage for an individual query is done with the EXPLAIN command; its application for this purpose is illustrated in Section 14.1. It is also possible to gather overall statistics about index usage in a running server, as described in Section 25.2.

It is difficult to formulate a general procedure for determining which indexes to create. There are a number of typical cases that have been shown in the examples throughout the previous sections. A good deal of experimentation is often necessary. The rest of this section gives some tips for that:

- Always run ANALYZE first. This command collects statistics about the distribution of the values in the table. This information is required to estimate the number of rows returned by a query, which is needed by the planner to assign realistic costs to each possible query plan. In absence of any real statistics, some default values are assumed, which are almost certain to be inaccurate. Examining an application's index usage without having run ANALYZE is therefore a lost cause. See Section 22.1.3 and Section 22.1.6 for more information.
- Use real data for experimentation. Using test data for setting up indexes will tell you what indexes you need for the test data, but that is all.

It is especially fatal to use very small test data sets. While selecting 1000 out of 100000 rows could be a candidate for an index, selecting 1 out of 100 rows will hardly be, because the 100 rows probably fit within a single disk page, and there is no plan that can beat sequentially fetching 1 disk page.

Also be careful when making up test data, which is often unavoidable when the application is not yet in production. Values that are very similar, completely random, or inserted in sorted order will skew the statistics away from the distribution that real data would have.

- When indexes are not used, it can be useful for testing to force their use. There are run-time parameters that can turn off various plan types (see Section 17.7.1). For instance, turning off sequential scans (`enable_seqscan`) and nested-loop joins (`enable_nestloop`), which are the most basic plans, will force the system to use a different plan. If the system still chooses a sequential scan or nested-loop join then there is probably a more fundamental reason why the index is not being used; for example, the query condition does not match the index. (What kind of query can use what kind of index is explained in the previous sections.)
- If forcing index usage does use the index, then there are two possibilities: Either the system is right and using the index is indeed not appropriate, or the cost estimates of the query plans are not reflecting reality. So you should time your query with and without indexes. The `EXPLAIN ANALYZE` command can be useful here.
- If it turns out that the cost estimates are wrong, there are, again, two possibilities. The total cost is computed from the per-row costs of each plan node times the selectivity estimate of the plan node. The costs estimated for the plan nodes can be adjusted via run-time parameters (described in Section 17.7.2). An inaccurate selectivity estimate is due to insufficient statistics. It might be possible to improve this by tuning the statistics-gathering parameters (see `ALTER TABLE`).

If you do not succeed in adjusting the costs to be more appropriate, then you might have to resort to forcing index usage explicitly. You might also want to contact the LightDB developers to examine the issue.

---

# Chapter 12. Full Text Search

## 12.1. Introduction

Full Text Searching (or just *text search*) provides the capability to identify natural-language *documents* that satisfy a *query*, and optionally to sort them by relevance to the query. The most common type of search is to find all documents containing given *query terms* and return them in order of their *similarity* to the query. Notions of *query* and *similarity* are very flexible and depend on the specific application. The simplest search considers *query* as a set of words and *similarity* as the frequency of query words in the document.

Textual search operators have existed in databases for years. LightDB has `~`, `~*`, `LIKE`, and `ILIKE` operators for textual data types, but they lack many essential properties required by modern information systems:

- There is no linguistic support, even for English. Regular expressions are not sufficient because they cannot easily handle derived words, e.g., *satisfies* and *satisfy*. You might miss documents that contain *satisfies*, although you probably would like to find them when searching for *satisfy*. It is possible to use `OR` to search for multiple derived forms, but this is tedious and error-prone (some words can have several thousand derivatives).
- They provide no ordering (ranking) of search results, which makes them ineffective when thousands of matching documents are found.
- They tend to be slow because there is no index support, so they must process all documents for every search.

Full text indexing allows documents to be *preprocessed* and an index saved for later rapid searching. Preprocessing includes:

*Parsing documents into tokens.* It is useful to identify various classes of tokens, e.g., numbers, words, complex words, email addresses, so that they can be processed differently. In principle token classes depend on the specific application, but for most purposes it is adequate to use a predefined set of classes. LightDB uses a *parser* to perform this step. A standard parser is provided, and custom parsers can be created for specific needs.

*Converting tokens into lexemes.* A lexeme is a string, just like a token, but it has been *normalized* so that different forms of the same word are made alike. For example, normalization almost always includes folding upper-case letters to lower-case, and often involves removal of suffixes (such as `s` or `es` in English). This allows searches to find variant forms of the same word, without tediously entering all the possible variants. Also, this step typically eliminates *stop words*, which are words that are so common that they are useless for searching. (In short, then, tokens are raw fragments of the document text, while lexemes are words that are believed useful for indexing and searching.) LightDB uses *dictionaries* to perform this step. Various standard dictionaries are provided, and custom ones can be created for specific needs.

*Storing preprocessed documents optimized for searching.* For example, each document can be represented as a sorted array of normalized lexemes. Along with the lexemes it is often desirable to store positional information to use for *proximity ranking*, so that a document that contains a more “dense” region of query words is assigned a higher rank than one with scattered query words.

Dictionaries allow fine-grained control over how tokens are normalized. With appropriate dictionaries, you can:

- Define stop words that should not be indexed.
- Map synonyms to a single word using Ispell.
- Map phrases to a single word using a thesaurus.
- Map different variations of a word to a canonical form using an Ispell dictionary.

- Map different variations of a word to a canonical form using Snowball stemmer rules.

A data type `tsvector` is provided for storing preprocessed documents, along with a type `tsquery` for representing processed queries (Section 8.11). There are many functions and operators available for these data types (Section 9.13), the most important of which is the match operator `@@`, which we introduce in Section 12.1.2. Full text searches can be accelerated using indexes (Section 12.9).

### 12.1.1. What Is a Document?

A *document* is the unit of searching in a full text search system; for example, a magazine article or email message. The text search engine must be able to parse documents and store associations of lexemes (key words) with their parent document. Later, these associations are used to search for documents that contain query words.

For searches within LightDB, a document is normally a textual field within a row of a database table, or possibly a combination (concatenation) of such fields, perhaps stored in several tables or obtained dynamically. In other words, a document can be constructed from different parts for indexing and it might not be stored anywhere as a whole. For example:

```
SELECT title || ' ' || author || ' ' || abstract || ' ' || body
       AS document
FROM messages
WHERE mid = 12;
```

```
SELECT m.title || ' ' || m.author || ' ' || m.abstract || ' ' ||
       d.body AS document
FROM messages m, docs d
WHERE m.mid = d.did AND m.mid = 12;
```

#### Note

Actually, in these example queries, `coalesce` should be used to prevent a single `NULL` attribute from causing a `NULL` result for the whole document.

Another possibility is to store the documents as simple text files in the file system. In this case, the database can be used to store the full text index and to execute searches, and some unique identifier can be used to retrieve the document from the file system. However, retrieving files from outside the database requires superuser permissions or special function support, so this is usually less convenient than keeping all the data inside LightDB. Also, keeping everything inside the database allows easy access to document metadata to assist in indexing and display.

For text search purposes, each document must be reduced to the preprocessed `tsvector` format. Searching and ranking are performed entirely on the `tsvector` representation of a document — the original text need only be retrieved when the document has been selected for display to a user. We therefore often speak of the `tsvector` as being the document, but of course it is only a compact representation of the full document.

### 12.1.2. Basic Text Matching

Full text searching in LightDB is based on the match operator `@@`, which returns `true` if a `tsvector` (document) matches a `tsquery` (query). It doesn't matter which data type is written first:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector @@ 'cat
& rat'::tsquery;
?column?
```



```
-----  
t
```

```
SELECT 'fat & cow'::tsquery @@ 'a fat cat sat on a mat and ate a  
fat rat'::tsvector;  
?column?
```

```
-----  
f
```

As the above example suggests, a `tsquery` is not just raw text, any more than a `tsvector` is. A `tsquery` contains search terms, which must be already-normalized lexemes, and may combine multiple terms using AND, OR, NOT, and FOLLOWED BY operators. (For syntax details see Section 8.11.2.) There are functions `to_tsquery`, `plainto_tsquery`, and `phraseto_tsquery` that are helpful in converting user-written text into a proper `tsquery`, primarily by normalizing words appearing in the text. Similarly, `to_tsvector` is used to parse and normalize a document string. So in practice a text search match would look more like this:

```
SELECT to_tsvector('fat cats ate fat rats') @@ to_tsquery('fat &  
rat');  
?column?
```

```
-----  
t
```

Observe that this match would not succeed if written as

```
SELECT 'fat cats ate fat rats'::tsvector @@ to_tsquery('fat &  
rat');  
?column?
```

```
-----  
f
```

since here no normalization of the word `rats` will occur. The elements of a `tsvector` are lexemes, which are assumed already normalized, so `rats` does not match `rat`.

The `@@` operator also supports `text` input, allowing explicit conversion of a text string to `tsvector` or `tsquery` to be skipped in simple cases. The variants available are:

```
tsvector @@ tsquery  
tsquery  @@ tsvector  
text     @@ tsquery  
text     @@ text
```

The first two of these we saw already. The form `text @@ tsquery` is equivalent to `to_tsvector(x) @@ y`. The form `text @@ text` is equivalent to `to_tsvector(x) @@ plainto_tsquery(y)`.

Within a `tsquery`, the `&` (AND) operator specifies that both its arguments must appear in the document to have a match. Similarly, the `|` (OR) operator specifies that at least one of its arguments must appear, while the `!` (NOT) operator specifies that its argument must *not* appear in order to have a match. For example, the query `fat & ! rat` matches documents that contain `fat` but not `rat`.

Searching for phrases is possible with the help of the `<->` (FOLLOWED BY) `tsquery` operator, which matches only if its arguments have matches that are adjacent and in the given order. For example:

```
SELECT to_tsvector('fatal error') @@ to_tsquery('fatal <-> error');
```

```

?column?
-----
t

SELECT to_tsvector('error is not fatal') @@ to_tsquery('fatal <->
error');
?column?
-----
f

```

There is a more general version of the FOLLOWED BY operator having the form  $\langle N \rangle$ , where  $N$  is an integer standing for the difference between the positions of the matching lexemes.  $\langle 1 \rangle$  is the same as  $\langle - \rangle$ , while  $\langle 2 \rangle$  allows exactly one other lexeme to appear between the matches, and so on. The `phraseto_tsquery` function makes use of this operator to construct a `tsquery` that can match a multi-word phrase when some of the words are stop words. For example:

```

SELECT phraseto_tsquery('cats ate rats');
       phraseto_tsquery
-----
'cat' <-> 'ate' <-> 'rat'

SELECT phraseto_tsquery('the cats ate the rats');
       phraseto_tsquery
-----
'cat' <-> 'ate' <2> 'rat'

```

A special case that's sometimes useful is that  $\langle 0 \rangle$  can be used to require that two patterns match the same word.

Parentheses can be used to control nesting of the `tsquery` operators. Without parentheses, `|` binds least tightly, then `&`, then `<->`, and `!` most tightly.

It's worth noticing that the AND/OR/NOT operators mean something subtly different when they are within the arguments of a FOLLOWED BY operator than when they are not, because within FOLLOWED BY the exact position of the match is significant. For example, normally `!x` matches only documents that do not contain `x` anywhere. But `!x <-> y` matches `y` if it is not immediately after an `x`; an occurrence of `x` elsewhere in the document does not prevent a match. Another example is that `x & y` normally only requires that `x` and `y` both appear somewhere in the document, but `(x & y) <-> z` requires `x` and `y` to match at the same place, immediately before a `z`. Thus this query behaves differently from `x <-> z & y <-> z`, which will match a document containing two separate sequences `x z` and `y z`. (This specific query is useless as written, since `x` and `y` could not match at the same place; but with more complex situations such as prefix-match patterns, a query of this form could be useful.)

### 12.1.3. Configurations

The above are all simple text search examples. As mentioned before, full text search functionality includes the ability to do many more things: skip indexing certain words (stop words), process synonyms, and use sophisticated parsing, e.g., parse based on more than just white space. This functionality is controlled by *text search configurations*. LightDB comes with predefined configurations for many languages, and you can easily create your own configurations. (Itsql's `\dF` command shows all available configurations.)

During installation an appropriate configuration is selected and `default_text_search_config` is set accordingly in `lightdb.conf`. If you are using the same text search configuration for the entire cluster you can use the value in `lightdb.conf`. To use different configurations throughout the cluster but the same configuration within any one database, use `ALTER DATABASE ... SET`. Otherwise, you can set `default_text_search_config` in each session.

Each text search function that depends on a configuration has an optional `regconfig` argument, so that the configuration to use can be specified explicitly. `default_text_search_config` is used only when this argument is omitted.

We provide two configurations for text search parsers. They are set accordingly in `lightdb.conf`. You can modify this value during the session:

- `lightdb_tsearch_non_stopwords` is used to customize non-stop words, which is just the opposite of stop words.
- `lightdb_tsearch_word_superpose` is used to overlay the effect of using stop words and non-stop words. This configuration does not support chinese text parsing.

To make it easier to build custom text search configurations, a configuration is built up from simpler database objects. LightDB's text search facility provides four types of configuration-related database objects:

- *Text search parsers* break documents into tokens and classify each token (for example, as words or numbers).
- *Text search dictionaries* convert tokens to normalized form and reject stop words.
- *Text search templates* provide the functions underlying dictionaries. (A dictionary simply specifies a template and a set of parameters for the template.)
- *Text search configurations* select a parser and a set of dictionaries to use to normalize the tokens produced by the parser.

Text search parsers and templates are built from low-level C functions; therefore it requires C programming ability to develop new ones, and superuser privileges to install one into a database. (There are examples of add-on parsers and templates in the `contrib/` area of the LightDB distribution.) Since dictionaries and configurations just parameterize and connect together some underlying parsers and templates, no special privilege is needed to create a new dictionary or configuration. Examples of creating custom dictionaries and configurations appear later in this chapter.

## 12.2. Tables and Indexes

The examples in the previous section illustrated full text matching using simple constant strings. This section shows how to search table data, optionally using indexes.

### 12.2.1. Searching a Table

It is possible to do a full text search without an index. A simple query to print the `title` of each row that contains the word `friend` in its `body` field is:

```
SELECT title
FROM pgweb
WHERE to_tsvector('english', body) @@ to_tsquery('english',
'friend');
```

This will also find related words such as `friends` and `friendly`, since all these are reduced to the same normalized lexeme.

The query above specifies that the `english` configuration is to be used to parse and normalize the strings. Alternatively we could omit the configuration parameters:

```
SELECT title
FROM pgweb
WHERE to_tsvector(body) @@ to_tsquery('friend');
```

This query will use the configuration set by `default_text_search_config`.

A more complex example is to select the ten most recent documents that contain `create` and `table` in the `title` or `body`:

```
SELECT title
FROM pgweb
WHERE to_tsvector(title || ' ' || body) @@ to_tsquery('create &
table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

For clarity we omitted the `coalesce` function calls which would be needed to find rows that contain `NULL` in one of the two fields.

Although these queries will work without an index, most applications will find this approach too slow, except perhaps for occasional ad-hoc searches. Practical use of text searching usually requires creating an index.

## 12.2.2. Creating Indexes

We can create a GIN index (Section 12.9) to speed up text searches:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english',
body));
```

Notice that the 2-argument version of `to_tsvector` is used. Only text search functions that specify a configuration name can be used in expression indexes (Section 11.7). This is because the index contents must be unaffected by `default_text_search_config`. If they were affected, the index contents might be inconsistent because different entries could contain `tsvector`s that were created with different text search configurations, and there would be no way to guess which was which. It would be impossible to dump and restore such an index correctly.

Because the two-argument version of `to_tsvector` was used in the index above, only a query reference that uses the 2-argument version of `to_tsvector` with the same configuration name will use that index. That is, `WHERE to_tsvector('english', body) @@ 'a & b'` can use the index, but `WHERE to_tsvector(body) @@ 'a & b'` cannot. This ensures that an index will be used only with the same configuration used to create the index entries.

It is possible to set up more complex expression indexes wherein the configuration name is specified by another column, e.g.:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector(config_name,
body));
```

where `config_name` is a column in the `pgweb` table. This allows mixed configurations in the same index while recording which configuration was used for each index entry. This would be useful, for example, if the document collection contained documents in different languages. Again, queries that are meant to use the index must be phrased to match, e.g., `WHERE to_tsvector(config_name, body) @@ 'a & b'`.

Indexes can even concatenate columns:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english',
title || ' ' || body));
```

Another approach is to create a separate `tsvector` column to hold the output of `to_tsvector`. To keep this column automatically up to date with its source data, use a stored generated column. This

example is a concatenation of `title` and `body`, using `coalesce` to ensure that one field will still be indexed when the other is `NULL`:

```
ALTER TABLE pgweb
  ADD COLUMN textsearchable_index_col tsvector
  GENERATED ALWAYS AS (to_tsvector('english',
  coalesce(title, '') || ' ' || coalesce(body, ''))) STORED;
```

Then we create a GIN index to speed up the search:

```
CREATE INDEX textsearch_idx ON pgweb USING GIN
  (textsearchable_index_col);
```

Now we are ready to perform a fast full text search:

```
SELECT title
FROM pgweb
WHERE textsearchable_index_col @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

One advantage of the separate-column approach over an expression index is that it is not necessary to explicitly specify the text search configuration in queries in order to make use of the index. As shown in the example above, the query can depend on `default_text_search_config`. Another advantage is that searches will be faster, since it will not be necessary to redo the `to_tsvector` calls to verify index matches. (This is more important when using a GiST index than a GIN index; see Section 12.9.) The expression-index approach is simpler to set up, however, and it requires less disk space since the `tsvector` representation is not stored explicitly.

## 12.3. Controlling Text Search

To implement full text searching there must be a function to create a `tsvector` from a document and a `tsquery` from a user query. Also, we need to return results in a useful order, so we need a function that compares documents with respect to their relevance to the query. It's also important to be able to display the results nicely. LightDB provides support for all of these functions.

### 12.3.1. Parsing Documents

LightDB provides the function `to_tsvector` for converting a document to the `tsvector` data type.

```
to_tsvector([ config regconfig, ] document text) returns tsvector
```

`to_tsvector` parses a textual document into tokens, reduces the tokens to lexemes, and returns a `tsvector` which lists the lexemes together with their positions in the document. The document is processed according to the specified or default text search configuration. Here is a simple example:

```
SELECT to_tsvector('english', 'a fat cat sat on a mat - it ate a
fat rats');
           to_tsvector
-----
'ate':9 'cat':3 'fat':2,11 'mat':7 'rat':12 'sat':4
```

In the example above we see that the resulting `tsvector` does not contain the words `a`, `on`, or `it`, the word `rats` became `rat`, and the punctuation sign `-` was ignored.

The `to_tsvector` function internally calls a parser which breaks the document text into tokens and assigns a type to each token. For each token, a list of dictionaries (Section 12.6) is consulted, where the list can vary depending on the token type. The first dictionary that *recognizes* the token emits one or more normalized *lexemes* to represent the token. For example, `rats` became `rat` because one of the dictionaries recognized that the word `rats` is a plural form of `rat`. Some words are recognized as *stop words* (Section 12.6.1), which causes them to be ignored since they occur too frequently to be useful in searching. In our example these are `a`, `on`, and `it`. If no dictionary in the list recognizes the token then it is also ignored. In this example that happened to the punctuation sign `-` because there are in fact no dictionaries assigned for its token type (`Space symbols`), meaning space tokens will never be indexed. The choices of parser, dictionaries and which types of tokens to index are determined by the selected text search configuration (Section 12.7). It is possible to have many different configurations in the same database, and predefined configurations are available for various languages. In our example we used the default configuration `english` for the English language.

The function `setweight` can be used to label the entries of a `tsvector` with a given *weight*, where a weight is one of the letters A, B, C, or D. This is typically used to mark entries coming from different parts of a document, such as title versus body. Later, this information can be used for ranking of search results.

Because `to_tsvector(NULL)` will return `NULL`, it is recommended to use `coalesce` whenever a field might be null. Here is the recommended method for creating a `tsvector` from a structured document:

```
UPDATE tt SET ti =
    setweight(to_tsvector(coalesce(title, '')), 'A') ||
    setweight(to_tsvector(coalesce(keyword, '')), 'B') ||
    setweight(to_tsvector(coalesce(abstract, '')), 'C') ||
    setweight(to_tsvector(coalesce(body, '')), 'D');
```

Here we have used `setweight` to label the source of each lexeme in the finished `tsvector`, and then merged the labeled `tsvector` values using the `tsvector` concatenation operator `||`. (Section 12.4.1 gives details about these operations.)

## 12.3.2. Parsing Queries

LightDB provides the functions `to_tsquery`, `plainto_tsquery`, `phraseto_tsquery` and `websearch_to_tsquery` for converting a query to the `tsquery` data type. `to_tsquery` offers access to more features than either `plainto_tsquery` or `phraseto_tsquery`, but it is less forgiving about its input. `websearch_to_tsquery` is a simplified version of `to_tsquery` with an alternative syntax, similar to the one used by web search engines.

`to_tsquery([ config regconfig, ] querytext text)` returns `tsquery`

`to_tsquery` creates a `tsquery` value from `querytext`, which must consist of single tokens separated by the `tsquery` operators `&` (AND), `|` (OR), `!` (NOT), and `<->` (FOLLOWED BY), possibly grouped using parentheses. In other words, the input to `to_tsquery` must already follow the general rules for `tsquery` input, as described in Section 8.11.2. The difference is that while basic `tsquery` input takes the tokens at face value, `to_tsquery` normalizes each token into a lexeme using the specified or default configuration, and discards any tokens that are stop words according to the configuration. For example:

```
SELECT to_tsquery('english', 'The & Fat & Rats');
```

```
to_tsquery
```

```
-----  
'fat' & 'rat'
```

As in basic `tsquery` input, weight(s) can be attached to each lexeme to restrict it to match only `tsvector` lexemes of those weight(s). For example:

```
SELECT to_tsquery('english', 'Fat | Rats:AB');  
to_tsquery  
-----  
'fat' | 'rat':AB
```

Also, `*` can be attached to a lexeme to specify prefix matching:

```
SELECT to_tsquery('supern:*A & star:A*B');  
to_tsquery  
-----  
'supern':*A & 'star':*AB
```

Such a lexeme will match any word in a `tsvector` that begins with the given string.

`to_tsquery` can also accept single-quoted phrases. This is primarily useful when the configuration includes a thesaurus dictionary that may trigger on such phrases. In the example below, a thesaurus contains the rule `supernovae stars : sn`:

```
SELECT to_tsquery(''supernovae stars' & !crab');  
to_tsquery  
-----  
'sn' & !'crab'
```

Without quotes, `to_tsquery` will generate a syntax error for tokens that are not separated by an AND, OR, or FOLLOWED BY operator.

```
plainto_tsquery([ config regconfig, ] querytext text)  
returns tsquery
```

`plainto_tsquery` transforms the unformatted text `querytext` to a `tsquery` value. The text is parsed and normalized much as for `to_tsvector`, then the `&` (AND) `tsquery` operator is inserted between surviving words.

Example:

```
SELECT plainto_tsquery('english', 'The Fat Rats');  
plainto_tsquery  
-----  
'fat' & 'rat'
```

Note that `plainto_tsquery` will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input:

```
SELECT plainto_tsquery('english', 'The Fat & Rats:C');  
plainto_tsquery  
-----
```

```
'fat' & 'rat' & 'c'
```

Here, all the input punctuation was discarded.

```
phraseto_tsquery([ config regconfig, ] querytext text)
returns tsquery
```

`phraseto_tsquery` behaves much like `plainto_tsquery`, except that it inserts the `<->` (FOLLOWED BY) operator between surviving words instead of the `&` (AND) operator. Also, stop words are not simply discarded, but are accounted for by inserting `<N>` operators rather than `<->` operators. This function is useful when searching for exact lexeme sequences, since the FOLLOWED BY operators check lexeme order not just the presence of all the lexemes.

Example:

```
SELECT phraseto_tsquery('english', 'The Fat Rats');
phraseto_tsquery
-----
'fat' <-> 'rat'
```

Like `plainto_tsquery`, the `phraseto_tsquery` function will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input:

```
SELECT phraseto_tsquery('english', 'The Fat & Rats:C');
phraseto_tsquery
-----
'fat' <-> 'rat' <-> 'c'
```

```
websearch_to_tsquery([ config regconfig, ] querytext text)
returns tsquery
```

`websearch_to_tsquery` creates a `tsquery` value from `querytext` using an alternative syntax in which simple unformatted text is a valid query. Unlike `plainto_tsquery` and `phraseto_tsquery`, it also recognizes certain operators. Moreover, this function will never raise syntax errors, which makes it possible to use raw user-supplied input for search. The following syntax is supported:

- `unquoted text`: text not inside quote marks will be converted to terms separated by `&` operators, as if processed by `plainto_tsquery`.
- `"quoted text"`: text inside quote marks will be converted to terms separated by `<->` operators, as if processed by `phraseto_tsquery`.
- `OR`: the word “or” will be converted to the `|` operator.
- `-`: a dash will be converted to the `!` operator.

Other punctuation is ignored. So like `plainto_tsquery` and `phraseto_tsquery`, the `websearch_to_tsquery` function will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input.

Examples:

```
SELECT websearch_to_tsquery('english', 'The fat rats');
websearch_to_tsquery
-----
```



```
'fat' & 'rat'
(1 row)

SELECT websearch_to_tsquery('english', '"supernovae stars" -crab');
       websearch_to_tsquery
-----
'supernova' <-> 'star' & !'crab'
(1 row)

SELECT websearch_to_tsquery('english', '"sad cat" or "fat rat"');
       websearch_to_tsquery
-----
'sad' <-> 'cat' | 'fat' <-> 'rat'
(1 row)

SELECT websearch_to_tsquery('english', 'signal -"segmentation
       fault"');
       websearch_to_tsquery
-----
'signal' & !( 'segment' <-> 'fault' )
(1 row)

SELECT websearch_to_tsquery('english', '"") ( dummy \\ query <-
>');
       websearch_to_tsquery
-----
'dummi' & 'queri'
(1 row)
```

### 12.3.3. Ranking Search Results

Ranking attempts to measure how relevant documents are to a particular query, so that when there are many matches the most relevant ones can be shown first. LightDB provides two predefined ranking functions, which take into account lexical, proximity, and structural information; that is, they consider how often the query terms appear in the document, how close together the terms are in the document, and how important is the part of the document where they occur. However, the concept of relevancy is vague and very application-specific. Different applications might require additional information for ranking, e.g., document modification time. The built-in ranking functions are only examples. You can write your own ranking functions and/or combine their results with additional factors to fit your specific needs.

The two ranking functions currently available are:

```
ts_rank([ weights float4[], ] vector tsvector, query tsquery [,
normalization integer ]) returns float4
```

Ranks vectors based on the frequency of their matching lexemes.

```
ts_rank_cd([ weights float4[], ] vector tsvector, query tsquery [,
normalization integer ]) returns float4
```

This function computes the *cover density* ranking for the given document vector and query, as described in Clarke, Cormack, and Tudhope's "Relevance Ranking for One to Three Term Queries" in the journal "Information Processing and Management", 1999. Cover density is similar to `ts_rank` ranking except that the proximity of matching lexemes to each other is taken into consideration.

This function requires lexeme positional information to perform its calculation. Therefore, it ignores any "stripped" lexemes in the `tsvector`. If there are no unstripped lexemes in the input,

the result will be zero. (See Section 12.4.1 for more information about the `strip` function and positional information in `tsvectors`.)

For both these functions, the optional `weights` argument offers the ability to weigh word instances more or less heavily depending on how they are labeled. The weight arrays specify how heavily to weigh each category of word, in the order:

```
{D-weight, C-weight, B-weight, A-weight}
```

If no `weights` are provided, then these defaults are used:

```
{0.1, 0.2, 0.4, 1.0}
```

Typically weights are used to mark words from special areas of the document, like the title or an initial abstract, so they can be treated with more or less importance than words in the document body.

Since a longer document has a greater chance of containing a query term it is reasonable to take into account document size, e.g., a hundred-word document with five instances of a search word is probably more relevant than a thousand-word document with five instances. Both ranking functions take an integer `normalization` option that specifies whether and how a document's length should impact its rank. The integer option controls several behaviors, so it is a bit mask: you can specify one or more behaviors using `|` (for example, `2|4`).

- 0 (the default) ignores the document length
- 1 divides the rank by 1 + the logarithm of the document length
- 2 divides the rank by the document length
- 4 divides the rank by the mean harmonic distance between extents (this is implemented only by `ts_rank_cd`)
- 8 divides the rank by the number of unique words in document
- 16 divides the rank by 1 + the logarithm of the number of unique words in document
- 32 divides the rank by itself + 1

If more than one flag bit is specified, the transformations are applied in the order listed.

It is important to note that the ranking functions do not use any global information, so it is impossible to produce a fair normalization to 1% or 100% as sometimes desired. Normalization option 32 (`rank / (rank+1)`) can be applied to scale all ranks into the range zero to one, but of course this is just a cosmetic change; it will not affect the ordering of the search results.

Here is an example that selects only the ten highest-ranked matches:

```
SELECT title, ts_rank_cd(textsearch, query) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
```

title	rank
Neutrinos in the Sun	3.1
The Sudbury Neutrino Detector	2.4
A MACHO View of Galactic Dark Matter	2.01317
Hot Gas and Dark Matter	1.91171
The Virgo Cluster: Hot Plasma and Dark Matter	1.90953
Rafting for Solar Neutrinos	1.9
NGC 4650A: Strange Galaxy and Dark Matter	1.85774
Hot Gas and Dark Matter	1.6123
Ice Fishing for Cosmic Neutrinos	1.6
Weak Lensing Distorts the Universe	0.818218

This is the same example using normalized ranking:

```
SELECT title, ts_rank_cd(textsearch, query, 32 /* rank/(rank+1)
*/ ) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
```

title	rank
Neutrinos in the Sun	0.756097569485493
The Sudbury Neutrino Detector	0.705882361190954
A MACHO View of Galactic Dark Matter	0.668123210574724
Hot Gas and Dark Matter	0.65655958650282
The Virgo Cluster: Hot Plasma and Dark Matter	0.656301290640973
Rafting for Solar Neutrinos	0.655172410958162
NGC 4650A: Strange Galaxy and Dark Matter	0.650072921219637
Hot Gas and Dark Matter	0.617195790024749
Ice Fishing for Cosmic Neutrinos	0.615384618911517
Weak Lensing Distorts the Universe	0.450010798361481

Ranking can be expensive since it requires consulting the `tsvector` of each matching document, which can be I/O bound and therefore slow. Unfortunately, it is almost impossible to avoid since practical queries often result in large numbers of matches.

## 12.3.4. Highlighting Results

To present search results it is ideal to show a part of each document and how it is related to the query. Usually, search engines show fragments of the document with marked search terms. LightDB provides a function `ts_headline` that implements this functionality.

```
ts_headline([ config regconfig, ] document text, query tsquery
[, options text ]) returns text
```

`ts_headline` accepts a document along with a query, and returns an excerpt from the document in which terms from the query are highlighted. The configuration to be used to parse the document can be specified by `config`; if `config` is omitted, the `default_text_search_config` configuration is used.

If an `options` string is specified it must consist of a comma-separated list of one or more `option=value` pairs. The available options are:

- `MaxWords`, `MinWords` (integers): these numbers determine the longest and shortest headlines to output. The default values are 35 and 15.
- `ShortWord` (integer): words of this length or less will be dropped at the start and end of a headline, unless they are query terms. The default value of three eliminates common English articles.
- `HighlightAll` (boolean): if `true` the whole document will be used as the headline, ignoring the preceding three parameters. The default is `false`.
- `MaxFragments` (integer): maximum number of text fragments to display. The default value of zero selects a non-fragment-based headline generation method. A value greater than zero selects fragment-based headline generation (see below).
- `StartSel`, `StopSel` (strings): the strings with which to delimit query words appearing in the document, to distinguish them from other excerpted words. The default values are “<b>” and “</b>”, which can be suitable for HTML output.
- `FragmentDelimiter` (string): When more than one fragment is displayed, the fragments will be separated by this string. The default is “ . . . ”.

These option names are recognized case-insensitively. You must double-quote string values if they contain spaces or commas.

In non-fragment-based headline generation, `ts_headline` locates matches for the given *query* and chooses a single one to display, preferring matches that have more query words within the allowed headline length. In fragment-based headline generation, `ts_headline` locates the query matches and splits each match into “fragments” of no more than `MaxWords` words each, preferring fragments with more query words, and when possible “stretching” fragments to include surrounding words. The fragment-based mode is thus more useful when the query matches span large sections of the document, or when it's desirable to display multiple matches. In either mode, if no query matches can be identified, then a single fragment of the first `MinWords` words in the document will be displayed.

For example:

```
SELECT ts_headline('english',
  'The most common type of search
  is to find all documents containing given query terms
  and return them in order of their similarity to the
  query.',
  to_tsquery('english', 'query & similarity'));
      ts_headline
-----
containing given <b>query</b> terms                +
and return them in order of their <b>similarity</b> to the+
<b>query</b>.
```

```
SELECT ts_headline('english',
  'Search terms may occur
  many times in a document,
  requiring ranking of the search matches to decide which
  occurrences to display in the result.',
  to_tsquery('english', 'search & term'),
  'MaxFragments=10, MaxWords=7, MinWords=3, StartSel=<<,
  StopSel=>>');
      ts_headline
-----
<<Search>> <<terms>> may occur                    +
many times ... ranking of the <<search>> matches to decide
```

`ts_headline` uses the original document, not a `tsvector` summary, so it can be slow and should be used with care.

## 12.4. Additional Features

This section describes additional functions and operators that are useful in connection with text search.

### 12.4.1. Manipulating Documents

Section 12.3.1 showed how raw textual documents can be converted into `tsvector` values. LightDB also provides functions and operators that can be used to manipulate documents that are already in `tsvector` form.

```
tsvector || tsvector
```

The `tsvector` concatenation operator returns a vector which combines the lexemes and positional information of the two vectors given as arguments. Positions and weight labels are retained during the concatenation. Positions appearing in the right-hand vector are offset by the

largest position mentioned in the left-hand vector, so that the result is nearly equivalent to the result of performing `to_tsvector` on the concatenation of the two original document strings. (The equivalence is not exact, because any stop-words removed from the end of the left-hand argument will not affect the result, whereas they would have affected the positions of the lexemes in the right-hand argument if textual concatenation were used.)

One advantage of using concatenation in the vector form, rather than concatenating text before applying `to_tsvector`, is that you can use different configurations to parse different sections of the document. Also, because the `setweight` function marks all lexemes of the given vector the same way, it is necessary to parse the text and do `setweight` before concatenating if you want to label different parts of the document with different weights.

`setweight(vector tsvector, weight "char")` returns `tsvector`

`setweight` returns a copy of the input vector in which every position has been labeled with the given *weight*, either A, B, C, or D. (D is the default for new vectors and as such is not displayed on output.) These labels are retained when vectors are concatenated, allowing words from different parts of a document to be weighted differently by ranking functions.

Note that weight labels apply to *positions*, not *lexemes*. If the input vector has been stripped of positions then `setweight` does nothing.

`length(vector tsvector)` returns `integer`

Returns the number of lexemes stored in the vector.

`strip(vector tsvector)` returns `tsvector`

Returns a vector that lists the same lexemes as the given vector, but lacks any position or weight information. The result is usually much smaller than an unstripped vector, but it is also less useful. Relevance ranking does not work as well on stripped vectors as unstripped ones. Also, the `<->` (FOLLOWED BY) `tsquery` operator will never match stripped input, since it cannot determine the distance between lexeme occurrences.

A full list of `tsvector`-related functions is available in Table 9.43.

## 12.4.2. Manipulating Queries

Section 12.3.2 showed how raw textual queries can be converted into `tsquery` values. LightDB also provides functions and operators that can be used to manipulate queries that are already in `tsquery` form.

`tsquery && tsquery`

Returns the AND-combination of the two given queries.

`tsquery || tsquery`

Returns the OR-combination of the two given queries.

`!! tsquery`

Returns the negation (NOT) of the given query.

`tsquery <-> tsquery`

Returns a query that searches for a match to the first given query immediately followed by a match to the second given query, using the `<->` (FOLLOWED BY) `tsquery` operator. For example:

```
SELECT to_tsquery('fat') <-> to_tsquery('cat | rat');
       ?column?
```

```
-----
'fat' <-> ( 'cat' | 'rat' )
```

`tsquery_phrase(query1 tsquery, query2 tsquery [, distance integer])` returns `tsquery`

Returns a query that searches for a match to the first given query followed by a match to the second given query at a distance of exactly *distance* lexemes, using the `<N>` `tsquery` operator. For example:

```
SELECT tsquery_phrase(to_tsquery('fat'), to_tsquery('cat'), 10);
       tsquery_phrase
```

```
-----
'fat' <10> 'cat'
```

`numnode(query tsquery)` returns `integer`

Returns the number of nodes (lexemes plus operators) in a `tsquery`. This function is useful to determine if the *query* is meaningful (returns `> 0`), or contains only stop words (returns `0`). Examples:

```
SELECT numnode(plainto_tsquery('the any'));
NOTICE: query contains only stopword(s) or doesn't contain
       lexeme(s), ignored
       numnode
```

```
-----
0
```

```
SELECT numnode('foo & bar'::tsquery);
       numnode
```

```
-----
3
```

`querytree(query tsquery)` returns `text`

Returns the portion of a `tsquery` that can be used for searching an index. This function is useful for detecting unindexable queries, for example those containing only stop words or only negated terms. For example:

```
SELECT querytree(to_tsquery('defined'));
       querytree
```

```
-----
'defin'
```

```
SELECT querytree(to_tsquery('!defined'));
       querytree
```

```
-----
T
```

### 12.4.2.1. Query Rewriting

The `ts_rewrite` family of functions search a given `tsquery` for occurrences of a target subquery, and replace each occurrence with a substitute subquery. In essence this operation is a `tsquery`-specific version of substring replacement. A target and substitute combination can be thought of as a

*query rewrite rule*. A collection of such rewrite rules can be a powerful search aid. For example, you can expand the search using synonyms (e.g., `new york`, `big apple`, `nyc`, `gotham`) or narrow the search to direct the user to some hot topic. There is some overlap in functionality between this feature and thesaurus dictionaries (Section 12.6.4). However, you can modify a set of rewrite rules on-the-fly without reindexing, whereas updating a thesaurus requires reindexing to be effective.

```
ts_rewrite (query tsquery, target tsquery, substitute tsquery)
returns tsquery
```

This form of `ts_rewrite` simply applies a single rewrite rule: *target* is replaced by *substitute* wherever it appears in *query*. For example:

```
SELECT ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'c'::tsquery);
   ts_rewrite
-----
   'b' & 'c'
```

```
ts_rewrite (query tsquery, select text) returns tsquery
```

This form of `ts_rewrite` accepts a starting *query* and a SQL *select* command, which is given as a text string. The *select* must yield two columns of *tsquery* type. For each row of the *select* result, occurrences of the first column value (the target) are replaced by the second column value (the substitute) within the current *query* value. For example:

```
CREATE TABLE aliases (t tsquery PRIMARY KEY, s tsquery);
INSERT INTO aliases VALUES('a', 'c');

SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases');
   ts_rewrite
-----
   'b' & 'c'
```

Note that when multiple rewrite rules are applied in this way, the order of application can be important; so in practice you will want the source query to `ORDER BY` some ordering key.

Let's consider a real-life astronomical example. We'll expand query `supernovae` using table-driven rewriting rules:

```
CREATE TABLE aliases (t tsquery primary key, s tsquery);
INSERT INTO aliases VALUES(to_tsquery('supernovae'),
   to_tsquery('supernovae|sn'));

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM
aliases');
   ts_rewrite
-----
   'crab' & ( 'supernova' | 'sn' )
```

We can change the rewriting rules just by updating the table:

```
UPDATE aliases
SET s = to_tsquery('supernovae|sn & !nebulae')
WHERE t = to_tsquery('supernovae');

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM
aliases');
```

```
ts_rewrite
```

```
-----
'crab' & ( 'supernova' | 'sn' & !'nebula' )
```

Rewriting can be slow when there are many rewriting rules, since it checks every rule for a possible match. To filter out obvious non-candidate rules we can use the containment operators for the `tsquery` type. In the example below, we select only those rules which might match the original query:

```
SELECT ts_rewrite('a & b'::tsquery,
                  'SELECT t,s FROM aliases WHERE 'a & b'::tsquery
                  @> t');
ts_rewrite
-----
'b' & 'c'
```

### 12.4.3. Triggers for Automatic Updates

#### Note

The method described in this section has been obsoleted by the use of stored generated columns, as described in Section 12.2.2.

When using a separate column to store the `tsvector` representation of your documents, it is necessary to create a trigger to update the `tsvector` column when the document content columns change. Two built-in trigger functions are available for this, or you can write your own.

```
tsvector_update_trigger(tsvector_column_name,
                        config_name, text_column_name [, ... ])
tsvector_update_trigger_column(tsvector_column_name,
                               config_column_name, text_column_name [, ... ])
```

These trigger functions automatically compute a `tsvector` column from one or more textual columns, under the control of parameters specified in the `CREATE TRIGGER` command. An example of their use is:

```
CREATE TABLE messages (
    title      text,
    body       text,
    tsv        tsvector
);

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
ON messages FOR EACH ROW EXECUTE FUNCTION
tsvector_update_trigger(tsv, 'pg_catalog.english', title, body);

INSERT INTO messages VALUES('title here', 'the body text is here');

SELECT * FROM messages;
 title      |          body          |          tsv
-----+-----+-----
 title here | the body text is here | 'bodi':4 'text':5 'titl':1
```



```
SELECT title, body FROM messages WHERE tsv @@ to_tsquery('title &
body');
  title      |          body
-----+-----
title here  | the body text is here
```

Having created this trigger, any change in `title` or `body` will automatically be reflected into `tsv`, without the application having to worry about it.

The first trigger argument must be the name of the `tsvector` column to be updated. The second argument specifies the text search configuration to be used to perform the conversion. For `tsvector_update_trigger`, the configuration name is simply given as the second trigger argument. It must be schema-qualified as shown above, so that the trigger behavior will not change with changes in `search_path`. For `tsvector_update_trigger_column`, the second trigger argument is the name of another table column, which must be of type `regconfig`. This allows a per-row selection of configuration to be made. The remaining argument(s) are the names of textual columns (of type `text`, `varchar`, or `char`). These will be included in the document in the order given. `NULL` values will be skipped (but the other columns will still be indexed).

A limitation of these built-in triggers is that they treat all the input columns alike. To process columns differently — for example, to weight `title` differently from `body` — it is necessary to write a custom trigger. Here is an example using PL/pgSQL as the trigger language:

```
CREATE FUNCTION messages_trigger() RETURNS trigger AS $$
begin
    new.tsv :=
        setweight(to_tsvector('pg_catalog.english',
        coalesce(new.title, '')), 'A') ||
        setweight(to_tsvector('pg_catalog.english',
        coalesce(new.body, '')), 'D');
    return new;
end
$$ LANGUAGE plpgsql;

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
    ON messages FOR EACH ROW EXECUTE FUNCTION messages_trigger();
```

Keep in mind that it is important to specify the configuration name explicitly when creating `tsvector` values inside triggers, so that the column's contents will not be affected by changes to `default_text_search_config`. Failure to do this is likely to lead to problems such as search results changing after a dump and restore.

## 12.4.4. Gathering Document Statistics

The function `ts_stat` is useful for checking your configuration and for finding stop-word candidates.

```
ts_stat(sqlquery text, [ weights text, ]
        OUT word text, OUT ndoc integer,
        OUT nentry integer) returns setof record
```

*sqlquery* is a text value containing an SQL query which must return a single `tsvector` column. `ts_stat` executes the query and returns statistics about each distinct lexeme (word) contained in the `tsvector` data. The columns returned are

- *word* text — the value of a lexeme

- *ndoc* integer — number of documents (*tsvectors*) the word occurred in
- *nentry* integer — total number of occurrences of the word

If *weights* is supplied, only occurrences having one of those weights are counted.

For example, to find the ten most frequent words in a document collection:

```
SELECT * FROM ts_stat('SELECT vector FROM apod')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

The same, but counting only word occurrences with weight A or B:

```
SELECT * FROM ts_stat('SELECT vector FROM apod', 'ab')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

## 12.5. Parsers

Text search parsers are responsible for splitting raw document text into *tokens* and identifying each token's type, where the set of possible types is defined by the parser itself. Note that a parser does not modify the text at all — it simply identifies plausible word boundaries. Because of this limited scope, there is less need for application-specific custom parsers than there is for custom dictionaries. At present LightDB provides just one built-in parser, which has been found to be useful for a wide range of applications.

The built-in parser is named `pg_catalog.default`. It recognizes 23 token types, shown in Table 12.1.

**Table 12.1. Default Parser's Token Types**

Alias	Description	Example
<code>asciiword</code>	Word, all ASCII letters	<code>elephant</code>
<code>word</code>	Word, all letters	<code>mañana</code>
<code>numword</code>	Word, letters and digits	<code>beta1</code>
<code>asciihword</code>	Hyphenated word, all ASCII	<code>up-to-date</code>
<code>hword</code>	Hyphenated word, all letters	<code>lógico-matemática</code>
<code>numhword</code>	Hyphenated word, letters and digits	<code>postgresql-beta1</code>
<code>hword_ascii part</code>	Hyphenated word part, all ASCII	<code>postgresql</code> in the context <code>postgresql-beta1</code>
<code>hword_part</code>	Hyphenated word part, all letters	<code>lógico</code> or <code>matemática</code> in the context <code>lógico-matemática</code>
<code>hword_num part</code>	Hyphenated word part, letters and digits	<code>beta1</code> in the context <code>postgresql-beta1</code>
<code>email</code>	Email address	<code>foo@example.com</code>
<code>protocol</code>	Protocol head	<code>http://</code>
<code>url</code>	URL	<code>example.com/stuff/index.html</code>
<code>host</code>	Host	<code>example.com</code>

Alias	Description	Example
url_path	URL path	/stuff/index.html, in the context of a URL
file	File or path name	/usr/local/foo.txt, if not within a URL
sfloat	Scientific notation	-1.234e56
float	Decimal notation	-1.234
int	Signed integer	-1234
uint	Unsigned integer	1234
version	Version number	8.3.0
tag	XML tag	<a href="dictionaries.html">
entity	XML entity	&amp;
blank	Space symbols	(any whitespace or punctuation not otherwise recognized)

### Note

The parser's notion of a "letter" is determined by the database's locale setting, specifically `lc_ctype`. Words containing only the basic ASCII letters are reported as a separate token type, since it is sometimes useful to distinguish them. In most European languages, token types `word` and `asciiword` should be treated alike.

`email` does not support all valid email characters as defined by RFC 5322. Specifically, the only non-alphanumeric characters supported for email user names are period, dash, and underscore.

It is possible for the parser to produce overlapping tokens from the same piece of text. As an example, a hyphenated word will be reported both as the entire word and as each component:

```
SELECT alias, description, token FROM ts_debug('foo-bar-beta1');
      alias      | description | token
-----+-----+-----
numhword        | Hyphenated word, letters and digits | foo-
bar-beta1
hword_asciipart | Hyphenated word part, all ASCII     | foo
blank           | Space symbols                       | -
hword_asciipart | Hyphenated word part, all ASCII     | bar
blank           | Space symbols                       | -
hword_numpart   | Hyphenated word part, letters and digits | beta1
```

This behavior is desirable since it allows searches to work for both the whole compound word and for components. Here is another instructive example:

```
SELECT alias, description, token FROM ts_debug('http://example.com/
stuff/index.html');
      alias      | description | token
-----+-----+-----
protocol        | Protocol head | http://
url             | URL          | example.com/stuff/index.html
```

host		Host		example.com
url_path		URL path		/stuff/index.html

## 12.6. Dictionaries

Dictionaries are used to eliminate words that should not be considered in a search (*stop words*), and to *normalize* words so that different derived forms of the same word will match. A successfully normalized word is called a *lexeme*. Aside from improving search quality, normalization and removal of stop words reduce the size of the `tsvector` representation of a document, thereby improving performance. Normalization does not always have linguistic meaning and usually depends on application semantics.

Some examples of normalization:

- Linguistic — Ispell dictionaries try to reduce input words to a normalized form; stemmer dictionaries remove word endings
- URL locations can be canonicalized to make equivalent URLs match:
  - `http://www.pgsql.ru/db/mw/index.html`
  - `http://www.pgsql.ru/db/mw/`
  - `http://www.pgsql.ru/db/./db/mw/index.html`
- Color names can be replaced by their hexadecimal values, e.g., `red`, `green`, `blue`, `magenta` → `FF0000`, `00FF00`, `0000FF`, `FF00FF`
- If indexing numbers, we can remove some fractional digits to reduce the range of possible numbers, so for example `3.14159265359`, `3.1415926`, `3.14` will be the same after normalization if only two digits are kept after the decimal point.

A dictionary is a program that accepts a token as input and returns:

- an array of lexemes if the input token is known to the dictionary (notice that one token can produce more than one lexeme)
- a single lexeme with the `TSL_FILTER` flag set, to replace the original token with a new token to be passed to subsequent dictionaries (a dictionary that does this is called a *filtering dictionary*)
- an empty array if the dictionary knows the token, but it is a stop word
- `NULL` if the dictionary does not recognize the input token

LightDB provides predefined dictionaries for many languages. There are also several predefined templates that can be used to create new dictionaries with custom parameters. Each predefined dictionary template is described below. If no existing template is suitable, it is possible to create new ones; see the `contrib/` area of the LightDB distribution for examples.

A text search configuration binds a parser together with a set of dictionaries to process the parser's output tokens. For each token type that the parser can return, a separate list of dictionaries is specified by the configuration. When a token of that type is found by the parser, each dictionary in the list is consulted in turn, until some dictionary recognizes it as a known word. If it is identified as a stop word, or if no dictionary recognizes the token, it will be discarded and not indexed or searched for. Normally, the first dictionary that returns a non-`NULL` output determines the result, and any remaining dictionaries are not consulted; but a filtering dictionary can replace the given word with a modified word, which is then passed to subsequent dictionaries.

The general rule for configuring a list of dictionaries is to place first the most narrow, most specific dictionary, then the more general dictionaries, finishing with a very general dictionary, like a Snowball stemmer or `simple`, which recognizes everything. For example, for an astronomy-specific search (`astro_en` configuration) one could bind token type `asciiword` (ASCII word) to a synonym dictionary of astronomical terms, a general English dictionary and a Snowball English stemmer:

```
ALTER TEXT SEARCH CONFIGURATION astro_en
  ADD MAPPING FOR asciiword WITH astrosyn, english_ispell,
  english_stem;
```

A filtering dictionary can be placed anywhere in the list, except at the end where it'd be useless. Filtering dictionaries are useful to partially normalize words to simplify the task of later dictionaries. For example, a filtering dictionary could be used to remove accents from accented letters, as is done by the `unaccent` module.

## 12.6.1. Stop Words

Stop words are words that are very common, appear in almost every document, and have no discrimination value. Therefore, they can be ignored in the context of full text searching. For example, every English text contains words like `a` and `the`, so it is useless to store them in an index. However, stop words do affect the positions in `tsvector`, which in turn affect ranking:

```
SELECT to_tsvector('english', 'in the list of stop words');
       to_tsvector
-----
 'list':3 'stop':5 'word':6
```

The missing positions 1,2,4 are because of stop words. Ranks calculated for documents with and without stop words are quite different:

```
SELECT ts_rank_cd (to_tsvector('english', 'in the list of stop
                          words'), to_tsquery('list & stop'));
       ts_rank_cd
-----
           0.05
```

```
SELECT ts_rank_cd (to_tsvector('english', 'list stop words'),
                  to_tsquery('list & stop'));
       ts_rank_cd
-----
           0.1
```

It is up to the specific dictionary how it treats stop words. For example, `ispell` dictionaries first normalize words and then look at the list of stop words, while `Snowball` stemmers first check the list of stop words. The reason for the different behavior is an attempt to decrease noise.

## 12.6.2. Simple Dictionary

The `simple` dictionary template operates by converting the input token to lower case and checking it against a file of stop words. If it is found in the file then an empty array is returned, causing the token to be discarded. If not, the lower-cased form of the word is returned as the normalized lexeme. Alternatively, the dictionary can be configured to report non-stop-words as unrecognized, allowing them to be passed on to the next dictionary in the list.

Here is an example of a dictionary definition using the `simple` template:

```
CREATE TEXT SEARCH DICTIONARY public.simple_dict (
    TEMPLATE = pg_catalog.simple,
    STOPWORDS = english
);
```

Here, `english` is the base name of a file of stop words. The file's full name will be `$$SHAREDIR/tsearch_data/english.stop`, where `$$SHAREDIR` means the `LightDB` installation's shared-data directory, often `/usr/local/share/postgresql` (use `lt_config --sharedir` to determine it if you're not sure). The file format is simply a list of words, one per line. Blank lines and

trailing spaces are ignored, and upper case is folded to lower case, but no other processing is done on the file contents.

Now we can test our dictionary:

```
SELECT ts_lexize('public.simple_dict', 'Yes');
ts_lexize
-----
{yes}

SELECT ts_lexize('public.simple_dict', 'The');
ts_lexize
-----
{}
```

We can also choose to return NULL, instead of the lower-cased word, if it is not found in the stop words file. This behavior is selected by setting the dictionary's `Accept` parameter to `false`. Continuing the example:

```
ALTER TEXT SEARCH DICTIONARY public.simple_dict ( Accept = false );

SELECT ts_lexize('public.simple_dict', 'Yes');
ts_lexize
-----

SELECT ts_lexize('public.simple_dict', 'The');
ts_lexize
-----
{}
```

With the default setting of `Accept = true`, it is only useful to place a `simple` dictionary at the end of a list of dictionaries, since it will never pass on any token to a following dictionary. Conversely, `Accept = false` is only useful when there is at least one following dictionary.

### Caution

Most types of dictionaries rely on configuration files, such as files of stop words. These files *must* be stored in UTF-8 encoding. They will be translated to the actual database encoding, if that is different, when they are read into the server.

### Caution

Normally, a database session will read a dictionary configuration file only once, when it is first used within the session. If you modify a configuration file and want to force existing sessions to pick up the new contents, issue an `ALTER TEXT SEARCH DICTIONARY` command on the dictionary. This can be a “dummy” update that doesn't actually change any parameter values.

## 12.6.3. Synonym Dictionary

This dictionary template is used to create dictionaries that replace a word with a synonym. Phrases are not supported (use the thesaurus template (Section 12.6.4) for that). A synonym dictionary can be used

to overcome linguistic problems, for example, to prevent an English stemmer dictionary from reducing the word “Paris” to “pari”. It is enough to have a `Paris pari` line in the synonym dictionary and put it before the `english_stem` dictionary. For example:

```
SELECT * FROM ts_debug('english', 'Paris');
  alias | description | token | dictionaries | dictionary
  | lexemes
-----+-----+-----+-----
+-----+-----
  asciiword | Word, all ASCII | Paris | {english_stem} |
  english_stem | {pari}

CREATE TEXT SEARCH DICTIONARY my_synonym (
  TEMPLATE = synonym,
  SYNONYMS = my_synonyms
);

ALTER TEXT SEARCH CONFIGURATION english
  ALTER MAPPING FOR asciiword
  WITH my_synonym, english_stem;
```

```
SELECT * FROM ts_debug('english', 'Paris');
  alias | description | token | dictionaries |
  dictionary | lexemes
-----+-----+-----+-----
+-----+-----
  asciiword | Word, all ASCII | Paris | {my_synonym,english_stem} |
  my_synonym | {pari}
```

The only parameter required by the `synonym` template is `SYNONYMS`, which is the base name of its configuration file — `my_synonyms` in the above example. The file's full name will be `$$SHAREDIR/tsearch_data/my_synonyms.syn` (where `$$SHAREDIR` means the LightDB installation's shared-data directory). The file format is just one line per word to be substituted, with the word followed by its synonym, separated by white space. Blank lines and trailing spaces are ignored.

The `synonym` template also has an optional parameter `CaseSensitive`, which defaults to `false`. When `CaseSensitive` is `false`, words in the synonym file are folded to lower case, as are input tokens. When it is `true`, words and tokens are not folded to lower case, but are compared as-is.

An asterisk (\*) can be placed at the end of a synonym in the configuration file. This indicates that the synonym is a prefix. The asterisk is ignored when the entry is used in `to_tsvector()`, but when it is used in `to_tsquery()`, the result will be a query item with the prefix match marker (see Section 12.3.2). For example, suppose we have these entries in `$$SHAREDIR/tsearch_data/synonym_sample.syn`:

```
postgres      pgsql
postgresql    pgsql
postgre pgsql
google        googl
indices index*
```

Then we will get these results:

```
mydb=# CREATE TEXT SEARCH DICTIONARY syn (template=synonym,
  synonyms='synonym_sample');
mydb=# SELECT ts_lexize('syn', 'indices');
```

```

ts_lexize
-----
{index}
(1 row)

mydb=# CREATE TEXT SEARCH CONFIGURATION tst (copy=simple);
mydb=# ALTER TEXT SEARCH CONFIGURATION tst ALTER MAPPING FOR
  asciiword WITH syn;
mydb=# SELECT to_tsvector('tst', 'indices');
  to_tsvector
-----
 'index':1
(1 row)

mydb=# SELECT to_tsquery('tst', 'indices');
  to_tsquery
-----
 'index':*
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector;
  tsvector
-----
 'are' 'indexes' 'useful' 'very'
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector @@
  to_tsquery('tst', 'indices');
 ?column?
-----
 t
(1 row)

```

## 12.6.4. Thesaurus Dictionary

A thesaurus dictionary (sometimes abbreviated as TZ) is a collection of words that includes information about the relationships of words and phrases, i.e., broader terms (BT), narrower terms (NT), preferred terms, non-preferred terms, related terms, etc.

Basically a thesaurus dictionary replaces all non-preferred terms by one preferred term and, optionally, preserves the original terms for indexing as well. LightDB's current implementation of the thesaurus dictionary is an extension of the synonym dictionary with added *phrase* support. A thesaurus dictionary requires a configuration file of the following format:

```

# this is a comment
sample word(s) : indexed word(s)
more sample word(s) : more indexed word(s)
...

```

where the colon (:) symbol acts as a delimiter between a phrase and its replacement.

A thesaurus dictionary uses a *subdictionary* (which is specified in the dictionary's configuration) to normalize the input text before checking for phrase matches. It is only possible to select one *subdictionary*. An error is reported if the *subdictionary* fails to recognize a word. In that case, you should remove the use of the word or teach the *subdictionary* about it. You can place an asterisk (\*) at the beginning of an indexed word to skip applying the *subdictionary* to it, but all sample words *must* be known to the *subdictionary*.



The thesaurus dictionary chooses the longest match if there are multiple phrases matching the input, and ties are broken by using the last definition.

Specific stop words recognized by the subdictionary cannot be specified; instead use ? to mark the location where any stop word can appear. For example, assuming that a and the are stop words according to the subdictionary:

```
? one ? two : ssw
```

matches a one the two and the one a two; both would be replaced by ssw.

Since a thesaurus dictionary has the capability to recognize phrases it must remember its state and interact with the parser. A thesaurus dictionary uses these assignments to check if it should handle the next word or stop accumulation. The thesaurus dictionary must be configured carefully. For example, if the thesaurus dictionary is assigned to handle only the `asciiword` token, then a thesaurus dictionary definition like `one ?` will not work since token type `uint` is not assigned to the thesaurus dictionary.

### Caution

Thesauruses are used during indexing so any change in the thesaurus dictionary's parameters *requires* reindexing. For most other dictionary types, small changes such as adding or removing stopwords does not force reindexing.

## 12.6.4.1. Thesaurus Configuration

To define a new thesaurus dictionary, use the `thesaurus` template. For example:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_simple (  
    TEMPLATE = thesaurus,  
    DictFile = mythesaurus,  
    Dictionary = pg_catalog.english_stem  
);
```

Here:

- `thesaurus_simple` is the new dictionary's name
- `mythesaurus` is the base name of the thesaurus configuration file. (Its full name will be `$SHAREDIR/tsearch_data/mythesaurus.ths`, where `$SHAREDIR` means the installation shared-data directory.)
- `pg_catalog.english_stem` is the subdictionary (here, a Snowball English stemmer) to use for thesaurus normalization. Notice that the subdictionary will have its own configuration (for example, stop words), which is not shown here.

Now it is possible to bind the thesaurus dictionary `thesaurus_simple` to the desired token types in a configuration, for example:

```
ALTER TEXT SEARCH CONFIGURATION russian  
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart  
    WITH thesaurus_simple;
```

## 12.6.4.2. Thesaurus Example

Consider a simple astronomical thesaurus `thesaurus_astro`, which contains some astronomical word combinations:

```
supernovae stars : sn
crab nebulae : crab
```

Below we create a dictionary and bind some token types to an astronomical thesaurus and English stemmer:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_astro (
    TEMPLATE = thesaurus,
    DictFile = thesaurus_astro,
    Dictionary = english_stem
);

ALTER TEXT SEARCH CONFIGURATION russian
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart
    WITH thesaurus_astro, english_stem;
```

Now we can see how it works. `ts_lexize` is not very useful for testing a thesaurus, because it treats its input as a single token. Instead we can use `plainto_tsquery` and `to_tsvector` which will break their input strings into multiple tokens:

```
SELECT plainto_tsquery('supernova star');
plainto_tsquery
-----
'sn'

SELECT to_tsvector('supernova star');
to_tsvector
-----
'sn':1
```

In principle, one can use `to_tsquery` if you quote the argument:

```
SELECT to_tsquery(''supernova star'');
to_tsquery
-----
'sn'
```

Notice that `supernova star` matches `supernovae stars` in `thesaurus_astro` because we specified the `english_stem` stemmer in the thesaurus definition. The stemmer removed the `e` and `s`.

To index the original phrase as well as the substitute, just include it in the right-hand part of the definition:

```
supernovae stars : sn supernovae stars

SELECT plainto_tsquery('supernova star');
plainto_tsquery
-----
'sn' & 'supernova' & 'star'
```

## 12.6.5. Ispell Dictionary

The Ispell dictionary template supports *morphological dictionaries*, which can normalize many different linguistic forms of a word into the same lexeme. For example, an English Ispell dictionary can

match all declensions and conjugations of the search term bank, e.g., banking, banked, banks, banks', and bank's.

The standard LightDB distribution does not include any Ispell configuration files. Dictionaries for a large number of languages are available from Ispell<sup>1</sup>. Also, some more modern dictionary file formats are supported — MySpell<sup>2</sup> (OO < 2.0.1) and Hunspell<sup>3</sup> (OO >= 2.0.2). A large list of dictionaries is available on the OpenOffice Wiki<sup>4</sup>.

To create an Ispell dictionary perform these steps:

- download dictionary configuration files. OpenOffice extension files have the .oxt extension. It is necessary to extract .aff and .dic files, change extensions to .affix and .dict. For some dictionary files it is also needed to convert characters to the UTF-8 encoding with commands (for example, for a Norwegian language dictionary):

```
iconv -f ISO_8859-1 -t UTF-8 -o nn_no.affix nn_NO.aff
iconv -f ISO_8859-1 -t UTF-8 -o nn_no.dict nn_NO.dic
```

- copy files to the \$SHAREDIR/tsearch\_data directory
- load files into LightDB with the following command:

```
CREATE TEXT SEARCH DICTIONARY english_hunspell (
    TEMPLATE = ispell,
    DictFile = en_us,
    AffFile = en_us,
    Stopwords = english);
```

Here, DictFile, AffFile, and StopWords specify the base names of the dictionary, affixes, and stop-words files. The stop-words file has the same format explained above for the simple dictionary type. The format of the other files is not specified here but is available from the above-mentioned web sites.

Ispell dictionaries usually recognize a limited set of words, so they should be followed by another broader dictionary; for example, a Snowball dictionary, which recognizes everything.

The .affix file of Ispell has the following structure:

```
prefixes
flag *A:
    . > RE # As in enter > reenter
suffixes
flag T:
    E > ST # As in late > latest
    [^AEIOU]Y > -Y, IEST # As in dirty > dirtiest
    [AEIOU]Y > EST # As in gray > grayest
    [^EY] > EST # As in small > smallest
```

And the .dict file has the following structure:

```
lapse/ADGRS
lard/DGRS
large/PRTY
```

<sup>1</sup> <https://www.cs.hmc.edu/~geoff/ispell.html>

<sup>2</sup> <https://en.wikipedia.org/wiki/MySpell>

<sup>3</sup> <https://sourceforge.net/projects/hunspell/>

<sup>4</sup> <https://wiki.openoffice.org/wiki/Dictionaries>

lark/MRS

Format of the .dict file is:

basic\_form/affix\_class\_name

In the .affix file every affix flag is described in the following format:

```
condition > [-stripping_letters,] adding_affix
```

Here, condition has a format similar to the format of regular expressions. It can use groupings [...] and [^...]. For example, [AEIOU]Y means that the last letter of the word is "y" and the penultimate letter is "a", "e", "i", "o" or "u". [^EY] means that the last letter is neither "e" nor "y".

Ispell dictionaries support splitting compound words; a useful feature. Notice that the affix file should specify a special flag using the compoundwords controlled statement that marks dictionary words that can participate in compound formation:

```
compoundwords controlled z
```

Here are some examples for the Norwegian language:

```
SELECT ts_lexize('norwegian_ispell',
  'overbuljongterningpakkmasterassistent');
  {over,buljong,terning,pakk,mester,assistent}
SELECT ts_lexize('norwegian_ispell', 'sjokoladefabrikk');
  {sjokoladefabrikk,sjokolade,fabrikk}
```

MySpell format is a subset of Hunspell. The .affix file of Hunspell has the following structure:

```
PFX A Y 1
PFX A 0 re .
SFX T N 4
SFX T 0 st e
SFX T y iest [^aeiouly
SFX T 0 est [aeiouly
SFX T 0 est [^ey]
```

The first line of an affix class is the header. Fields of an affix rules are listed after the header:

- parameter name (PFX or SFX)
- flag (name of the affix class)
- stripping characters from beginning (at prefix) or end (at suffix) of the word
- adding affix
- condition that has a format similar to the format of regular expressions.

The .dict file looks like the .dict file of Ispell:

```
larder/M
lardy/RT
large/RSPMYT
largehearted
```

**Note**

MySpell does not support compound words. Hunspell has sophisticated support for compound words. At present, LightDB implements only the basic compound word operations of Hunspell.

## 12.6.6. Snowball Dictionary

The Snowball dictionary template is based on a project by Martin Porter, inventor of the popular Porter's stemming algorithm for the English language. Snowball now provides stemming algorithms for many languages (see the Snowball site<sup>5</sup> for more information). Each algorithm understands how to reduce common variant forms of words to a base, or stem, spelling within its language. A Snowball dictionary requires a `language` parameter to identify which stemmer to use, and optionally can specify a `stopword` file name that gives a list of words to eliminate. (LightDB's standard stopword lists are also provided by the Snowball project.) For example, there is a built-in definition equivalent to

```
CREATE TEXT SEARCH DICTIONARY english_stem (
    TEMPLATE = snowball,
    Language = english,
    StopWords = english
);
```

The stopword file format is the same as already explained.

A Snowball dictionary recognizes everything, whether or not it is able to simplify the word, so it should be placed at the end of the dictionary list. It is useless to have it before any other dictionary because a token will never pass through it to the next dictionary.

## 12.7. Configuration Example

A text search configuration specifies all options necessary to transform a document into a `tsvector`: the parser to use to break text into tokens, and the dictionaries to use to transform each token into a lexeme. Every call of `to_tsvector` or `to_tsquery` needs a text search configuration to perform its processing. The configuration parameter `default_text_search_config` specifies the name of the default configuration, which is the one used by text search functions if an explicit configuration parameter is omitted. It can be set in `lightdb.conf`, or set for an individual session using the `SET` command.

Several predefined text search configurations are available, and you can create custom configurations easily. To facilitate management of text search objects, a set of SQL commands is available, and there are several `ltsql` commands that display information about text search objects (Section 12.10).

As an example we will create a configuration `lt`, starting by duplicating the built-in `english` configuration:

```
CREATE TEXT SEARCH CONFIGURATION public.lt ( COPY =
    pg_catalog.english );
```

We will use a LightDB-specific synonym list and store it in `$$SHAREDIR/tsearch_data/lt_dict.syn`. The file contents look like:

```
postgres    lt
```

<sup>5</sup> <https://snowballstem.org/>

```
pgsql      lt
postgres  lt
```

We define the synonym dictionary like this:

```
CREATE TEXT SEARCH DICTIONARY lt_dict (
    TEMPLATE = synonym,
    SYNONYMS = lt_dict
);
```

Next we register the Ispell dictionary `english_ispell`, which has its own configuration files:

```
CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);
```

Now we can set up the mappings for words in configuration `lt`:

```
ALTER TEXT SEARCH CONFIGURATION lt
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart,
                    word, hword, hword_part
    WITH lt_dict, english_ispell, english_stem;
```

We choose not to index or search some token types that the built-in configuration does handle:

```
ALTER TEXT SEARCH CONFIGURATION lt
    DROP MAPPING FOR email, url, url_path, sfloat, float;
```

Now we can test our configuration:

```
SELECT * FROM ts_debug('public.lt', '
LightDB, the highly scalable, SQL compliant, open source object-
relational
database management system, is now undergoing beta testing of the
next
version of our software.
');
```

The next step is to set the session to use the new configuration, which was created in the `public` schema:

```
=> \dF
    List of text search configurations
 Schema | Name | Description
-----+-----+-----
 public | lt   |

SET default_text_search_config = 'public.lt';
SET

SHOW default_text_search_config;
```

```
default_text_search_config
```

```
-----
public.lt
```

## 12.8. Testing and Debugging Text Search

The behavior of a custom text search configuration can easily become confusing. The functions described in this section are useful for testing text search objects. You can test a complete configuration, or test parsers and dictionaries separately.

### 12.8.1. Configuration Testing

The function `ts_debug` allows easy testing of a text search configuration.

```
ts_debug([ config regconfig, ] document text,
         OUT alias text,
         OUT description text,
         OUT token text,
         OUT dictionaries regdictionary[],
         OUT dictionary regdictionary,
         OUT lexemes text[])
returns setof record
```

`ts_debug` displays information about every token of *document* as produced by the parser and processed by the configured dictionaries. It uses the configuration specified by *config*, or `default_text_search_config` if that argument is omitted.

`ts_debug` returns one row for each token identified in the text by the parser. The columns returned are

- *alias text* — short name of the token type
- *description text* — description of the token type
- *token text* — text of the token
- *dictionaries regdictionary[]* — the dictionaries selected by the configuration for this token type
- *dictionary regdictionary* — the dictionary that recognized the token, or NULL if none did
- *lexemes text[]* — the lexeme(s) produced by the dictionary that recognized the token, or NULL if none did; an empty array ({} ) means it was recognized as a stop word

Here is a simple example:

```
SELECT * FROM ts_debug('english', 'a fat  cat sat on a mat - it ate
a fat rats');
  alias | description | token | dictionaries | dictionary
  | lexemes
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
asciiword | Word, all ASCII | a | {english_stem} |
english_stem | {}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | fat | {english_stem} |
english_stem | {fat}
blank | Space symbols | | {} |
|
```

```

asciiword | Word, all ASCII | cat | {english_stem} |
english_stem | {cat}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | sat | {english_stem} |
english_stem | {sat}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | on | {english_stem} |
english_stem | {}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | a | {english_stem} |
english_stem | {}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | mat | {english_stem} |
english_stem | {mat}
blank | Space symbols | | {} |
|
blank | Space symbols | - | {} |
|
asciiword | Word, all ASCII | it | {english_stem} |
english_stem | {}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | ate | {english_stem} |
english_stem | {ate}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | a | {english_stem} |
english_stem | {}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | fat | {english_stem} |
english_stem | {fat}
blank | Space symbols | | {} |
|
asciiword | Word, all ASCII | rats | {english_stem} |
english_stem | {rat}

```

For a more extensive demonstration, we first create a `public.english` configuration and Ispell dictionary for the English language:

```

CREATE TEXT SEARCH CONFIGURATION public.english ( COPY =
pg_catalog.english );

CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);

ALTER TEXT SEARCH CONFIGURATION public.english
    ALTER MAPPING FOR asciiword WITH english_ispell, english_stem;

```



```

SELECT * FROM ts_debug('public.english', 'The Brightest
supernovaes');
  alias | description | token | dictionaries
        | dictionary | lexemes
-----+-----+-----+-----
+-----+-----+-----+-----
asciiword | Word, all ASCII | The |
{english_ispell,english_stem} | english_ispell | {}
blank | Space symbols | | {}
| | |
asciiword | Word, all ASCII | Brightest |
{english_ispell,english_stem} | english_ispell | {bright}
blank | Space symbols | | {}
| | |
asciiword | Word, all ASCII | supernovaes |
{english_ispell,english_stem} | english_stem | {supernova}

```

In this example, the word `Brightest` was recognized by the parser as an ASCII word (alias `asciiword`). For this token type the dictionary list is `english_ispell` and `english_stem`. The word was recognized by `english_ispell`, which reduced it to the noun `bright`. The word `supernovaes` is unknown to the `english_ispell` dictionary so it was passed to the next dictionary, and, fortunately, was recognized (in fact, `english_stem` is a Snowball dictionary which recognizes everything; that is why it was placed at the end of the dictionary list).

The word `The` was recognized by the `english_ispell` dictionary as a stop word (Section 12.6.1) and will not be indexed. The spaces are discarded too, since the configuration provides no dictionaries at all for them.

You can reduce the width of the output by explicitly specifying which columns you want to see:

```

SELECT alias, token, dictionary, lexemes
FROM ts_debug('public.english', 'The Brightest supernovaes');
  alias | token | dictionary | lexemes
-----+-----+-----+-----
asciiword | The | english_ispell | {}
blank | | |
asciiword | Brightest | english_ispell | {bright}
blank | | |
asciiword | supernovaes | english_stem | {supernova}

```

## 12.8.2. Parser Testing

The following functions allow direct testing of a text search parser.

```

ts_parse(parser_name text, document text,
         OUT tokid integer, OUT token text) returns setof record
ts_parse(parser_oid oid, document text,
         OUT tokid integer, OUT token text) returns setof record

```

`ts_parse` parses the given *document* and returns a series of records, one for each token produced by parsing. Each record includes a `tokid` showing the assigned token type and a `token` which is the text of the token. For example:

```

SELECT * FROM ts_parse('default', '123 - a number');
 tokid | token

```

```

-----+-----
22 | 123
12 |
12 | -
1  | a
12 |
1  | number

```

`ts_token_type(parser_name text, OUT tokid integer, OUT alias text, OUT description text)` returns setof record

`ts_token_type(parser_oid oid, OUT tokid integer, OUT alias text, OUT description text)` returns setof record

`ts_token_type` returns a table which describes each type of token the specified parser can recognize. For each token type, the table gives the integer `tokid` that the parser uses to label a token of that type, the `alias` that names the token type in configuration commands, and a short description. For example:

```

SELECT * FROM ts_token_type('default');
 tokid |      alias      |      description

```

```

-----+-----
+-----+-----
1  | asciiword      | Word, all ASCII
2  | word           | Word, all letters
3  | numword        | Word, letters and digits
4  | email          | Email address
5  | url            | URL
6  | host           | Host
7  | sfloat         | Scientific notation
8  | version        | Version number
9  | hword_numpart  | Hyphenated word part, letters and digits
10 | hword_part     | Hyphenated word part, all letters
11 | hword_asciipart | Hyphenated word part, all ASCII
12 | blank          | Space symbols
13 | tag            | XML tag
14 | protocol       | Protocol head
15 | numhword       | Hyphenated word, letters and digits
16 | asciihword     | Hyphenated word, all ASCII
17 | hword          | Hyphenated word, all letters
18 | url_path       | URL path
19 | file           | File or path name
20 | float          | Decimal notation
21 | int            | Signed integer
22 | uint           | Unsigned integer
23 | entity         | XML entity

```

### 12.8.3. Dictionary Testing

The `ts_lexize` function facilitates dictionary testing.

`ts_lexize(dict regdictionary, token text)` returns `text[]`

`ts_lexize` returns an array of lexemes if the input *token* is known to the dictionary, or an empty array if the token is known to the dictionary but it is a stop word, or NULL if it is an unknown word.

Examples:

```
SELECT ts_lexize('english_stem', 'stars');
 ts_lexize
-----
 {star}

SELECT ts_lexize('english_stem', 'a');
 ts_lexize
-----
 {}
```

### Note

The `ts_lexize` function expects a single *token*, not text. Here is a case where this can be confusing:

```
SELECT ts_lexize('thesaurus_astro', 'supernovae stars')
 is null;
?column?
-----
 t
```

The thesaurus dictionary `thesaurus_astro` does know the phrase `supernovae stars`, but `ts_lexize` fails since it does not parse the input text but treats it as a single token. Use `plainto_tsquery` or `to_tsvector` to test thesaurus dictionaries, for example:

```
SELECT plainto_tsquery('supernovae stars');
 plainto_tsquery
-----
 'sn'
```

## 12.9. Preferred Index Types for Text Search

There are two kinds of indexes that can be used to speed up full text searches: GIN and GiST. Note that indexes are not mandatory for full text searching, but in cases where a column is searched on a regular basis, an index is usually desirable.

To create such an index, do one of:

```
CREATE INDEX name ON table USING GIN (column);
```

Creates a GIN (Generalized Inverted Index)-based index. The *column* must be of `tsvector` type.

```
CREATE INDEX name ON table USING GIST (column [ { DEFAULT |
tsvector_ops } (siglen = number) ] );
```

Creates a GiST (Generalized Search Tree)-based index. The *column* can be of `tsvector` or `tsquery` type. Optional integer parameter *siglen* determines signature length in bytes (see below for details).

GIN indexes are the preferred text search index type. As inverted indexes, they contain an index entry for each word (lexeme), with a compressed list of matching locations. Multi-word searches can find the first match, then use the index to remove rows that are lacking additional words. GIN indexes store only the words (lexemes) of `tsvector` values, and not their weight labels. Thus a table row recheck is needed when using a query that involves weights.

A GiST index is *lossy*, meaning that the index might produce false matches, and it is necessary to check the actual table row to eliminate such false matches. (LightDB does this automatically when needed.) GiST indexes are lossy because each document is represented in the index by a fixed-length signature. The signature length in bytes is determined by the value of the optional integer parameter `siglen`. The default signature length (when `siglen` is not specified) is 124 bytes, the maximum signature length is 2024 bytes. The signature is generated by hashing each word into a single bit in an `n`-bit string, with all these bits OR-ed together to produce an `n`-bit document signature. When two words hash to the same bit position there will be a false match. If all words in the query have matches (real or false) then the table row must be retrieved to see if the match is correct. Longer signatures lead to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

A GiST index can be covering, i.e., use the `INCLUDE` clause. Included columns can have data types without any GiST operator class. Included attributes will be stored uncompressed.

Lossiness causes performance degradation due to unnecessary fetches of table records that turn out to be false matches. Since random access to table records is slow, this limits the usefulness of GiST indexes. The likelihood of false matches depends on several factors, in particular the number of unique words, so using dictionaries to reduce this number is recommended.

Note that GIN index build time can often be improved by increasing `maintenance_work_mem`, while GiST index build time is not sensitive to that parameter.

Partitioning of big collections and the proper use of GIN and GiST indexes allows the implementation of very fast searches with online update. Partitioning can be done at the database level using table inheritance, or by distributing documents over servers and collecting external search results, e.g., via Foreign Data access. The latter is possible because ranking functions use only local information.

## 12.10. Itsql Support

Information about text search configuration objects can be obtained in Itsql using a set of commands:

```
\dF{d,p,t}[+] [PATTERN]
```

An optional `+` produces more details.

The optional parameter `PATTERN` can be the name of a text search object, optionally schema-qualified. If `PATTERN` is omitted then information about all visible objects will be displayed. `PATTERN` can be a regular expression and can provide *separate* patterns for the schema and object names. The following examples illustrate this:

```
=> \dF *fulltext*
      List of text search configurations
 Schema | Name           | Description
-----+-----+-----
 public | fulltext_cfg |
```

```
=> \dF *.fulltext*
      List of text search configurations
 Schema | Name           | Description
```

```
-----+-----
fulltext | fulltext_cfg |
public   | fulltext_cfg |
```

The available commands are:

```
\dF[+] [PATTERN]
```

List text search configurations (add + for more detail).

```
=> \dF russian
```

```

List of text search configurations
  Schema | Name | Description
-----+-----
pg_catalog | russian | configuration for russian language
```

```
=> \dF+ russian
```

```
Text search configuration "pg_catalog.russian"
```

```
Parser: "pg_catalog.default"
```

```

Token | Dictionaries
-----+-----
asciihword | english_stem
asciword   | english_stem
email      | simple
file       | simple
float      | simple
host       | simple
hword      | russian_stem
hword_asciipart | english_stem
hword_numpart | simple
hword_part | russian_stem
int        | simple
numhword   | simple
numword    | simple
sfloat     | simple
uint       | simple
url        | simple
url_path   | simple
version    | simple
word       | russian_stem
```

```
\dFd[+] [PATTERN]
```

List text search dictionaries (add + for more detail).

```
=> \dFd
```

```

List of text search dictionaries
  Schema | Name | Description
-----+-----
pg_catalog | arabic_stem | snowball stemmer for arabic language
pg_catalog | danish_stem | snowball stemmer for danish language
pg_catalog | dutch_stem | snowball stemmer for dutch language
```

```

pg_catalog | english_stem | snowball stemmer for english
language
pg_catalog | finnish_stem | snowball stemmer for finnish
language
pg_catalog | french_stem | snowball stemmer for french
language
pg_catalog | german_stem | snowball stemmer for german
language
pg_catalog | greek_stem | snowball stemmer for greek
language
pg_catalog | hungarian_stem | snowball stemmer for hungarian
language
pg_catalog | indonesian_stem | snowball stemmer for indonesian
language
pg_catalog | irish_stem | snowball stemmer for irish
language
pg_catalog | italian_stem | snowball stemmer for italian
language
pg_catalog | lithuanian_stem | snowball stemmer for lithuanian
language
pg_catalog | nepali_stem | snowball stemmer for nepali
language
pg_catalog | norwegian_stem | snowball stemmer for norwegian
language
pg_catalog | portuguese_stem | snowball stemmer for portuguese
language
pg_catalog | romanian_stem | snowball stemmer for romanian
language
pg_catalog | russian_stem | snowball stemmer for russian
language
pg_catalog | simple | simple dictionary: just lower
case and check for stopword
pg_catalog | spanish_stem | snowball stemmer for spanish
language
pg_catalog | swedish_stem | snowball stemmer for swedish
language
pg_catalog | tamil_stem | snowball stemmer for tamil
language
pg_catalog | turkish_stem | snowball stemmer for turkish
language

```

`\dFp[+] [PATTERN]`

List text search parsers (add + for more detail).

```

=> \dFp
      List of text search parsers
      Schema | Name | Description
      -----+-----+-----
pg_catalog | default | default word parser
=> \dFp+
      Text search parser "pg_catalog.default"
      Method | Function | Description
      -----+-----+-----
Start parse | prsd_start |
Get next token | prsd_nexttoken |
End parse | prsd_end |
Get headline | prsd_headline |

```

```
Get token types | prsd_lextype |
```

Token types for parser "pg_catalog.default"	
Token name	Description
asciihword	Hyphenated word, all ASCII
asciiword	Word, all ASCII
blank	Space symbols
email	Email address
entity	XML entity
file	File or path name
float	Decimal notation
host	Host
hword	Hyphenated word, all letters
hword_asciipart	Hyphenated word part, all ASCII
hword_numpart	Hyphenated word part, letters and digits
hword_part	Hyphenated word part, all letters
int	Signed integer
numhword	Hyphenated word, letters and digits
numword	Word, letters and digits
protocol	Protocol head
sfloat	Scientific notation
tag	XML tag
uint	Unsigned integer
url	URL
url_path	URL path
version	Version number
word	Word, all letters

(23 rows)

```
\dFt[+] [PATTERN]
```

List text search templates (add + for more detail).

```
=> \dFt
```

List of text search templates		
Schema	Name	Description
pg_catalog	ispell	ispell dictionary
pg_catalog	simple	simple dictionary: just lower case and check for stopword
pg_catalog	snowball	snowball stemmer
pg_catalog	synonym	synonym dictionary: replace word by its synonym
pg_catalog	thesaurus	thesaurus dictionary: phrase by phrase substitution

## 12.11. Limitations

The current limitations of LightDB's text search features are:

- The length of each lexeme must be less than 2 kilobytes
- The length of a `tsvector` (lexemes + positions) must be less than 1 megabyte
- The number of lexemes must be less than  $2^{64}$
- Position values in `tsvector` must be greater than 0 and no more than 16,383

- The match distance in a  $\langle N \rangle$  (FOLLOWED BY) `tsquery` operator cannot be more than 16,384
- No more than 256 positions per lexeme
- The number of nodes (lexemes + operators) in a `tsquery` must be less than 32,768

For comparison, the LightDB 8.1 documentation contained 10,441 unique words, a total of 335,420 words, and the most frequent word “postgresql” was mentioned 6,127 times in 655 documents.

Another example — the LightDB mailing list archives contained 910,989 unique words with 57,491,343 lexemes in 461,020 messages.



---

# Chapter 13. Concurrency Control

This chapter describes the behavior of the LightDB database system when two or more sessions try to access the same data at the same time. The goals in that situation are to allow efficient access for all sessions while maintaining strict data integrity. Every developer of database applications should be familiar with the topics covered in this chapter.

## 13.1. Introduction

LightDB provides a rich set of tools for developers to manage concurrent access to data. Internally, data consistency is maintained by using a multiversion model (Multiversion Concurrency Control, MVCC). This means that each SQL statement sees a snapshot of data (a *database version*) as it was some time ago, regardless of the current state of the underlying data. This prevents statements from viewing inconsistent data produced by concurrent transactions performing updates on the same data rows, providing *transaction isolation* for each database session. MVCC, by eschewing the locking methodologies of traditional database systems, minimizes lock contention in order to allow for reasonable performance in multiuser environments.

The main advantage of using the MVCC model of concurrency control rather than locking is that in MVCC locks acquired for querying (reading) data do not conflict with locks acquired for writing data, and so reading never blocks writing and writing never blocks reading. LightDB maintains this guarantee even when providing the strictest level of transaction isolation through the use of an innovative *Serializable Snapshot Isolation* (SSI) level.

Table- and row-level locking facilities are also available in LightDB for applications which don't generally need full transaction isolation and prefer to explicitly manage particular points of conflict. However, proper use of MVCC will generally provide better performance than locks. In addition, application-defined advisory locks provide a mechanism for acquiring locks that are not tied to a single transaction.

## 13.2. Transaction Isolation

The SQL standard defines four levels of transaction isolation. The most strict is Serializable, which is defined by the standard in a paragraph which says that any concurrent execution of a set of Serializable transactions is guaranteed to produce the same effect as running them one at a time in some order. The other three levels are defined in terms of phenomena, resulting from interaction between concurrent transactions, which must not occur at each level. The standard notes that due to the definition of Serializable, none of these phenomena are possible at that level. (This is hardly surprising -- if the effect of the transactions must be consistent with having been run one at a time, how could you see any phenomena caused by interactions?)

The phenomena which are prohibited at various levels are:

dirty read

A transaction reads data written by a concurrent uncommitted transaction.

nonrepeatable read

A transaction re-reads data it has previously read and finds that data has been modified by another transaction (that committed since the initial read).

phantom read

A transaction re-executes a query returning a set of rows that satisfy a search condition and finds that the set of rows satisfying the condition has changed due to another recently-committed transaction.

serialization anomaly

The result of successfully committing a group of transactions is inconsistent with all possible orderings of running those transactions one at a time.

The SQL standard and LightDB-implemented transaction isolation levels are described in Table 13.1.

**Table 13.1. Transaction Isolation Levels**

Isolation Level	Dirty Read	Nonrepeatable Read	Phantom Read	Serialization Anomaly
Read uncommitted	Allowed, but not in LightDB	Possible	Possible	Possible
Read committed	Not possible	Possible	Possible	Possible
Repeatable read	Not possible	Not possible	Allowed, but not in LightDB	Possible
Serializable	Not possible	Not possible	Not possible	Not possible

In LightDB, you can request any of the four standard transaction isolation levels, but internally only three distinct isolation levels are implemented, i.e., LightDB's Read Uncommitted mode behaves like Read Committed. This is because it is the only sensible way to map the standard isolation levels to LightDB's multiversion concurrency control architecture.

The table also shows that LightDB's Repeatable Read implementation does not allow phantom reads. This is acceptable under the SQL standard because the standard specifies which anomalies must *not* occur at certain isolation levels; higher guarantees are acceptable. The behavior of the available isolation levels is detailed in the following subsections.

To set the transaction isolation level of a transaction, use the command SET TRANSACTION.

### Important

Some LightDB data types and functions have special rules regarding transactional behavior. In particular, changes made to a sequence (and therefore the counter of a column declared using `serial`) are immediately visible to all other transactions and are not rolled back if the transaction that made the changes aborts. See Section 9.17 and Section 8.1.4.

## 13.2.1. Read Committed Isolation Level

*Read Committed* is the default isolation level in LightDB. When a transaction uses this isolation level, a `SELECT` query (without a `FOR UPDATE/SHARE` clause) sees only data committed before the query began; it never sees either uncommitted data or changes committed during query execution by concurrent transactions. In effect, a `SELECT` query sees a snapshot of the database as of the instant the query begins to run. However, `SELECT` does see the effects of previous updates executed within its own transaction, even though they are not yet committed. Also note that two successive `SELECT` commands can see different data, even though they are within a single transaction, if other transactions commit changes after the first `SELECT` starts and before the second `SELECT` starts.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the command start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the would-be updater will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first

updater rolls back, then its effects are negated and the second updater can proceed with updating the originally found row. If the first updater commits, the second updater will ignore the row if the first updater deleted it, otherwise it will attempt to apply its operation to the updated version of the row. The search condition of the command (the `WHERE` clause) is re-evaluated to see if the updated version of the row still matches the search condition. If so, the second updater proceeds with its operation using the updated version of the row. In the case of `SELECT FOR UPDATE` and `SELECT FOR SHARE`, this means it is the updated version of the row that is locked and returned to the client.

`INSERT` with an `ON CONFLICT DO UPDATE` clause behaves similarly. In Read Committed mode, each row proposed for insertion will either insert or update. Unless there are unrelated errors, one of those two outcomes is guaranteed. If a conflict originates in another transaction whose effects are not yet visible to the `INSERT`, the `UPDATE` clause will affect that row, even though possibly *no* version of that row is conventionally visible to the command.

`INSERT` with an `ON CONFLICT DO NOTHING` clause may have insertion not proceed for a row due to the outcome of another transaction whose effects are not visible to the `INSERT` snapshot. Again, this is only the case in Read Committed mode.

Because of the above rules, it is possible for an updating command to see an inconsistent snapshot: it can see the effects of concurrent updating commands on the same rows it is trying to update, but it does not see effects of those commands on other rows in the database. This behavior makes Read Committed mode unsuitable for commands that involve complex search conditions; however, it is just right for simpler cases. For example, consider updating bank balances with transactions like:

```
BEGIN;
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  12345;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  7534;
COMMIT;
```

If two such transactions concurrently try to change the balance of account 12345, we clearly want the second transaction to start with the updated version of the account's row. Because each command is affecting only a predetermined row, letting it see the updated version of the row does not create any troublesome inconsistency.

More complex usage can produce undesirable results in Read Committed mode. For example, consider a `DELETE` command operating on data that is being both added and removed from its restriction criteria by another command, e.g., assume `website` is a two-row table with `website.hits` equaling 9 and 10:

```
BEGIN;
UPDATE website SET hits = hits + 1;
-- run from another session: DELETE FROM website WHERE hits = 10;
COMMIT;
```

The `DELETE` will have no effect even though there is a `website.hits = 10` row before and after the `UPDATE`. This occurs because the pre-update row value 9 is skipped, and when the `UPDATE` completes and `DELETE` obtains a lock, the new row value is no longer 10 but 11, which no longer matches the criteria.

Because Read Committed mode starts each command with a new snapshot that includes all transactions committed up to that instant, subsequent commands in the same transaction will see the effects of the committed concurrent transaction in any case. The point at issue above is whether or not a *single* command sees an absolutely consistent view of the database.

The partial transaction isolation provided by Read Committed mode is adequate for many applications, and this mode is fast and simple to use; however, it is not sufficient for all cases. Applications that

do complex queries and updates might require a more rigorously consistent view of the database than Read Committed mode provides.

## 13.2.2. Repeatable Read Isolation Level

The *Repeatable Read* isolation level only sees data committed before the transaction began; it never sees either uncommitted data or changes committed during transaction execution by concurrent transactions. (However, the query does see the effects of previous updates executed within its own transaction, even though they are not yet committed.) This is a stronger guarantee than is required by the SQL standard for this isolation level, and prevents all of the phenomena described in Table 13.1 except for serialization anomalies. As mentioned above, this is specifically allowed by the standard, which only describes the *minimum* protections each isolation level must provide.

This level is different from Read Committed in that a query in a repeatable read transaction sees a snapshot as of the start of the first non-transaction-control statement in the *transaction*, not as of the start of the current statement within the transaction. Thus, successive `SELECT` commands within a *single* transaction see the same data, i.e., they do not see changes made by other transactions that committed after their own transaction started.

Applications using this level must be prepared to retry transactions due to serialization failures.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the transaction start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the repeatable read transaction will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first updater rolls back, then its effects are negated and the repeatable read transaction can proceed with updating the originally found row. But if the first updater commits (and actually updated or deleted the row, not just locked it) then the repeatable read transaction will be rolled back with the message

```
ERROR: could not serialize access due to concurrent update
```

because a repeatable read transaction cannot modify or lock rows changed by other transactions after the repeatable read transaction began.

When an application receives this error message, it should abort the current transaction and retry the whole transaction from the beginning. The second time through, the transaction will see the previously-committed change as part of its initial view of the database, so there is no logical conflict in using the new version of the row as the starting point for the new transaction's update.

Note that only updating transactions might need to be retried; read-only transactions will never have serialization conflicts.

The Repeatable Read mode provides a rigorous guarantee that each transaction sees a completely stable view of the database. However, this view will not necessarily always be consistent with some serial (one at a time) execution of concurrent transactions of the same level. For example, even a read only transaction at this level may see a control record updated to show that a batch has been completed but *not* see one of the detail records which is logically part of the batch because it read an earlier revision of the control record. Attempts to enforce business rules by transactions running at this isolation level are not likely to work correctly without careful use of explicit locks to block conflicting transactions.

The Repeatable Read isolation level is implemented using a technique known in academic database literature and in some other database products as *Snapshot Isolation*. Differences in behavior and performance may be observed when compared with systems that use a traditional locking technique that reduces concurrency. Some other systems may even offer Repeatable Read and Snapshot Isolation as distinct isolation levels with different behavior. The permitted phenomena that distinguish the two techniques were not formalized by database researchers until after the SQL standard was developed, and are outside the scope of this manual. For a full treatment, please see [berenson95].

**Note**

Prior to LightDB version 9.1, a request for the Serializable transaction isolation level provided exactly the same behavior described here. To retain the legacy Serializable behavior, Repeatable Read should now be requested.

### 13.2.3. Serializable Isolation Level

The *Serializable* isolation level provides the strictest transaction isolation. This level emulates serial transaction execution for all committed transactions; as if transactions had been executed one after another, serially, rather than concurrently. However, like the Repeatable Read level, applications using this level must be prepared to retry transactions due to serialization failures. In fact, this isolation level works exactly the same as Repeatable Read except that it monitors for conditions which could make execution of a concurrent set of serializable transactions behave in a manner inconsistent with all possible serial (one at a time) executions of those transactions. This monitoring does not introduce any blocking beyond that present in repeatable read, but there is some overhead to the monitoring, and detection of the conditions which could cause a *serialization anomaly* will trigger a *serialization failure*.

As an example, consider a table `mytab`, initially containing:

class	value
1	10
1	20
2	100
2	200

Suppose that serializable transaction A computes:

```
SELECT SUM(value) FROM mytab WHERE class = 1;
```

and then inserts the result (30) as the `value` in a new row with `class = 2`. Concurrently, serializable transaction B computes:

```
SELECT SUM(value) FROM mytab WHERE class = 2;
```

and obtains the result 300, which it inserts in a new row with `class = 1`. Then both transactions try to commit. If either transaction were running at the Repeatable Read isolation level, both would be allowed to commit; but since there is no serial order of execution consistent with the result, using Serializable transactions will allow one transaction to commit and will roll the other back with this message:

```
ERROR: could not serialize access due to read/write dependencies among transactions
```

This is because if A had executed before B, B would have computed the sum 330, not 300, and similarly the other order would have resulted in a different sum computed by A.

When relying on Serializable transactions to prevent anomalies, it is important that any data read from a permanent user table not be considered valid until the transaction which read it has successfully committed. This is true even for read-only transactions, except that data read within a *deferrable* read-only transaction is known to be valid as soon as it is read, because such a transaction waits until it can acquire a snapshot guaranteed to be free from such problems before starting to read any data. In

all other cases applications must not depend on results read during a transaction that later aborted; instead, they should retry the transaction until it succeeds.

To guarantee true serializability LightDB uses *predicate locking*, which means that it keeps locks which allow it to determine when a write would have had an impact on the result of a previous read from a concurrent transaction, had it run first. In LightDB these locks do not cause any blocking and therefore can *not* play any part in causing a deadlock. They are used to identify and flag dependencies among concurrent Serializable transactions which in certain combinations can lead to serialization anomalies. In contrast, a Read Committed or Repeatable Read transaction which wants to ensure data consistency may need to take out a lock on an entire table, which could block other users attempting to use that table, or it may use `SELECT FOR UPDATE` or `SELECT FOR SHARE` which not only can block other transactions but cause disk access.

Predicate locks in LightDB, like in most other database systems, are based on data actually accessed by a transaction. These will show up in the `pg_locks` system view with a mode of `SIReadLock`. The particular locks acquired during execution of a query will depend on the plan used by the query, and multiple finer-grained locks (e.g., tuple locks) may be combined into fewer coarser-grained locks (e.g., page locks) during the course of the transaction to prevent exhaustion of the memory used to track the locks. A `READ ONLY` transaction may be able to release its `SIRead` locks before completion, if it detects that no conflicts can still occur which could lead to a serialization anomaly. In fact, `READ ONLY` transactions will often be able to establish that fact at startup and avoid taking any predicate locks. If you explicitly request a `SERIALIZABLE READ ONLY DEFERRABLE` transaction, it will block until it can establish this fact. (This is the *only* case where Serializable transactions block but Repeatable Read transactions don't.) On the other hand, `SIRead` locks often need to be kept past transaction commit, until overlapping read write transactions complete.

Consistent use of Serializable transactions can simplify development. The guarantee that any set of successfully committed concurrent Serializable transactions will have the same effect as if they were run one at a time means that if you can demonstrate that a single transaction, as written, will do the right thing when run by itself, you can have confidence that it will do the right thing in any mix of Serializable transactions, even without any information about what those other transactions might do, or it will not successfully commit. It is important that an environment which uses this technique have a generalized way of handling serialization failures (which always return with a `SQLSTATE` value of '40001'), because it will be very hard to predict exactly which transactions might contribute to the read/write dependencies and need to be rolled back to prevent serialization anomalies. The monitoring of read/write dependencies has a cost, as does the restart of transactions which are terminated with a serialization failure, but balanced against the cost and blocking involved in use of explicit locks and `SELECT FOR UPDATE` or `SELECT FOR SHARE`, Serializable transactions are the best performance choice for some environments.

While LightDB's Serializable transaction isolation level only allows concurrent transactions to commit if it can prove there is a serial order of execution that would produce the same effect, it doesn't always prevent errors from being raised that would not occur in true serial execution. In particular, it is possible to see unique constraint violations caused by conflicts with overlapping Serializable transactions even after explicitly checking that the key isn't present before attempting to insert it. This can be avoided by making sure that *all* Serializable transactions that insert potentially conflicting keys explicitly check if they can do so first. For example, imagine an application that asks the user for a new key and then checks that it doesn't exist already by trying to select it first, or generates a new key by selecting the maximum existing key and adding one. If some Serializable transactions insert new keys directly without following this protocol, unique constraints violations might be reported even in cases where they could not occur in a serial execution of the concurrent transactions.

For optimal performance when relying on Serializable transactions for concurrency control, these issues should be considered:

- Declare transactions as `READ ONLY` when possible.
- Control the number of active connections, using a connection pool if needed. This is always an important performance consideration, but it can be particularly important in a busy system using Serializable transactions.

- Don't put more into a single transaction than needed for integrity purposes.
- Don't leave connections dangling “idle in transaction” longer than necessary. The configuration parameter `idle_in_transaction_session_timeout` may be used to automatically disconnect lingering sessions.
- Eliminate explicit locks, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` where no longer needed due to the protections automatically provided by Serializable transactions.
- When the system is forced to combine multiple page-level predicate locks into a single relation-level predicate lock because the predicate lock table is short of memory, an increase in the rate of serialization failures may occur. You can avoid this by increasing `max_pred_locks_per_transaction`, `max_pred_locks_per_relation`, and/or `max_pred_locks_per_page`.
- A sequential scan will always necessitate a relation-level predicate lock. This can result in an increased rate of serialization failures. It may be helpful to encourage the use of index scans by reducing `random_page_cost` and/or increasing `cpu_tuple_cost`. Be sure to weigh any decrease in transaction rollbacks and restarts against any overall change in query execution time.

The Serializable isolation level is implemented using a technique known in academic database literature as Serializable Snapshot Isolation, which builds on Snapshot Isolation by adding checks for serialization anomalies. Some differences in behavior and performance may be observed when compared with other systems that use a traditional locking technique. Please see [ports12] for detailed information.

## 13.3. Explicit Locking

LightDB provides various lock modes to control concurrent access to data in tables. These modes can be used for application-controlled locking in situations where MVCC does not give the desired behavior. Also, most LightDB commands automatically acquire locks of appropriate modes to ensure that referenced tables are not dropped or modified in incompatible ways while the command executes. (For example, `TRUNCATE` cannot safely be executed concurrently with other operations on the same table, so it obtains an `ACCESS EXCLUSIVE` lock on the table to enforce that.)

To examine a list of the currently outstanding locks in a database server, use the `pg_locks` system view. For more information on monitoring the status of the lock manager subsystem, refer to Chapter 25.

### 13.3.1. Table-Level Locks

The list below shows the available lock modes and the contexts in which they are used automatically by LightDB. You can also acquire any of these locks explicitly with the command `LOCK`. Remember that all of these lock modes are table-level locks, even if the name contains the word “row”; the names of the lock modes are historical. To some extent the names reflect the typical usage of each lock mode — but the semantics are all the same. The only real difference between one lock mode and another is the set of lock modes with which each conflicts (see Table 13.2). Two transactions cannot hold locks of conflicting modes on the same table at the same time. (However, a transaction never conflicts with itself. For example, it might acquire `ACCESS EXCLUSIVE` lock and later acquire `ACCESS SHARE` lock on the same table.) Non-conflicting lock modes can be held concurrently by many transactions. Notice in particular that some lock modes are self-conflicting (for example, an `ACCESS EXCLUSIVE` lock cannot be held by more than one transaction at a time) while others are not self-conflicting (for example, an `ACCESS SHARE` lock can be held by multiple transactions).

#### Table-Level Lock Modes

`ACCESS SHARE` (`AccessShareLock`)

Conflicts with the `ACCESS EXCLUSIVE` lock mode only.

The `SELECT` command acquires a lock of this mode on referenced tables. In general, any query that only *reads* a table and does not modify it will acquire this lock mode.

`ROW SHARE` (RowShareLock)

Conflicts with the `EXCLUSIVE` and `ACCESS EXCLUSIVE` lock modes.

The `SELECT FOR UPDATE` and `SELECT FOR SHARE` commands acquire a lock of this mode on the target table(s) (in addition to `ACCESS SHARE` locks on any other tables that are referenced but not selected `FOR UPDATE/FOR SHARE`).

`ROW EXCLUSIVE` (RowExclusiveLock)

Conflicts with the `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes.

The commands `UPDATE`, `DELETE`, and `INSERT` acquire this lock mode on the target table (in addition to `ACCESS SHARE` locks on any other referenced tables). In general, this lock mode will be acquired by any command that *modifies data* in a table.

`SHARE UPDATE EXCLUSIVE` (ShareUpdateExclusiveLock)

Conflicts with the `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects a table against concurrent schema changes and `VACUUM` runs.

Acquired by `VACUUM` (without `FULL`), `ANALYZE`, `CREATE INDEX CONCURRENTLY`, `CREATE STATISTICS`, `COMMENT ON`, `REINDEX CONCURRENTLY`, and certain `ALTER INDEX` and `ALTER TABLE` variants (for full details see `ALTER INDEX` and `ALTER TABLE`).

`SHARE` (ShareLock)

Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects a table against concurrent data changes.

Acquired by `CREATE INDEX` (without `CONCURRENTLY`).

`SHARE ROW EXCLUSIVE` (ShareRowExclusiveLock)

Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects a table against concurrent data changes, and is self-exclusive so that only one session can hold it at a time.

Acquired by `CREATE TRIGGER` and some forms of `ALTER TABLE` (see `ALTER TABLE`).

`EXCLUSIVE` (ExclusiveLock)

Conflicts with the `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode allows only concurrent `ACCESS SHARE` locks, i.e., only reads from the table can proceed in parallel with a transaction holding this lock mode.

Acquired by `REFRESH MATERIALIZED VIEW CONCURRENTLY`.

`ACCESS EXCLUSIVE` (AccessExclusiveLock)

Conflicts with locks of all modes (`ACCESS SHARE`, `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE`). This mode guarantees that the holder is the only transaction accessing the table in any way.

Acquired by the `DROP TABLE`, `TRUNCATE`, `REINDEX`, `CLUSTER`, `VACUUM FULL`, and `REFRESH MATERIALIZED VIEW` (without `CONCURRENTLY`) commands. Many forms of



ALTER INDEX and ALTER TABLE also acquire a lock at this level. This is also the default lock mode for LOCK TABLE statements that do not specify a mode explicitly.

**Tip**

Only an ACCESS EXCLUSIVE lock blocks a SELECT (without FOR UPDATE/SHARE) statement.

Once acquired, a lock is normally held until the end of the transaction. But if a lock is acquired after establishing a savepoint, the lock is released immediately if the savepoint is rolled back to. This is consistent with the principle that ROLLBACK cancels all effects of the commands since the savepoint. The same holds for locks acquired within a PL/pgSQL exception block: an error escape from the block releases locks acquired within it.

**Table 13.2. Conflicting Lock Modes**

Requested Lock Mode	Existing Lock Mode							
	ACCESS SHARE	ROW SHARE	ROW EXCL.	SHARE UPDATE EXCL.	SHARE	SHARE ROW EXCL.	EXCL.	ACCESS EXCL.
ACCESS SHARE								X
ROW SHARE							X	X
ROW EXCL.					X	X	X	X
SHARE UPDATE EXCL.				X	X	X	X	X
SHARE			X	X		X	X	X
SHARE ROW EXCL.			X	X	X	X	X	X
EXCL.		X	X	X	X	X	X	X
ACCESS EXCL.	X	X	X	X	X	X	X	X

### 13.3.2. Row-Level Locks

In addition to table-level locks, there are row-level locks, which are listed as below with the contexts in which they are used automatically by LightDB. See Table 13.3 for a complete table of row-level lock conflicts. Note that a transaction can hold conflicting locks on the same row, even in different subtransactions; but other than that, two transactions can never hold conflicting locks on the same row. Row-level locks do not affect data querying; they block only *writers and lockers* to the same row. Row-level locks are released at transaction end or during savepoint rollback, just like table-level locks.

#### Row-Level Lock Modes

FOR UPDATE

FOR UPDATE causes the rows retrieved by the SELECT statement to be locked as though for update. This prevents them from being locked, modified or deleted by other transactions until

the current transaction ends. That is, other transactions that attempt UPDATE, DELETE, SELECT FOR UPDATE, SELECT FOR NO KEY UPDATE, SELECT FOR SHARE or SELECT FOR KEY SHARE of these rows will be blocked until the current transaction ends; conversely, SELECT FOR UPDATE will wait for a concurrent transaction that has run any of those commands on the same row, and will then lock and return the updated row (or no row, if the row was deleted). Within a REPEATABLE READ or SERIALIZABLE transaction, however, an error will be thrown if a row to be locked has changed since the transaction started. For further discussion see Section 13.4.

The FOR UPDATE lock mode is also acquired by any DELETE on a row, and also by an UPDATE that modifies the values of certain columns. Currently, the set of columns considered for the UPDATE case are those that have a unique index on them that can be used in a foreign key (so partial indexes and expressional indexes are not considered), but this may change in the future.

**FOR NO KEY UPDATE**

Behaves similarly to FOR UPDATE, except that the lock acquired is weaker: this lock will not block SELECT FOR KEY SHARE commands that attempt to acquire a lock on the same rows. This lock mode is also acquired by any UPDATE that does not acquire a FOR UPDATE lock.

**FOR SHARE**

Behaves similarly to FOR NO KEY UPDATE, except that it acquires a shared lock rather than exclusive lock on each retrieved row. A shared lock blocks other transactions from performing UPDATE, DELETE, SELECT FOR UPDATE or SELECT FOR NO KEY UPDATE on these rows, but it does not prevent them from performing SELECT FOR SHARE or SELECT FOR KEY SHARE.

**FOR KEY SHARE**

Behaves similarly to FOR SHARE, except that the lock is weaker: SELECT FOR UPDATE is blocked, but not SELECT FOR NO KEY UPDATE. A key-shared lock blocks other transactions from performing DELETE or any UPDATE that changes the key values, but not other UPDATE, and neither does it prevent SELECT FOR NO KEY UPDATE, SELECT FOR SHARE, or SELECT FOR KEY SHARE.

LightDB doesn't remember any information about modified rows in memory, so there is no limit on the number of rows locked at one time. However, locking a row might cause a disk write, e.g., SELECT FOR UPDATE modifies selected rows to mark them locked, and so will result in disk writes.

**Table 13.3. Conflicting Row-Level Locks**

Requested Lock Mode	Current Lock Mode			
	FOR KEY SHARE	FOR SHARE	FOR NO KEY UPDATE	FOR UPDATE
FOR KEY SHARE				X
FOR SHARE			X	X
FOR NO KEY UPDATE		X	X	X
FOR UPDATE	X	X	X	X

### 13.3.3. Page-Level Locks

In addition to table and row locks, page-level share/exclusive locks are used to control read/write access to table pages in the shared buffer pool. These locks are released immediately after a row is fetched or updated. Application developers normally need not be concerned with page-level locks, but they are mentioned here for completeness.

### 13.3.4. Deadlocks

The use of explicit locking can increase the likelihood of *deadlocks*, wherein two (or more) transactions each hold locks that the other wants. For example, if transaction 1 acquires an exclusive lock on table A and then tries to acquire an exclusive lock on table B, while transaction 2 has already exclusive-locked table B and now wants an exclusive lock on table A, then neither one can proceed. LightDB automatically detects deadlock situations and resolves them by aborting one of the transactions involved, allowing the other(s) to complete. (Exactly which transaction will be aborted is difficult to predict and should not be relied upon.)

Note that deadlocks can also occur as the result of row-level locks (and thus, they can occur even if explicit locking is not used). Consider the case in which two concurrent transactions modify a table. The first transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  11111;
```

This acquires a row-level lock on the row with the specified account number. Then, the second transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  22222;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  11111;
```

The first UPDATE statement successfully acquires a row-level lock on the specified row, so it succeeds in updating that row. However, the second UPDATE statement finds that the row it is attempting to update has already been locked, so it waits for the transaction that acquired the lock to complete. Transaction two is now waiting on transaction one to complete before it continues execution. Now, transaction one executes:

```
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  22222;
```

Transaction one attempts to acquire a row-level lock on the specified row, but it cannot: transaction two already holds such a lock. So it waits for transaction two to complete. Thus, transaction one is blocked on transaction two, and transaction two is blocked on transaction one: a deadlock condition. LightDB will detect this situation and abort one of the transactions.

The best defense against deadlocks is generally to avoid them by being certain that all applications using a database acquire locks on multiple objects in a consistent order. In the example above, if both transactions had updated the rows in the same order, no deadlock would have occurred. One should also ensure that the first lock acquired on an object in a transaction is the most restrictive mode that will be needed for that object. If it is not feasible to verify this in advance, then deadlocks can be handled on-the-fly by retrying transactions that abort due to deadlocks.

So long as no deadlock situation is detected, a transaction seeking either a table-level or row-level lock will wait indefinitely for conflicting locks to be released. This means it is a bad idea for applications to hold transactions open for long periods of time (e.g., while waiting for user input).

### 13.3.5. Advisory Locks

LightDB provides a means for creating locks that have application-defined meanings. These are called *advisory locks*, because the system does not enforce their use — it is up to the application to use them correctly. Advisory locks can be useful for locking strategies that are an awkward fit for the MVCC model. For example, a common use of advisory locks is to emulate pessimistic locking strategies typical of so-called “flat file” data management systems. While a flag stored in a table could be used for the same purpose, advisory locks are faster, avoid table bloat, and are automatically cleaned up by the server at the end of the session.

There are two ways to acquire an advisory lock in LightDB: at session level or at transaction level. Once acquired at session level, an advisory lock is held until explicitly released or the session ends. Unlike standard lock requests, session-level advisory lock requests do not honor transaction semantics: a lock acquired during a transaction that is later rolled back will still be held following the rollback, and likewise an unlock is effective even if the calling transaction fails later. A lock can be acquired multiple times by its owning process; for each completed lock request there must be a corresponding unlock request before the lock is actually released. Transaction-level lock requests, on the other hand, behave more like regular lock requests: they are automatically released at the end of the transaction, and there is no explicit unlock operation. This behavior is often more convenient than the session-level behavior for short-term usage of an advisory lock. Session-level and transaction-level lock requests for the same advisory lock identifier will block each other in the expected way. If a session already holds a given advisory lock, additional requests by it will always succeed, even if other sessions are awaiting the lock; this statement is true regardless of whether the existing lock hold and new request are at session level or transaction level.

Like all locks in LightDB, a complete list of advisory locks currently held by any session can be found in the `pg_locks` system view.

Both advisory locks and regular locks are stored in a shared memory pool whose size is defined by the configuration variables `max_locks_per_transaction` and `max_connections`. Care must be taken not to exhaust this memory or the server will be unable to grant any locks at all. This imposes an upper limit on the number of advisory locks grantable by the server, typically in the tens to hundreds of thousands depending on how the server is configured.

In certain cases using advisory locking methods, especially in queries involving explicit ordering and `LIMIT` clauses, care must be taken to control the locks acquired because of the order in which SQL expressions are evaluated. For example:

```
SELECT pg_advisory_lock(id) FROM foo WHERE id = 12345; -- ok
SELECT pg_advisory_lock(id) FROM foo WHERE id > 12345 LIMIT 100; --
  danger!
SELECT pg_advisory_lock(q.id) FROM
(
  SELECT id FROM foo WHERE id > 12345 LIMIT 100
) q; -- ok
```

In the above queries, the second form is dangerous because the `LIMIT` is not guaranteed to be applied before the locking function is executed. This might cause some locks to be acquired that the application was not expecting, and hence would fail to release (until it ends the session). From the point of view of the application, such locks would be dangling, although still viewable in `pg_locks`.

The functions provided to manipulate advisory locks are described in Section 9.27.10.

## 13.4. Data Consistency Checks at the Application Level

It is very difficult to enforce business rules regarding data integrity using Read Committed transactions because the view of the data is shifting with each statement, and even a single statement may not restrict itself to the statement's snapshot if a write conflict occurs.

While a Repeatable Read transaction has a stable view of the data throughout its execution, there is a subtle issue with using MVCC snapshots for data consistency checks, involving something known as *read/write conflicts*. If one transaction writes data and a concurrent transaction attempts to read the same data (whether before or after the write), it cannot see the work of the other transaction. The reader then appears to have executed first regardless of which started first or which committed first. If that is as far as it goes, there is no problem, but if the reader also writes data which is read by a concurrent transaction there is now a transaction which appears to have run before either of the

previously mentioned transactions. If the transaction which appears to have executed last actually commits first, it is very easy for a cycle to appear in a graph of the order of execution of the transactions. When such a cycle appears, integrity checks will not work correctly without some help.

As mentioned in Section 13.2.3, Serializable transactions are just Repeatable Read transactions which add nonblocking monitoring for dangerous patterns of read/write conflicts. When a pattern is detected which could cause a cycle in the apparent order of execution, one of the transactions involved is rolled back to break the cycle.

## 13.4.1. Enforcing Consistency with Serializable Transactions

If the Serializable transaction isolation level is used for all writes and for all reads which need a consistent view of the data, no other effort is required to ensure consistency. Software from other environments which is written to use serializable transactions to ensure consistency should “just work” in this regard in LightDB.

When using this technique, it will avoid creating an unnecessary burden for application programmers if the application software goes through a framework which automatically retries transactions which are rolled back with a serialization failure. It may be a good idea to set `default_transaction_isolation` to `serializable`. It would also be wise to take some action to ensure that no other transaction isolation level is used, either inadvertently or to subvert integrity checks, through checks of the transaction isolation level in triggers.

See Section 13.2.3 for performance suggestions.

### Warning

This level of integrity protection using Serializable transactions does not yet extend to hot standby mode (Section 24.5). Because of that, those using hot standby may want to use Repeatable Read and explicit locking on the master.

## 13.4.2. Enforcing Consistency with Explicit Blocking Locks

When non-serializable writes are possible, to ensure the current validity of a row and protect it against concurrent updates one must use `SELECT FOR UPDATE`, `SELECT FOR SHARE`, or an appropriate `LOCK TABLE` statement. (`SELECT FOR UPDATE` and `SELECT FOR SHARE` lock just the returned rows against concurrent updates, while `LOCK TABLE` locks the whole table.) This should be taken into account when porting applications to LightDB from other environments.

Also of note to those converting from other environments is the fact that `SELECT FOR UPDATE` does not ensure that a concurrent transaction will not update or delete a selected row. To do that in LightDB you must actually update the row, even if no values need to be changed. `SELECT FOR UPDATE` temporarily blocks other transactions from acquiring the same lock or executing an `UPDATE` or `DELETE` which would affect the locked row, but once the transaction holding this lock commits or rolls back, a blocked transaction will proceed with the conflicting operation unless an actual `UPDATE` of the row was performed while the lock was held.

Global validity checks require extra thought under non-serializable MVCC. For example, a banking application might wish to check that the sum of all credits in one table equals the sum of debits in another table, when both tables are being actively updated. Comparing the results of two successive `SELECT sum( . . . )` commands will not work reliably in Read Committed mode, since the second query will likely include the results of transactions not counted by the first. Doing the two sums in a single repeatable read transaction will give an accurate picture of only the effects of transactions that

committed before the repeatable read transaction started — but one might legitimately wonder whether the answer is still relevant by the time it is delivered. If the repeatable read transaction itself applied some changes before trying to make the consistency check, the usefulness of the check becomes even more debatable, since now it includes some but not all post-transaction-start changes. In such cases a careful person might wish to lock all tables needed for the check, in order to get an indisputable picture of current reality. A `SHARE` mode (or higher) lock guarantees that there are no uncommitted changes in the locked table, other than those of the current transaction.

Note also that if one is relying on explicit locking to prevent concurrent changes, one should either use Read Committed mode, or in Repeatable Read mode be careful to obtain locks before performing queries. A lock obtained by a repeatable read transaction guarantees that no other transactions modifying the table are still running, but if the snapshot seen by the transaction predates obtaining the lock, it might predate some now-committed changes in the table. A repeatable read transaction's snapshot is actually frozen at the start of its first query or data-modification command (`SELECT`, `INSERT`, `UPDATE`, or `DELETE`), so it is possible to obtain locks explicitly before the snapshot is frozen.

## 13.5. Caveats

Some DDL commands, currently only `TRUNCATE` and the table-rewriting forms of `ALTER TABLE`, are not MVCC-safe. This means that after the truncation or rewrite commits, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the DDL command committed. This will only be an issue for a transaction that did not access the table in question before the DDL command started — any transaction that has done so would hold at least an `ACCESS SHARE` table lock, which would block the DDL command until that transaction completes. So these commands will not cause any apparent inconsistency in the table contents for successive queries on the target table, but they could cause visible inconsistency between the contents of the target table and other tables in the database.

Support for the Serializable transaction isolation level has not yet been added to Hot Standby replication targets (described in Section 24.5). The strictest isolation level currently supported in hot standby mode is Repeatable Read. While performing all permanent database writes within Serializable transactions on the master will ensure that all standbys will eventually reach a consistent state, a Repeatable Read transaction run on the standby can sometimes see a transient state that is inconsistent with any serial execution of the transactions on the master.

Internal access to the system catalogs is not done using the isolation level of the current transaction. This means that newly created database objects such as tables are visible to concurrent Repeatable Read and Serializable transactions, even though the rows they contain are not. In contrast, queries that explicitly examine the system catalogs don't see rows representing concurrently created database objects, in the higher isolation levels.

## 13.6. Locking and Indexes

Though LightDB provides nonblocking read/write access to table data, nonblocking read/write access is not currently offered for every index access method implemented in LightDB. The various index types are handled as follows:

### B-tree, GiST indexes

Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. These index types provide the highest concurrency without deadlock conditions.

### Hash indexes

Share/exclusive hash-bucket-level locks are used for read/write access. Locks are released after the whole bucket is processed. Bucket-level locks provide better concurrency than index-level ones, but deadlock is possible since the locks are held longer than one index operation.

### GIN indexes

Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. But note that insertion of a GIN-indexed value usually produces several index key insertions per row, so GIN might do substantial work for a single value's insertion.

Currently, B-tree indexes offer the best performance for concurrent applications; since they also have more features than hash indexes, they are the recommended index type for concurrent applications that need to index scalar data. When dealing with non-scalar data, B-trees are not useful, and GiST or GIN indexes should be used instead.

---

# Chapter 14. Performance Tips

Query performance can be affected by many things. Some of these can be controlled by the user, while others are fundamental to the underlying design of the system. This chapter provides some hints about understanding and tuning LightDB performance.

## 14.1. Using EXPLAIN

LightDB devises a *query plan* for each query it receives. Choosing the right plan to match the query structure and the properties of the data is absolutely critical for good performance, so the system includes a complex *planner* that tries to choose good plans. You can use the EXPLAIN command to see what query plan the planner creates for any query. Plan-reading is an art that requires some experience to master, but this section attempts to cover the basics.

Examples in this section are drawn from the regression test database after doing a VACUUM ANALYZE, using 9.3 development sources. You should be able to get similar results if you try the examples yourself, but your estimated costs and row counts might vary slightly because ANALYZE's statistics are random samples rather than exact, and because costs are inherently somewhat platform-dependent.

The examples use EXPLAIN's default “text” output format, which is compact and convenient for humans to read. If you want to feed EXPLAIN's output to a program for further analysis, you should use one of its machine-readable output formats (XML, JSON, or YAML) instead.

### 14.1.1. EXPLAIN Basics

The structure of a query plan is a tree of *plan nodes*. Nodes at the bottom level of the tree are scan nodes: they return raw rows from a table. There are different types of scan nodes for different table access methods: sequential scans, index scans, and bitmap index scans. There are also non-table row sources, such as VALUES clauses and set-returning functions in FROM, which have their own scan node types. If the query requires joining, aggregation, sorting, or other operations on the raw rows, then there will be additional nodes above the scan nodes to perform these operations. Again, there is usually more than one possible way to do these operations, so different node types can appear here too. The output of EXPLAIN has one line for each node in the plan tree, showing the basic node type plus the cost estimates that the planner made for the execution of that plan node. Additional lines might appear, indented from the node's summary line, to show additional properties of the node. The very first line (the summary line for the topmost node) has the estimated total execution cost for the plan; it is this number that the planner seeks to minimize.

Here is a trivial example, just to show what the output looks like:

```
EXPLAIN SELECT * FROM tenk1;

                QUERY PLAN
-----
Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

Since this query has no WHERE clause, it must scan all the rows of the table, so the planner has chosen to use a simple sequential scan plan. The numbers that are quoted in parentheses are (left to right):

- Estimated start-up cost. This is the time expended before the output phase can begin, e.g., time to do the sorting in a sort node.
- Estimated total cost. This is stated on the assumption that the plan node is run to completion, i.e., all available rows are retrieved. In practice a node's parent node might stop short of reading all available rows (see the LIMIT example below).



- Estimated number of rows output by this plan node. Again, the node is assumed to be run to completion.
- Estimated average width of rows output by this plan node (in bytes).

The costs are measured in arbitrary units determined by the planner's cost parameters (see Section 17.7.2). Traditional practice is to measure the costs in units of disk page fetches; that is, `seq_page_cost` is conventionally set to 1.0 and the other cost parameters are set relative to that. The examples in this section are run with the default cost parameters.

It's important to understand that the cost of an upper-level node includes the cost of all its child nodes. It's also important to realize that the cost only reflects things that the planner cares about. In particular, the cost does not consider the time spent transmitting result rows to the client, which could be an important factor in the real elapsed time; but the planner ignores it because it cannot change it by altering the plan. (Every correct plan will output the same row set, we trust.)

The `rows` value is a little tricky because it is not the number of rows processed or scanned by the plan node, but rather the number emitted by the node. This is often less than the number scanned, as a result of filtering by any `WHERE`-clause conditions that are being applied at the node. Ideally the top-level rows estimate will approximate the number of rows actually returned, updated, or deleted by the query.

Returning to our example:

```
EXPLAIN SELECT * FROM tenk1;
```

```
QUERY PLAN
```

```
-----  
Seq Scan on tenk1 (cost=0.00..458.00 rows=10000 width=244)
```

These numbers are derived very straightforwardly. If you do:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';
```

you will find that `tenk1` has 358 disk pages and 10000 rows. The estimated cost is computed as (disk pages read \* `seq_page_cost`) + (rows scanned \* `cpu_tuple_cost`). By default, `seq_page_cost` is 1.0 and `cpu_tuple_cost` is 0.01, so the estimated cost is  $(358 * 1.0) + (10000 * 0.01) = 458$ .

Now let's modify the query to add a `WHERE` condition:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 7000;
```

```
QUERY PLAN
```

```
-----  
Seq Scan on tenk1 (cost=0.00..483.00 rows=7001 width=244)  
  Filter: (unique1 < 7000)
```

Notice that the `EXPLAIN` output shows the `WHERE` clause being applied as a “filter” condition attached to the `Seq Scan` plan node. This means that the plan node checks the condition for each row it scans, and outputs only the ones that pass the condition. The estimate of output rows has been reduced because of the `WHERE` clause. However, the scan will still have to visit all 10000 rows, so the cost hasn't decreased; in fact it has gone up a bit (by  $10000 * \text{cpu\_operator\_cost}$ , to be exact) to reflect the extra CPU time spent checking the `WHERE` condition.

The actual number of rows this query would select is 7000, but the `rows` estimate is only approximate. If you try to duplicate this experiment, you will probably get a slightly different estimate; moreover, it can change after each `ANALYZE` command, because the statistics produced by `ANALYZE` are taken from a randomized sample of the table.

Now, let's make the condition more restrictive:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100;
```

```
QUERY PLAN
```

```
-----
Bitmap Heap Scan on tenk1 (cost=5.07..229.20 rows=101 width=244)
  Recheck Cond: (unique1 < 100)
  -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0)
    Index Cond: (unique1 < 100)
```

Here the planner has decided to use a two-step plan: the child plan node visits an index to find the locations of rows matching the index condition, and then the upper plan node actually fetches those rows from the table itself. Fetching rows separately is much more expensive than reading them sequentially, but because not all the pages of the table have to be visited, this is still cheaper than a sequential scan. (The reason for using two plan levels is that the upper plan node sorts the row locations identified by the index into physical order before reading them, to minimize the cost of separate fetches. The “bitmap” mentioned in the node names is the mechanism that does the sorting.)

Now let's add another condition to the WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND stringul =
'xxx';
```

```
QUERY PLAN
```

```
-----
Bitmap Heap Scan on tenk1 (cost=5.04..229.43 rows=1 width=244)
  Recheck Cond: (unique1 < 100)
  Filter: (stringul = 'xxx'::name)
  -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0)
    Index Cond: (unique1 < 100)
```

The added condition `stringul = 'xxx'` reduces the output row count estimate, but not the cost because we still have to visit the same set of rows. Notice that the `stringul` clause cannot be applied as an index condition, since this index is only on the `unique1` column. Instead it is applied as a filter on the rows retrieved by the index. Thus the cost has actually gone up slightly to reflect this extra checking.

In some cases the planner will prefer a “simple” index scan plan:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 = 42;
```

```
QUERY PLAN
```

```
-----
Index Scan using tenk1_unique1 on tenk1 (cost=0.29..8.30 rows=1
width=244)
  Index Cond: (unique1 = 42)
```

In this type of plan the table rows are fetched in index order, which makes them even more expensive to read, but there are so few that the extra cost of sorting the row locations is not worth it. You'll most often see this plan type for queries that fetch just a single row. It's also often used for queries that have an `ORDER BY` condition that matches the index order, because then no extra sorting step is needed to satisfy the `ORDER BY`. In this example, adding `ORDER BY unique1` would use the same plan because the index already implicitly provides the requested ordering.

The planner may implement an `ORDER BY` clause in several ways. The above example shows that such an ordering clause may be implemented implicitly. The planner may also add an explicit sort step:

```
EXPLAIN SELECT * FROM tenk1 ORDER BY unique1;
                QUERY PLAN
-----
Sort  (cost=1109.39..1134.39 rows=10000 width=244)
  Sort Key: unique1
  -> Seq Scan on tenk1  (cost=0.00..445.00 rows=10000 width=244)
```

If a part of the plan guarantees an ordering on a prefix of the required sort keys, then the planner may instead decide to use an incremental sort step:

```
EXPLAIN SELECT * FROM tenk1 ORDER BY four, ten LIMIT 100;
                QUERY PLAN
-----
Limit  (cost=521.06..538.05 rows=100 width=244)
  -> Incremental Sort  (cost=521.06..2220.95 rows=10000
width=244)
    Sort Key: four, ten
    Presorted Key: four
    -> Index Scan using index_tenk1_on_four on tenk1
(cost=0.29..1510.08 rows=10000 width=244)
```

Compared to regular sorts, sorting incrementally allows returning tuples before the entire result set has been sorted, which particularly enables optimizations with `LIMIT` queries. It may also reduce memory usage and the likelihood of spilling sorts to disk, but it comes at the cost of the increased overhead of splitting the result set into multiple sorting batches.

If there are separate indexes on several of the columns referenced in `WHERE`, the planner might choose to use an `AND` or `OR` combination of the indexes:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000;
                QUERY PLAN
-----
Bitmap Heap Scan on tenk1  (cost=25.08..60.21 rows=10 width=244)
  Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
  -> BitmapAnd  (cost=25.08..25.08 rows=10 width=0)
    -> Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04
rows=101 width=0)
      Index Cond: (unique1 < 100)
    -> Bitmap Index Scan on tenk1_unique2  (cost=0.00..19.78
rows=999 width=0)
      Index Cond: (unique2 > 9000)
```

But this requires visiting both indexes, so it's not necessarily a win compared to using just one index and treating the other condition as a filter. If you vary the ranges involved you'll see the plan change accordingly.

Here is an example showing the effects of `LIMIT`:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000
LIMIT 2;
```

## QUERY PLAN

```
-----
Limit (cost=0.29..14.48 rows=2 width=244)
-> Index Scan using tenk1_unique2 on tenk1 (cost=0.29..71.27
rows=10 width=244)
    Index Cond: (unique2 > 9000)
    Filter: (unique1 < 100)
```

This is the same query as above, but we added a LIMIT so that not all the rows need be retrieved, and the planner changed its mind about what to do. Notice that the total cost and row count of the Index Scan node are shown as if it were run to completion. However, the Limit node is expected to stop after retrieving only a fifth of those rows, so its total cost is only a fifth as much, and that's the actual estimated cost of the query. This plan is preferred over adding a Limit node to the previous plan because the Limit could not avoid paying the startup cost of the bitmap scan, so the total cost would be something over 25 units with that approach.

Let's try joining two tables, using the columns we have been discussing:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;
```

## QUERY PLAN

```
-----
Nested Loop (cost=4.65..118.62 rows=10 width=488)
-> Bitmap Heap Scan on tenk1 t1 (cost=4.36..39.47 rows=10
width=244)
    Recheck Cond: (unique1 < 10)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.36
rows=10 width=0)
        Index Cond: (unique1 < 10)
    -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.29..7.91
rows=1 width=244)
        Index Cond: (unique2 = t1.unique2)
```

In this plan, we have a nested-loop join node with two table scans as inputs, or children. The indentation of the node summary lines reflects the plan tree structure. The join's first, or “outer”, child is a bitmap scan similar to those we saw before. Its cost and row count are the same as we'd get from `SELECT ... WHERE unique1 < 10` because we are applying the WHERE clause `unique1 < 10` at that node. The `t1.unique2 = t2.unique2` clause is not relevant yet, so it doesn't affect the row count of the outer scan. The nested-loop join node will run its second, or “inner” child once for each row obtained from the outer child. Column values from the current outer row can be plugged into the inner scan; here, the `t1.unique2` value from the outer row is available, so we get a plan and costs similar to what we saw above for a simple `SELECT ... WHERE t2.unique2 = constant` case. (The estimated cost is actually a bit lower than what was seen above, as a result of caching that's expected to occur during the repeated index scans on `t2`.) The costs of the loop node are then set on the basis of the cost of the outer scan, plus one repetition of the inner scan for each outer row ( $10 * 7.91$ , here), plus a little CPU time for join processing.

In this example the join's output row count is the same as the product of the two scans' row counts, but that's not true in all cases because there can be additional WHERE clauses that mention both tables and so can only be applied at the join point, not to either input scan. Here's an example:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
```

```
WHERE t1.unique1 < 10 AND t2.unique2 < 10 AND t1.hundred <
t2.hundred;
```

## QUERY PLAN

```
-----
Nested Loop (cost=4.65..49.46 rows=33 width=488)
  Join Filter: (t1.hundred < t2.hundred)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.36..39.47 rows=10
width=244)
    Recheck Cond: (unique1 < 10)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.36
rows=10 width=0)
      Index Cond: (unique1 < 10)
  -> Materialize (cost=0.29..8.51 rows=10 width=244)
    -> Index Scan using tenk2_unique2 on tenk2 t2
(cost=0.29..8.46 rows=10 width=244)
      Index Cond: (unique2 < 10)
```

The condition `t1.hundred < t2.hundred` can't be tested in the `tenk2_unique2` index, so it's applied at the join node. This reduces the estimated output row count of the join node, but does not change either input scan.

Notice that here the planner has chosen to “materialize” the inner relation of the join, by putting a `Materialize` plan node atop it. This means that the `t2` index scan will be done just once, even though the nested-loop join node needs to read that data ten times, once for each row from the outer relation. The `Materialize` node saves the data in memory as it's read, and then returns the data from memory on each subsequent pass.

When dealing with outer joins, you might see join plan nodes with both “Join Filter” and plain “Filter” conditions attached. Join Filter conditions come from the outer join's `ON` clause, so a row that fails the Join Filter condition could still get emitted as a null-extended row. But a plain Filter condition is applied after the outer-join rules and so acts to remove rows unconditionally. In an inner join there is no semantic difference between these types of filters.

If we change the query's selectivity a bit, we might get a very different join plan:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;
```

## QUERY PLAN

```
-----
Hash Join (cost=230.47..713.98 rows=101 width=488)
  Hash Cond: (t2.unique2 = t1.unique2)
  -> Seq Scan on tenk2 t2 (cost=0.00..445.00 rows=10000
width=244)
  -> Hash (cost=229.20..229.20 rows=101 width=244)
    -> Bitmap Heap Scan on tenk1 t1 (cost=5.07..229.20
rows=101 width=244)
      Recheck Cond: (unique1 < 100)
      -> Bitmap Index Scan on tenk1_unique1
(cost=0.00..5.04 rows=101 width=0)
        Index Cond: (unique1 < 100)
```

Here, the planner has chosen to use a hash join, in which rows of one table are entered into an in-memory hash table, after which the other table is scanned and the hash table is probed for matches to each row. Again note how the indentation reflects the plan structure: the bitmap scan on `tenk1` is the

input to the Hash node, which constructs the hash table. That's then returned to the Hash Join node, which reads rows from its outer child plan and searches the hash table for each one.

Another possible type of join is a merge join, illustrated here:

```
EXPLAIN SELECT *
FROM tenk1 t1, onek t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                QUERY PLAN
-----
Merge Join (cost=198.11..268.19 rows=10 width=488)
  Merge Cond: (t1.unique2 = t2.unique2)
    -> Index Scan using tenk1_unique2 on tenk1 t1
        (cost=0.29..656.28 rows=101 width=244)
        Filter: (unique1 < 100)
    -> Sort (cost=197.83..200.33 rows=1000 width=244)
        Sort Key: t2.unique2
        -> Seq Scan on onek t2 (cost=0.00..148.00 rows=1000
            width=244)
```

Merge join requires its input data to be sorted on the join keys. In this plan the `tenk1` data is sorted by using an index scan to visit the rows in the correct order, but a sequential scan and sort is preferred for `onek`, because there are many more rows to be visited in that table. (Sequential-scan-and-sort frequently beats an index scan for sorting many rows, because of the nonsequential disk access required by the index scan.)

One way to look at variant plans is to force the planner to disregard whatever strategy it thought was the cheapest, using the enable/disable flags described in Section 17.7.1. (This is a crude tool, but useful. See also Section 14.3.) For example, if we're unconvinced that sequential-scan-and-sort is the best way to deal with table `onek` in the previous example, we could try

```
SET enable_sort = off;

EXPLAIN SELECT *
FROM tenk1 t1, onek t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                QUERY PLAN
-----
Merge Join (cost=0.56..292.65 rows=10 width=488)
  Merge Cond: (t1.unique2 = t2.unique2)
    -> Index Scan using tenk1_unique2 on tenk1 t1
        (cost=0.29..656.28 rows=101 width=244)
        Filter: (unique1 < 100)
    -> Index Scan using onek_unique2 on onek t2 (cost=0.28..224.79
        rows=1000 width=244)
```

which shows that the planner thinks that sorting `onek` by index-scanning is about 12% more expensive than sequential-scan-and-sort. Of course, the next question is whether it's right about that. We can investigate that using `EXPLAIN ANALYZE`, as discussed below.

## 14.1.2. EXPLAIN ANALYZE

It is possible to check the accuracy of the planner's estimates by using `EXPLAIN`'s `ANALYZE` option. With this option, `EXPLAIN` actually executes the query, and then displays the true row counts and

true run time accumulated within each plan node, along with the same estimates that a plain EXPLAIN shows. For example, we might get a result like this:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;
```

QUERY

```
PLAN
-----
Nested Loop (cost=4.65..118.62 rows=10 width=488) (actual
time=0.128..0.377 rows=10 loops=1)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.36..39.47 rows=10
width=244) (actual time=0.057..0.121 rows=10 loops=1)
    Recheck Cond: (unique1 < 10)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.36
rows=10 width=0) (actual time=0.024..0.024 rows=10 loops=1)
      Index Cond: (unique1 < 10)
    -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.29..7.91
rows=1 width=244) (actual time=0.021..0.022 rows=1 loops=10)
      Index Cond: (unique2 = t1.unique2)
Planning time: 0.181 ms
Execution time: 0.501 ms
```

Note that the “actual time” values are in milliseconds of real time, whereas the `cost` estimates are expressed in arbitrary units; so they are unlikely to match up. The thing that's usually most important to look for is whether the estimated row counts are reasonably close to reality. In this example the estimates were all dead-on, but that's quite unusual in practice.

In some query plans, it is possible for a subplan node to be executed more than once. For example, the inner index scan will be executed once per outer row in the above nested-loop plan. In such cases, the `loops` value reports the total number of executions of the node, and the actual time and rows values shown are averages per-execution. This is done to make the numbers comparable with the way that the cost estimates are shown. Multiply by the `loops` value to get the total time actually spent in the node. In the above example, we spent a total of 0.220 milliseconds executing the index scans on `tenk2`.

In some cases EXPLAIN ANALYZE shows additional execution statistics beyond the plan node execution times and row counts. For example, Sort and Hash nodes provide extra information:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2 ORDER BY
t1.fivethous;
```

QUERY PLAN

```
-----
Sort (cost=717.34..717.59 rows=101 width=488) (actual
time=7.761..7.774 rows=100 loops=1)
  Sort Key: t1.fivethous
  Sort Method: quicksort Memory: 77kB
  -> Hash Join (cost=230.47..713.98 rows=101 width=488) (actual
time=0.711..7.427 rows=100 loops=1)
    Hash Cond: (t2.unique2 = t1.unique2)
```

```

-> Seq Scan on tenk2 t2 (cost=0.00..445.00 rows=10000
width=244) (actual time=0.007..2.583 rows=10000 loops=1)
-> Hash (cost=229.20..229.20 rows=101 width=244) (actual
time=0.659..0.659 rows=100 loops=1)
    Buckets: 1024 Batches: 1 Memory Usage: 28kB
-> Bitmap Heap Scan on tenk1 t1 (cost=5.07..229.20
rows=101 width=244) (actual time=0.080..0.526 rows=100 loops=1)
    Recheck Cond: (unique1 < 100)
-> Bitmap Index Scan on tenk1_unique1
(cost=0.00..5.04 rows=101 width=0) (actual time=0.049..0.049
rows=100 loops=1)
        Index Cond: (unique1 < 100)
Planning time: 0.194 ms
Execution time: 8.008 ms

```

The Sort node shows the sort method used (in particular, whether the sort was in-memory or on-disk) and the amount of memory or disk space needed. The Hash node shows the number of hash buckets and batches as well as the peak amount of memory used for the hash table. (If the number of batches exceeds one, there will also be disk space usage involved, but that is not shown.)

Another type of extra information is the number of rows removed by a filter condition:

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE ten < 7;
```

QUERY PLAN

```

-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=7000 width=244) (actual
time=0.016..5.107 rows=7000 loops=1)
  Filter: (ten < 7)
  Rows Removed by Filter: 3000
Planning time: 0.083 ms
Execution time: 5.905 ms

```

These counts can be particularly valuable for filter conditions applied at join nodes. The “Rows Removed” line only appears when at least one scanned row, or potential join pair in the case of a join node, is rejected by the filter condition.

A case similar to filter conditions occurs with “lossy” index scans. For example, consider this search for polygons containing a specific point:

```
EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon
'(0.5,2.0)';
```

QUERY PLAN

```

-----
Seq Scan on polygon_tbl (cost=0.00..1.05 rows=1 width=32) (actual
time=0.044..0.044 rows=0 loops=1)
  Filter: (f1 @> '((0.5,2))'::polygon)
  Rows Removed by Filter: 4
Planning time: 0.040 ms
Execution time: 0.083 ms

```

The planner thinks (quite correctly) that this sample table is too small to bother with an index scan, so we have a plain sequential scan in which all the rows got rejected by the filter condition. But if we force an index scan to be used, we see:



```
SET enable_seqscan TO off;
```

```
EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon
 '(0.5,2.0)';
```

QUERY PLAN

```
-----
Index Scan using gpolygonind on polygon_tbl (cost=0.13..8.15
rows=1 width=32) (actual time=0.062..0.062 rows=0 loops=1)
  Index Cond: (f1 @> '((0.5,2))':polygon)
  Rows Removed by Index Recheck: 1
Planning time: 0.034 ms
Execution time: 0.144 ms
```

Here we can see that the index returned one candidate row, which was then rejected by a recheck of the index condition. This happens because a GiST index is “lossy” for polygon containment tests: it actually returns the rows with polygons that overlap the target, and then we have to do the exact containment test on those rows.

EXPLAIN has a BUFFERS option that can be used with ANALYZE to get even more run time statistics:

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM tenk1 WHERE unique1 < 100
AND unique2 > 9000;
```

QUERY

PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=25.08..60.21 rows=10 width=244)
(actual time=0.323..0.342 rows=10 loops=1)
  Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
  Buffers: shared hit=15
  -> BitmapAnd (cost=25.08..25.08 rows=10 width=0) (actual
time=0.309..0.309 rows=0 loops=1)
    Buffers: shared hit=7
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0) (actual time=0.043..0.043 rows=100 loops=1)
      Index Cond: (unique1 < 100)
      Buffers: shared hit=2
    -> Bitmap Index Scan on tenk1_unique2 (cost=0.00..19.78
rows=999 width=0) (actual time=0.227..0.227 rows=999 loops=1)
      Index Cond: (unique2 > 9000)
      Buffers: shared hit=5
Planning time: 0.088 ms
Execution time: 0.423 ms
```

The numbers provided by BUFFERS help to identify which parts of the query are the most I/O-intensive.

Keep in mind that because EXPLAIN ANALYZE actually runs the query, any side-effects will happen as usual, even though whatever results the query might output are discarded in favor of printing the EXPLAIN data. If you want to analyze a data-modifying query without changing your tables, you can roll the command back afterwards, for example:

```
BEGIN;
```

```
EXPLAIN ANALYZE UPDATE tenk1 SET hundred = hundred + 1 WHERE
unique1 < 100;
```

QUERY

PLAN

```
-----
Update on tenk1 (cost=5.07..229.46 rows=101 width=250) (actual
time=14.628..14.628 rows=0 loops=1)
  -> Bitmap Heap Scan on tenk1 (cost=5.07..229.46 rows=101
width=250) (actual time=0.101..0.439 rows=100 loops=1)
    Recheck Cond: (unique1 < 100)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0) (actual time=0.043..0.043 rows=100 loops=1)
        Index Cond: (unique1 < 100)
Planning time: 0.079 ms
Execution time: 14.727 ms
```

ROLLBACK;

As seen in this example, when the query is an INSERT, UPDATE, or DELETE command, the actual work of applying the table changes is done by a top-level Insert, Update, or Delete plan node. The plan nodes underneath this node perform the work of locating the old rows and/or computing the new data. So above, we see the same sort of bitmap table scan we've seen already, and its output is fed to an Update node that stores the updated rows. It's worth noting that although the data-modifying node can take a considerable amount of run time (here, it's consuming the lion's share of the time), the planner does not currently add anything to the cost estimates to account for that work. That's because the work to be done is the same for every correct query plan, so it doesn't affect planning decisions.

When an UPDATE or DELETE command affects an inheritance hierarchy, the output might look like this:

```
EXPLAIN UPDATE parent SET f2 = f2 + 1 WHERE f1 = 101;
```

QUERY PLAN

```
-----
Update on parent (cost=0.00..24.53 rows=4 width=14)
  Update on parent
  Update on child1
  Update on child2
  Update on child3
  -> Seq Scan on parent (cost=0.00..0.00 rows=1 width=14)
      Filter: (f1 = 101)
  -> Index Scan using child1_f1_key on child1 (cost=0.15..8.17
rows=1 width=14)
      Index Cond: (f1 = 101)
  -> Index Scan using child2_f1_key on child2 (cost=0.15..8.17
rows=1 width=14)
      Index Cond: (f1 = 101)
  -> Index Scan using child3_f1_key on child3 (cost=0.15..8.17
rows=1 width=14)
      Index Cond: (f1 = 101)
```

In this example the Update node needs to consider three child tables as well as the originally-mentioned parent table. So there are four input scanning subplans, one per table. For clarity, the Update node is annotated to show the specific target tables that will be updated, in the same order as the corresponding subplans. (These annotations are new as of LightDB 9.5; in prior versions the reader had to intuit the target tables by inspecting the subplans.)

The `Planning time` shown by `EXPLAIN ANALYZE` is the time it took to generate the query plan from the parsed query and optimize it. It does not include parsing or rewriting.

The `Execution time` shown by `EXPLAIN ANALYZE` includes executor start-up and shut-down time, as well as the time to run any triggers that are fired, but it does not include parsing, rewriting, or planning time. Time spent executing `BEFORE` triggers, if any, is included in the time for the related `Insert`, `Update`, or `Delete` node; but time spent executing `AFTER` triggers is not counted there because `AFTER` triggers are fired after completion of the whole plan. The total time spent in each trigger (either `BEFORE` or `AFTER`) is also shown separately. Note that deferred constraint triggers will not be executed until end of transaction and are thus not considered at all by `EXPLAIN ANALYZE`.

### 14.1.3. Caveats

There are two significant ways in which run times measured by `EXPLAIN ANALYZE` can deviate from normal execution of the same query. First, since no output rows are delivered to the client, network transmission costs and I/O conversion costs are not included. Second, the measurement overhead added by `EXPLAIN ANALYZE` can be significant, especially on machines with slow `gettimeofday()` operating-system calls. You can use the `lt_test_timing` tool to measure the overhead of timing on your system.

`EXPLAIN` results should not be extrapolated to situations much different from the one you are actually testing; for example, results on a toy-sized table cannot be assumed to apply to large tables. The planner's cost estimates are not linear and so it might choose a different plan for a larger or smaller table. An extreme example is that on a table that only occupies one disk page, you'll nearly always get a sequential scan plan whether indexes are available or not. The planner realizes that it's going to take one disk page read to process the table in any case, so there's no value in expending additional page reads to look at an index. (We saw this happening in the `polygon_tbl` example above.)

There are cases in which the actual and estimated values won't match up well, but nothing is really wrong. One such case occurs when plan node execution is stopped short by a `LIMIT` or similar effect. For example, in the `LIMIT` query we used before,

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2
 > 9000 LIMIT 2;
```

```

                                                    QUERY
PLAN
-----
Limit  (cost=0.29..14.71 rows=2 width=244) (actual
time=0.177..0.249 rows=2 loops=1)
  -> Index Scan using tenk1_unique2 on tenk1  (cost=0.29..72.42
rows=10 width=244) (actual time=0.174..0.244 rows=2 loops=1)
    Index Cond: (unique2 > 9000)
    Filter: (unique1 < 100)
    Rows Removed by Filter: 287
Planning time: 0.096 ms
Execution time: 0.336 ms
```

the estimated cost and row count for the `Index Scan` node are shown as though it were run to completion. But in reality the `Limit` node stopped requesting rows after it got two, so the actual row count is only 2 and the run time is less than the cost estimate would suggest. This is not an estimation error, only a discrepancy in the way the estimates and true values are displayed.

Merge joins also have measurement artifacts that can confuse the unwary. A merge join will stop reading one input if it's exhausted the other input and the next key value in the one input is greater than the last key value of the other input; in such a case there can be no more matches and so no need to scan the rest of the first input. This results in not reading all of one child, with results like those

mentioned for `LIMIT`. Also, if the outer (first) child contains rows with duplicate key values, the inner (second) child is backed up and rescanned for the portion of its rows matching that key value. `EXPLAIN ANALYZE` counts these repeated emissions of the same inner rows as if they were real additional rows. When there are many outer duplicates, the reported actual row count for the inner child plan node can be significantly larger than the number of rows that are actually in the inner relation.

`BitmapAnd` and `BitmapOr` nodes always report their actual row counts as zero, due to implementation limitations.

Normally, `EXPLAIN` will display every plan node created by the planner. However, there are cases where the executor can determine that certain nodes need not be executed because they cannot produce any rows, based on parameter values that were not available at planning time. (Currently this can only happen for child nodes of an `Append` or `MergeAppend` node that is scanning a partitioned table.) When this happens, those plan nodes are omitted from the `EXPLAIN` output and a `Subplans Removed: N` annotation appears instead.

If `EXPLAIN ANALYZE` is used, all nodes will be displayed. Those nodes not be executed are noted with "never executed". When there are many such nodes, the explain output is boring and distracting. Set `lightdb_explain_no_runtime_pruned_partition` to on to eliminate nodes never executed. For example,

```
SET enable_partition_pruning = on;
SET lightdb_explain_no_runtime_pruned_partition = on;
EXPLSIN (ANALYZE) select * from measurement where logdate < (select
  date('2006-04-01'));
```

#### QUERY PLAN

```
-----
Append (cost=0.01..144.85 rows=2468 width=16) (actual
time=0.572..0.945 rows=8 loops=1)
  InitPlan 1 (returns $0)
    -> Result (cost=0.00..0.01 rows=1 width=4) (actual
time=0.002..0.002 rows=1 loops=1)
      -> Seq Scan on measurement_y2006m02 measurement_1
(cost=0.00..33.12 rows=617 width=16) (actual time=0.520..0.523
rows=4 loops=1)
        Filter: (logdate < $0)
      -> Seq Scan on measurement_y2006m03 measurement_2
(cost=0.00..33.12 rows=617 width=16) (actual time=0.361..0.365
rows=4 loops=1)
        Filter: (logdate < $0)
```

table `measurement` has four partitions, two of them pruned at runtime are not shown in query plan. Refer to Section 5.11.4 for more information.

## 14.2. Statistics Used by the Planner

### 14.2.1. Single-Column Statistics

As we saw in the previous section, the query planner needs to estimate the number of rows retrieved by a query in order to make good choices of query plans. This section provides a quick look at the statistics that the system uses for these estimates.

One component of the statistics is the total number of entries in each table and index, as well as the number of disk blocks occupied by each table and index. This information is kept in the table `pg_class`, in the columns `reltuples` and `relpages`. We can look at it with queries similar to this one:

```
SELECT relname, relkind, reltuples, relpages
FROM pg_class
WHERE relname LIKE 'tenk1%';
```

relname	relkind	reltuples	relpages
tenk1	r	10000	358
tenk1_hundred	i	10000	30
tenk1_thous_tenthous	i	10000	30
tenk1_unique1	i	10000	30
tenk1_unique2	i	10000	30

(5 rows)

Here we can see that `tenk1` contains 10000 rows, as do its indexes, but the indexes are (unsurprisingly) much smaller than the table.

For efficiency reasons, `reltuples` and `relpages` are not updated on-the-fly, and so they usually contain somewhat out-of-date values. They are updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`. A `VACUUM` or `ANALYZE` operation that does not scan the entire table (which is commonly the case) will incrementally update the `reltuples` count on the basis of the part of the table it did scan, resulting in an approximate value. In any case, the planner will scale the values it finds in `pg_class` to match the current physical table size, thus obtaining a closer approximation.

Most queries retrieve only a fraction of the rows in a table, due to `WHERE` clauses that restrict the rows to be examined. The planner thus needs to make an estimate of the *selectivity* of `WHERE` clauses, that is, the fraction of rows that match each condition in the `WHERE` clause. The information used for this task is stored in the `pg_statistic` system catalog. Entries in `pg_statistic` are updated by the `ANALYZE` and `VACUUM ANALYZE` commands, and are always approximate even when freshly updated.

Rather than look at `pg_statistic` directly, it's better to look at its view `pg_stats` when examining the statistics manually. `pg_stats` is designed to be more easily readable. Furthermore, `pg_stats` is readable by all, whereas `pg_statistic` is only readable by a superuser. (This prevents unprivileged users from learning something about the contents of other people's tables from the statistics. The `pg_stats` view is restricted to show only rows about tables that the current user can read.) For example, we might do:

```
SELECT attname, inherited, n_distinct,
       array_to_string(most_common_vals, E'\n') as most_common_vals
FROM pg_stats
WHERE tablename = 'road';
```

attname	inherited	n_distinct	most_common_vals
name	f	-0.363388	I- 580
Ramp+			I- 880
Ramp+			Sp Railroad
+			I- 580
+			I- 680
Ramp			

```

name      | t          | -0.284859 | I- 880
Ramp+    |           |           | I- 580
Ramp+    |           |           | I- 680
Ramp+    |           |           | I- 580
+        |           |           | State Hwy 13
Ramp
(2 rows)

```

Note that two rows are displayed for the same column, one corresponding to the complete inheritance hierarchy starting at the `road` table (`inherited=t`), and another one including only the `road` table itself (`inherited=f`).

The amount of information stored in `pg_statistic` by `ANALYZE`, in particular the maximum number of entries in the `most_common_vals` and `histogram_bounds` arrays for each column, can be set on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the `default_statistics_target` configuration variable. The default limit is presently 100 entries. Raising the limit might allow more accurate planner estimates to be made, particularly for columns with irregular data distributions, at the price of consuming more space in `pg_statistic` and slightly more time to compute the estimates. Conversely, a lower limit might be sufficient for columns with simple data distributions.

Further details about the planner's use of statistics can be found in Chapter 66.

## 14.2.2. Extended Statistics

It is common to see slow queries running bad execution plans because multiple columns used in the query clauses are correlated. The planner normally assumes that multiple conditions are independent of each other, an assumption that does not hold when column values are correlated. Regular statistics, because of their per-individual-column nature, cannot capture any knowledge about cross-column correlation. However, LightDB has the ability to compute *multivariate statistics*, which can capture such information.

Because the number of possible column combinations is very large, it's impractical to compute multivariate statistics automatically. Instead, *extended statistics objects*, more often called just *statistics objects*, can be created to instruct the server to obtain statistics across interesting sets of columns.

Statistics objects are created using the `CREATE STATISTICS` command. Creation of such an object merely creates a catalog entry expressing interest in the statistics. Actual data collection is performed by `ANALYZE` (either a manual command, or background auto-analyze). The collected values can be examined in the `pg_statistic_ext_data` catalog.

`ANALYZE` computes extended statistics based on the same sample of table rows that it takes for computing regular single-column statistics. Since the sample size is increased by increasing the statistics target for the table or any of its columns (as described in the previous section), a larger statistics target will normally result in more accurate extended statistics, as well as more time spent calculating them.

The following subsections describe the kinds of extended statistics that are currently supported.

### 14.2.2.1. Functional Dependencies

The simplest kind of extended statistics tracks *functional dependencies*, a concept used in definitions of database normal forms. We say that column `b` is functionally dependent on column `a` if knowledge of the value of `a` is sufficient to determine the value of `b`, that is there are no two rows having the same value of `a` but different values of `b`. In a fully normalized database, functional dependencies

should exist only on primary keys and superkeys. However, in practice many data sets are not fully normalized for various reasons; intentional denormalization for performance reasons is a common example. Even in a fully normalized database, there may be partial correlation between some columns, which can be expressed as partial functional dependency.

The existence of functional dependencies directly affects the accuracy of estimates in certain queries. If a query contains conditions on both the independent and the dependent column(s), the conditions on the dependent columns do not further reduce the result size; but without knowledge of the functional dependency, the query planner will assume that the conditions are independent, resulting in underestimating the result size.

To inform the planner about functional dependencies, `ANALYZE` can collect measurements of cross-column dependency. Assessing the degree of dependency between all sets of columns would be prohibitively expensive, so data collection is limited to those groups of columns appearing together in a statistics object defined with the `dependencies` option. It is advisable to create `dependencies` statistics only for column groups that are strongly correlated, to avoid unnecessary overhead in both `ANALYZE` and later query planning.

Here is an example of collecting functional-dependency statistics:

```
CREATE STATISTICS stts (dependencies) ON city, zip FROM zipcodes;

ANALYZE zipcodes;

SELECT stxname, stxkeys, stxddependencies
  FROM pg_statistic_ext join pg_statistic_ext_data on (oid =
  stxoid)
  WHERE stxname = 'stts';
 stxname | stxkeys | stxddependencies
-----+-----+-----
 stts   | 1 5    | {"1 => 5": 1.000000, "5 => 1": 0.423130}
(1 row)
```

Here it can be seen that column 1 (zip code) fully determines column 5 (city) so the coefficient is 1.0, while city only determines zip code about 42% of the time, meaning that there are many cities (58%) that are represented by more than a single ZIP code.

When computing the selectivity for a query involving functionally dependent columns, the planner adjusts the per-condition selectivity estimates using the dependency coefficients so as not to produce an underestimate.

#### 14.2.2.1.1. Limitations of Functional Dependencies

Functional dependencies are currently only applied when considering simple equality conditions that compare columns to constant values, and `IN` clauses with constant values. They are not used to improve estimates for equality conditions comparing two columns or comparing a column to an expression, nor for range clauses, `LIKE` or any other type of condition.

When estimating with functional dependencies, the planner assumes that conditions on the involved columns are compatible and hence redundant. If they are incompatible, the correct estimate would be zero rows, but that possibility is not considered. For example, given a query like

```
SELECT * FROM zipcodes WHERE city = 'San Francisco' AND zip =
'94105';
```

the planner will disregard the `city` clause as not changing the selectivity, which is correct. However, it will make the same assumption about

```
SELECT * FROM zipcodes WHERE city = 'San Francisco' AND zip =
'90210';
```

even though there will really be zero rows satisfying this query. Functional dependency statistics do not provide enough information to conclude that, however.

In many practical situations, this assumption is usually satisfied; for example, there might be a GUI in the application that only allows selecting compatible city and ZIP code values to use in a query. But if that's not the case, functional dependencies may not be a viable option.

### 14.2.2.2. Multivariate N-Distinct Counts

Single-column statistics store the number of distinct values in each column. Estimates of the number of distinct values when combining more than one column (for example, for `GROUP BY a, b`) are frequently wrong when the planner only has single-column statistical data, causing it to select bad plans.

To improve such estimates, `ANALYZE` can collect n-distinct statistics for groups of columns. As before, it's impractical to do this for every possible column grouping, so data is collected only for those groups of columns appearing together in a statistics object defined with the `ndistinct` option. Data will be collected for each possible combination of two or more columns from the set of listed columns.

Continuing the previous example, the n-distinct counts in a table of ZIP codes might look like the following:

```
CREATE STATISTICS stts2 (ndistinct) ON city, state, zip FROM
zipcodes;

ANALYZE zipcodes;

SELECT stxkeys AS k, stxdndistinct AS nd
FROM pg_statistic_ext join pg_statistic_ext_data on (oid =
stxoid)
WHERE stxname = 'stts2';
-[ RECORD 1 ]-----
--
k | 1 2 5
nd | {"1, 2": 33178, "1, 5": 33178, "2, 5": 27435, "1, 2, 5":
33178}
(1 row)
```

This indicates that there are three combinations of columns that have 33178 distinct values: ZIP code and state; ZIP code and city; and ZIP code, city and state (the fact that they are all equal is expected given that ZIP code alone is unique in this table). On the other hand, the combination of city and state has only 27435 distinct values.

It's advisable to create `ndistinct` statistics objects only on combinations of columns that are actually used for grouping, and for which misestimation of the number of groups is resulting in bad plans. Otherwise, the `ANALYZE` cycles are just wasted.

### 14.2.2.3. Multivariate MCV Lists

Another type of statistic stored for each column are most-common value lists. This allows very accurate estimates for individual columns, but may result in significant misestimates for queries with conditions on multiple columns.

To improve such estimates, `ANALYZE` can collect MCV lists on combinations of columns. Similarly to functional dependencies and n-distinct coefficients, it's impractical to do this for every possible column grouping. Even more so in this case, as the MCV list (unlike functional dependencies and n-



distinct coefficients) does store the common column values. So data is collected only for those groups of columns appearing together in a statistics object defined with the `mcv` option.

Continuing the previous example, the MCV list for a table of ZIP codes might look like the following (unlike for simpler types of statistics, a function is required for inspection of MCV contents):

```
CREATE STATISTICS stts3 (mcv) ON city, state FROM zipcodes;

ANALYZE zipcodes;

SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
           pg_mcv_list_items(stxdmcv) m WHERE stxname =
'stts3';
```

index	values	nulls	frequency
base_frequency			
0	{Washington, DC}	{f,f}	0.003467
2.7e-05			
1	{Apo, AE}	{f,f}	0.003067
1.9e-05			
2	{Houston, TX}	{f,f}	0.002167
0.000133			
3	{El Paso, TX}	{f,f}	0.002
0.000113			
4	{New York, NY}	{f,f}	0.001967
0.000114			
5	{Atlanta, GA}	{f,f}	0.001633
3.3e-05			
6	{Sacramento, CA}	{f,f}	0.001433
7.8e-05			
7	{Miami, FL}	{f,f}	0.0014
6e-05			
8	{Dallas, TX}	{f,f}	0.001367
8.8e-05			
9	{Chicago, IL}	{f,f}	0.001333
5.1e-05			
...			

(99 rows)

This indicates that the most common combination of city and state is Washington in DC, with actual frequency (in the sample) about 0.35%. The base frequency of the combination (as computed from the simple per-column frequencies) is only 0.0027%, resulting in two orders of magnitude underestimates.

It's advisable to create MCV statistics objects only on combinations of columns that are actually used in conditions together, and for which misestimation of the number of groups is resulting in bad plans. Otherwise, the `ANALYZE` and planning cycles are just wasted.

## 14.3. Controlling the Planner with Explicit JOIN Clauses

It is possible to control the query planner to some extent by using the explicit `JOIN` syntax. To see why this matters, we first need some background.

In a simple join query, such as:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
```

the planner is free to join the given tables in any order. For example, it could generate a query plan that joins A to B, using the WHERE condition `a.id = b.id`, and then joins C to this joined table, using the other WHERE condition. Or it could join B to C and then join A to that result. Or it could join A to C and then join them with B — but that would be inefficient, since the full Cartesian product of A and C would have to be formed, there being no applicable condition in the WHERE clause to allow optimization of the join. (All joins in the LightDB executor happen between two input tables, so it's necessary to build up the result in one or another of these fashions.) The important point is that these different join possibilities give semantically equivalent results but might have hugely different execution costs. Therefore, the planner will explore all of them to try to find the most efficient query plan.

When a query only involves two or three tables, there aren't many join orders to worry about. But the number of possible join orders grows exponentially as the number of tables expands. Beyond ten or so input tables it's no longer practical to do an exhaustive search of all the possibilities, and even for six or seven tables planning might take an annoyingly long time. When there are too many input tables, the LightDB planner will switch from exhaustive search to a *genetic* probabilistic search through a limited number of possibilities. (The switch-over threshold is set by the `geqo_threshold` run-time parameter.) The genetic search takes less time, but it won't necessarily find the best possible plan.

When the query involves outer joins, the planner has less freedom than it does for plain (inner) joins. For example, consider:

```
SELECT * FROM a LEFT JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

Although this query's restrictions are superficially similar to the previous example, the semantics are different because a row must be emitted for each row of A that has no matching row in the join of B and C. Therefore the planner has no choice of join order here: it must join B to C and then join A to that result. Accordingly, this query takes less time to plan than the previous query. In other cases, the planner might be able to determine that more than one join order is safe. For example, given:

```
SELECT * FROM a LEFT JOIN b ON (a.bid = b.id) LEFT JOIN c ON (a.cid = c.id);
```

it is valid to join A to either B or C first. Currently, only `FULL JOIN` completely constrains the join order. Most practical cases involving `LEFT JOIN` or `RIGHT JOIN` can be rearranged to some extent.

Explicit inner join syntax (`INNER JOIN`, `CROSS JOIN`, or unadorned `JOIN`) is semantically the same as listing the input relations in `FROM`, so it does not constrain the join order.

Even though most kinds of `JOIN` don't completely constrain the join order, it is possible to instruct the LightDB query planner to treat all `JOIN` clauses as constraining the join order anyway. For example, these three queries are logically equivalent:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
SELECT * FROM a CROSS JOIN b CROSS JOIN c WHERE a.id = b.id AND
  b.ref = c.id;
SELECT * FROM a JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

But if we tell the planner to honor the `JOIN` order, the second and third take less time to plan than the first. This effect is not worth worrying about for only three tables, but it can be a lifesaver with many tables.

To force the planner to follow the join order laid out by explicit `JOINS`, set the `join_collapse_limit` run-time parameter to 1. (Other possible values are discussed below.)

You do not need to constrain the join order completely in order to cut search time, because it's OK to use `JOIN` operators within items of a plain `FROM` list. For example, consider:

```
SELECT * FROM a CROSS JOIN b, c, d, e WHERE ...;
```

With `join_collapse_limit = 1`, this forces the planner to join A to B before joining them to other tables, but doesn't constrain its choices otherwise. In this example, the number of possible join orders is reduced by a factor of 5.

Constraining the planner's search in this way is a useful technique both for reducing planning time and for directing the planner to a good query plan. If the planner chooses a bad join order by default, you can force it to choose a better order via `JOIN` syntax — assuming that you know of a better order, that is. Experimentation is recommended.

A closely related issue that affects planning time is collapsing of subqueries into their parent query. For example, consider:

```
SELECT *
FROM x, y,
     (SELECT * FROM a, b, c WHERE something) AS ss
WHERE somethingelse;
```

This situation might arise from use of a view that contains a join; the view's `SELECT` rule will be inserted in place of the view reference, yielding a query much like the above. Normally, the planner will try to collapse the subquery into the parent, yielding:

```
SELECT * FROM x, y, a, b, c WHERE something AND somethingelse;
```

This usually results in a better plan than planning the subquery separately. (For example, the outer `WHERE` conditions might be such that joining X to A first eliminates many rows of A, thus avoiding the need to form the full logical output of the subquery.) But at the same time, we have increased the planning time; here, we have a five-way join problem replacing two separate three-way join problems. Because of the exponential growth of the number of possibilities, this makes a big difference. The planner tries to avoid getting stuck in huge join search problems by not collapsing a subquery if more than `from_collapse_limit` `FROM` items would result in the parent query. You can trade off planning time against quality of plan by adjusting this run-time parameter up or down.

`from_collapse_limit` and `join_collapse_limit` are similarly named because they do almost the same thing: one controls when the planner will “flatten out” subqueries, and the other controls when it will flatten out explicit joins. Typically you would either set `join_collapse_limit` equal to `from_collapse_limit` (so that explicit joins and subqueries act similarly) or set `join_collapse_limit` to 1 (if you want to control join order with explicit joins). But you might set them differently if you are trying to fine-tune the trade-off between planning time and run time.

## 14.4. Populating a Database

One might need to insert a large amount of data when first populating a database. This section contains some suggestions on how to make this process as efficient as possible.

### 14.4.1. Disable Autocommit

When using multiple `INSERTs`, turn off autocommit and just do one commit at the end. (In plain SQL, this means issuing `BEGIN` at the start and `COMMIT` at the end. Some client libraries might do

this behind your back, in which case you need to make sure the library does it when you want it done.) If you allow each insertion to be committed separately, LightDB is doing a lot of work for each row that is added. An additional benefit of doing all insertions in one transaction is that if the insertion of one row were to fail then the insertion of all rows inserted up to that point would be rolled back, so you won't be stuck with partially loaded data.

### 14.4.2. Use COPY

Use COPY to load all the rows in one command, instead of using a series of INSERT commands. The COPY command is optimized for loading large numbers of rows; it is less flexible than INSERT, but incurs significantly less overhead for large data loads. Since COPY is a single command, there is no need to disable autocommit if you use this method to populate a table.

If you cannot use COPY, it might help to use PREPARE to create a prepared INSERT statement, and then use EXECUTE as many times as required. This avoids some of the overhead of repeatedly parsing and planning INSERT. Different interfaces provide this facility in different ways; look for “prepared statements” in the interface documentation.

Note that loading a large number of rows using COPY is almost always faster than using INSERT, even if PREPARE is used and multiple insertions are batched into a single transaction.

COPY is fastest when used within the same transaction as an earlier CREATE TABLE or TRUNCATE command. In such cases no WAL needs to be written, because in case of an error, the files containing the newly loaded data will be removed anyway. However, this consideration only applies when wal\_level is minimal as all commands must write WAL otherwise.

### 14.4.3. Remove Indexes

If you are loading a freshly created table, the fastest method is to create the table, bulk load the table's data using COPY, then create any indexes needed for the table. Creating an index on pre-existing data is quicker than updating it incrementally as each row is loaded.

If you are adding large amounts of data to an existing table, it might be a win to drop the indexes, load the table, and then recreate the indexes. Of course, the database performance for other users might suffer during the time the indexes are missing. One should also think twice before dropping a unique index, since the error checking afforded by the unique constraint will be lost while the index is missing.

### 14.4.4. Remove Foreign Key Constraints

Just as with indexes, a foreign key constraint can be checked “in bulk” more efficiently than row-by-row. So it might be useful to drop foreign key constraints, load data, and re-create the constraints. Again, there is a trade-off between data load speed and loss of error checking while the constraint is missing.

What's more, when you load data into a table with existing foreign key constraints, each new row requires an entry in the server's list of pending trigger events (since it is the firing of a trigger that checks the row's foreign key constraint). Loading many millions of rows can cause the trigger event queue to overflow available memory, leading to intolerable swapping or even outright failure of the command. Therefore it may be *necessary*, not just desirable, to drop and re-apply foreign keys when loading large amounts of data. If temporarily removing the constraint isn't acceptable, the only other recourse may be to split up the load operation into smaller transactions.

### 14.4.5. Increase maintenance\_work\_mem

Temporarily increasing the maintenance\_work\_mem configuration variable when loading large amounts of data can lead to improved performance. This will help to speed up CREATE INDEX commands and ALTER TABLE ADD FOREIGN KEY commands. It won't do much for COPY itself, so this advice is only useful when you are using one or both of the above techniques.

## 14.4.6. Increase `max_wal_size`

Temporarily increasing the `max_wal_size` configuration variable can also make large data loads faster. This is because loading a large amount of data into LightDB will cause checkpoints to occur more often than the normal checkpoint frequency (specified by the `checkpoint_timeout` configuration variable). Whenever a checkpoint occurs, all dirty pages must be flushed to disk. By increasing `max_wal_size` temporarily during bulk data loads, the number of checkpoints that are required can be reduced.

## 14.4.7. Disable WAL Archival and Streaming Replication

When loading large amounts of data into an installation that uses WAL archiving or streaming replication, it might be faster to take a new base backup after the load has completed than to process a large amount of incremental WAL data. To prevent incremental WAL logging while loading, disable archiving and streaming replication, by setting `wal_level` to `minimal`, `archive_mode` to `off`, and `max_wal_senders` to zero. But note that changing these settings requires a server restart.

Aside from avoiding the time for the archiver or WAL sender to process the WAL data, doing this will actually make certain commands faster, because they do not to write WAL at all if `wal_level` is `minimal` and the current subtransaction (or top-level transaction) created or truncated the table or index they change. (They can guarantee crash safety more cheaply by doing an `fsync` at the end than by writing WAL.)

## 14.4.8. Run `ANALYZE` Afterwards

Whenever you have significantly altered the distribution of data within a table, running `ANALYZE` is strongly recommended. This includes bulk loading large amounts of data into the table. Running `ANALYZE` (or `VACUUM ANALYZE`) ensures that the planner has up-to-date statistics about the table. With no statistics or obsolete statistics, the planner might make poor decisions during query planning, leading to poor performance on any tables with inaccurate or nonexistent statistics. Note that if the autovacuum daemon is enabled, it might run `ANALYZE` automatically; see Section 22.1.3 and Section 22.1.6 for more information.

## 14.4.9. Some Notes about `lt_dump`

Dump scripts generated by `lt_dump` automatically apply several, but not all, of the above guidelines. To restore a `lt_dump` dump as quickly as possible, you need to do a few extra things manually. (Note that these points apply while *restoring* a dump, not while *creating* it. The same points apply whether loading a text dump with `ltsql` or using `lt_restore` to load from a `lt_dump` archive file.)

By default, `lt_dump` uses `COPY`, and when it is generating a complete schema-and-data dump, it is careful to load data before creating indexes and foreign keys. So in this case several guidelines are handled automatically. What is left for you to do is to:

- Set appropriate (i.e., larger than normal) values for `maintenance_work_mem` and `max_wal_size`.
- If using WAL archiving or streaming replication, consider disabling them during the restore. To do that, set `archive_mode` to `off`, `wal_level` to `minimal`, and `max_wal_senders` to zero before loading the dump. Afterwards, set them back to the right values and take a fresh base backup.
- Experiment with the parallel dump and restore modes of both `lt_dump` and `lt_restore` and find the optimal number of concurrent jobs to use. Dumping and restoring in parallel by means of the `-j` option should give you a significantly higher performance over the serial mode.
- Consider whether the whole dump should be restored as a single transaction. To do that, pass the `-1` or `--single-transaction` command-line option to `ltsql` or `lt_restore`. When using this

mode, even the smallest of errors will rollback the entire restore, possibly discarding many hours of processing. Depending on how interrelated the data is, that might seem preferable to manual cleanup, or not. `COPY` commands will run fastest if you use a single transaction and have WAL archiving turned off.

- If multiple CPUs are available in the database server, consider using `lt_restore's --jobs` option. This allows concurrent data loading and index creation.
- Run `ANALYZE` afterwards.

A data-only dump will still use `COPY`, but it does not drop or recreate indexes, and it does not normally touch foreign keys.<sup>1</sup> So when loading a data-only dump, it is up to you to drop and recreate indexes and foreign keys if you wish to use those techniques. It's still useful to increase `max_wal_size` while loading the data, but don't bother increasing `maintenance_work_mem`; rather, you'd do that while manually recreating indexes and foreign keys afterwards. And don't forget to `ANALYZE` when you're done; see Section 22.1.3 and Section 22.1.6 for more information.

## 14.5. Non-Durable Settings

Durability is a database feature that guarantees the recording of committed transactions even if the server crashes or loses power. However, durability adds significant database overhead, so if your site does not require such a guarantee, `LightDB` can be configured to run much faster. The following are configuration changes you can make to improve performance in such cases. Except as noted below, durability is still guaranteed in case of a crash of the database software; only abrupt operating system stoppage creates a risk of data loss or corruption when these settings are used.

- Place the database cluster's data directory in a memory-backed file system (i.e., RAM disk). This eliminates all database disk I/O, but limits data storage to the amount of available memory (and perhaps swap).
- Turn off `fsync`; there is no need to flush data to disk.
- Turn off `synchronous_commit`; there might be no need to force WAL writes to disk on every commit. This setting does risk transaction loss (though not data corruption) in case of a crash of the *database*.
- Turn off `full_page_writes`; there is no need to guard against partial page writes.
- Increase `max_wal_size` and `checkpoint_timeout`; this reduces the frequency of checkpoints, but increases the storage requirements of `/lt_wal`.
- Create unlogged tables to avoid WAL writes, though it makes the tables non-crash-safe.

---

<sup>1</sup> You can get the effect of disabling foreign keys by using the `--disable-triggers` option — but realize that that eliminates, rather than just postpones, foreign key validation, and so it is possible to insert bad data if you use it.

---

# Chapter 15. Parallel Query

LightDB can devise query plans that can leverage multiple CPUs in order to answer queries faster. This feature is known as parallel query. Many queries cannot benefit from parallel query, either due to limitations of the current implementation or because there is no imaginable query plan that is any faster than the serial query plan. However, for queries that can benefit, the speedup from parallel query is often very significant. Many queries can run more than twice as fast when using parallel query, and some queries can run four times faster or even more. Queries that touch a large amount of data but return only a few rows to the user will typically benefit most. This chapter explains some details of how parallel query works and in which situations it can be used so that users who wish to make use of it can understand what to expect.

## 15.1. How Parallel Query Works

When the optimizer determines that parallel query is the fastest execution strategy for a particular query, it will create a query plan that includes a *Gather* or *Gather Merge* node. Here is a simple example:

```
EXPLAIN SELECT * FROM ltbench_accounts WHERE filler LIKE '%x%';
                                QUERY PLAN
-----
Gather  (cost=1000.00..217018.43 rows=1 width=97)
  Workers Planned: 2
  -> Parallel Seq Scan on ltbench_accounts  (cost=0.00..216018.33
rows=1 width=97)
    Filter: (filler ~~ '%x%'::text)
(4 rows)
```

In all cases, the *Gather* or *Gather Merge* node will have exactly one child plan, which is the portion of the plan that will be executed in parallel. If the *Gather* or *Gather Merge* node is at the very top of the plan tree, then the entire query will execute in parallel. If it is somewhere else in the plan tree, then only the portion of the plan below it will run in parallel. In the example above, the query accesses only one table, so there is only one plan node other than the *Gather* node itself; since that plan node is a child of the *Gather* node, it will run in parallel.

Using `EXPLAIN`, you can see the number of workers chosen by the planner. When the *Gather* node is reached during query execution, the process that is implementing the user's session will request a number of background worker processes equal to the number of workers chosen by the planner. The number of background workers that the planner will consider using is limited to at most `max_parallel_workers_per_gather`. The total number of background workers that can exist at any one time is limited by both `max_worker_processes` and `max_parallel_workers`. Therefore, it is possible for a parallel query to run with fewer workers than planned, or even with no workers at all. The optimal plan may depend on the number of workers that are available, so this can result in poor query performance. If this occurrence is frequent, consider increasing `max_worker_processes` and `max_parallel_workers` so that more workers can be run simultaneously or alternatively reducing `max_parallel_workers_per_gather` so that the planner requests fewer workers.

Every background worker process that is successfully started for a given parallel query will execute the parallel portion of the plan. The leader will also execute that portion of the plan, but it has an additional responsibility: it must also read all of the tuples generated by the workers. When the parallel portion of the plan generates only a small number of tuples, the leader will often behave very much like an additional worker, speeding up query execution. Conversely, when the parallel portion of the plan generates a large number of tuples, the leader may be almost entirely occupied with reading the tuples generated by the workers and performing any further processing steps that are required by plan

nodes above the level of the `Gather` node or `Gather Merge` node. In such cases, the leader will do very little of the work of executing the parallel portion of the plan.

When the node at the top of the parallel portion of the plan is `Gather Merge` rather than `Gather`, it indicates that each process executing the parallel portion of the plan is producing tuples in sorted order, and that the leader is performing an order-preserving merge. In contrast, `Gather` reads tuples from the workers in whatever order is convenient, destroying any sort order that may have existed.

## 15.2. When Can Parallel Query Be Used?

There are several settings that can cause the query planner not to generate a parallel query plan under any circumstances. In order for any parallel query plans whatsoever to be generated, the following settings must be configured as indicated.

- `max_parallel_workers_per_gather` must be set to a value that is greater than zero. This is a special case of the more general principle that no more workers should be used than the number configured via `max_parallel_workers_per_gather`.

In addition, the system must not be running in single-user mode. Since the entire database system is running in single process in this situation, no background workers will be available.

Even when it is in general possible for parallel query plans to be generated, the planner will not generate them for a given query if any of the following are true:

- The query writes any data or locks any database rows. If a query contains a data-modifying operation either at the top level or within a CTE, no parallel plans for that query will be generated. As an exception, the commands `CREATE TABLE ... AS`, `SELECT INTO`, and `CREATE MATERIALIZED VIEW` that create a new table and populate it can use a parallel plan.
- The query might be suspended during execution. In any situation in which the system thinks that partial or incremental execution might occur, no parallel plan is generated. For example, a cursor created using `DECLARE CURSOR` will never use a parallel plan. Similarly, a PL/pgSQL loop of the form `FOR x IN query LOOP ... END LOOP` will never use a parallel plan, because the parallel query system is unable to verify that the code in the loop is safe to execute while parallel query is active.
- The query uses any function marked `PARALLEL UNSAFE`. Most system-defined functions are `PARALLEL SAFE`, but user-defined functions are marked `PARALLEL UNSAFE` by default. See the discussion of Section 15.4.
- The query is running inside of another query that is already parallel. For example, if a function called by a parallel query issues an SQL query itself, that query will never use a parallel plan. This is a limitation of the current implementation, but it may not be desirable to remove this limitation, since it could result in a single query using a very large number of processes.

Even when parallel query plan is generated for a particular query, there are several circumstances under which it will be impossible to execute that plan in parallel at execution time. If this occurs, the leader will execute the portion of the plan below the `Gather` node entirely by itself, almost as if the `Gather` node were not present. This will happen if any of the following conditions are met:

- No background workers can be obtained because of the limitation that the total number of background workers cannot exceed `max_worker_processes`.
- No background workers can be obtained because of the limitation that the total number of background workers launched for purposes of parallel query cannot exceed `max_parallel_workers`.
- The client sends an Execute message with a non-zero fetch count. See the discussion of the extended query protocol. Since `libpq` currently provides no way to send such a message, this can only occur when using a client that does not rely on `libpq`. If this is a frequent occurrence, it may be a good



idea to set `max_parallel_workers_per_gather` to zero in sessions where it is likely, so as to avoid generating query plans that may be suboptimal when run serially.

## 15.3. Parallel Plans

Because each worker executes the parallel portion of the plan to completion, it is not possible to simply take an ordinary query plan and run it using multiple workers. Each worker would produce a full copy of the output result set, so the query would not run any faster than normal but would produce incorrect results. Instead, the parallel portion of the plan must be what is known internally to the query optimizer as a *partial plan*; that is, it must be constructed so that each process that executes the plan will generate only a subset of the output rows in such a way that each required output row is guaranteed to be generated by exactly one of the cooperating processes. Generally, this means that the scan on the driving table of the query must be a parallel-aware scan.

### 15.3.1. Parallel Scans

The following types of parallel-aware table scans are currently supported.

- In a *parallel sequential scan*, the table's blocks will be divided among the cooperating processes. Blocks are handed out one at a time, so that access to the table remains sequential.
- In a *parallel bitmap heap scan*, one process is chosen as the leader. That process performs a scan of one or more indexes and builds a bitmap indicating which table blocks need to be visited. These blocks are then divided among the cooperating processes as in a parallel sequential scan. In other words, the heap scan is performed in parallel, but the underlying index scan is not.
- In a *parallel index scan* or *parallel index-only scan*, the cooperating processes take turns reading data from the index. Currently, parallel index scans are supported only for btree indexes. Each process will claim a single index block and will scan and return all tuples referenced by that block; other processes can at the same time be returning tuples from a different index block. The results of a parallel btree scan are returned in sorted order within each worker process.

Other scan types, such as scans of non-btree indexes, may support parallel scans in the future.

### 15.3.2. Parallel Joins

Just as in a non-parallel plan, the driving table may be joined to one or more other tables using a nested loop, hash join, or merge join. The inner side of the join may be any kind of non-parallel plan that is otherwise supported by the planner provided that it is safe to run within a parallel worker. Depending on the join type, the inner side may also be a parallel plan.

- In a *nested loop join*, the inner side is always non-parallel. Although it is executed in full, this is efficient if the inner side is an index scan, because the outer tuples and thus the loops that look up values in the index are divided over the cooperating processes.
- In a *merge join*, the inner side is always a non-parallel plan and therefore executed in full. This may be inefficient, especially if a sort must be performed, because the work and resulting data are duplicated in every cooperating process.
- In a *hash join* (without the "parallel" prefix), the inner side is executed in full by every cooperating process to build identical copies of the hash table. This may be inefficient if the hash table is large or the plan is expensive. In a *parallel hash join*, the inner side is a *parallel hash* that divides the work of building a shared hash table over the cooperating processes.

### 15.3.3. Parallel Aggregation

LightDB supports parallel aggregation by aggregating in two stages. First, each process participating in the parallel portion of the query performs an aggregation step, producing a partial result for each

group of which that process is aware. This is reflected in the plan as a `Partial Aggregate` node. Second, the partial results are transferred to the leader via `Gather` or `Gather Merge`. Finally, the leader re-aggregates the results across all workers in order to produce the final result. This is reflected in the plan as a `Finalize Aggregate` node.

Because the `Finalize Aggregate` node runs on the leader process, queries that produce a relatively large number of groups in comparison to the number of input rows will appear less favorable to the query planner. For example, in the worst-case scenario the number of groups seen by the `Finalize Aggregate` node could be as many as the number of input rows that were seen by all worker processes in the `Partial Aggregate` stage. For such cases, there is clearly going to be no performance benefit to using parallel aggregation. The query planner takes this into account during the planning process and is unlikely to choose parallel aggregate in this scenario.

Parallel aggregation is not supported in all situations. Each aggregate must be safe for parallelism and must have a combine function. If the aggregate has a transition state of type `internal`, it must have serialization and deserialization functions. See `CREATE AGGREGATE` for more details. Parallel aggregation is not supported if any aggregate function call contains `DISTINCT` or `ORDER BY` clause and is also not supported for ordered set aggregates or when the query involves `GROUPING SETS`. It can only be used when all joins involved in the query are also part of the parallel portion of the plan.

## 15.3.4. Parallel Append

Whenever LightDB needs to combine rows from multiple sources into a single result set, it uses an `Append` or `MergeAppend` plan node. This commonly happens when implementing `UNION ALL` or when scanning a partitioned table. Such nodes can be used in parallel plans just as they can in any other plan. However, in a parallel plan, the planner may instead use a `Parallel Append` node.

When an `Append` node is used in a parallel plan, each process will execute the child plans in the order in which they appear, so that all participating processes cooperate to execute the first child plan until it is complete and then move to the second plan at around the same time. When a `Parallel Append` is used instead, the executor will instead spread out the participating processes as evenly as possible across its child plans, so that multiple child plans are executed simultaneously. This avoids contention, and also avoids paying the startup cost of a child plan in those processes that never execute it.

Also, unlike a regular `Append` node, which can only have partial children when used within a parallel plan, a `Parallel Append` node can have both partial and non-partial child plans. Non-partial children will be scanned by only a single process, since scanning them more than once would produce duplicate results. Plans that involve appending multiple results sets can therefore achieve coarse-grained parallelism even when efficient partial plans are not available. For example, consider a query against a partitioned table that can only be implemented efficiently by using an index that does not support parallel scans. The planner might choose a `Parallel Append` of regular `Index Scan` plans; each individual index scan would have to be executed to completion by a single process, but different scans could be performed at the same time by different processes.

`enable_parallel_append` can be used to disable this feature.

## 15.3.5. Parallel Plan Tips

If a query that is expected to do so does not produce a parallel plan, you can try reducing `parallel_setup_cost` or `parallel_tuple_cost`. Of course, this plan may turn out to be slower than the serial plan that the planner preferred, but this will not always be the case. If you don't get a parallel plan even with very small values of these settings (e.g., after setting them both to zero), there may be some reason why the query planner is unable to generate a parallel plan for your query. See Section 15.2 and Section 15.4 for information on why this may be the case.

When executing a parallel plan, you can use `EXPLAIN (ANALYZE, VERBOSE)` to display per-worker statistics for each plan node. This may be useful in determining whether the work is being evenly distributed between all plan nodes and more generally in understanding the performance characteristics of the plan.

## 15.4. Parallel Safety

The planner classifies operations involved in a query as either *parallel safe*, *parallel restricted*, or *parallel unsafe*. A parallel safe operation is one that does not conflict with the use of parallel query. A parallel restricted operation is one that cannot be performed in a parallel worker, but that can be performed in the leader while parallel query is in use. Therefore, parallel restricted operations can never occur below a `Gather` or `Gather Merge` node, but can occur elsewhere in a plan that contains such a node. A parallel unsafe operation is one that cannot be performed while parallel query is in use, not even in the leader. When a query contains anything that is parallel unsafe, parallel query is completely disabled for that query.

The following operations are always parallel restricted:

- Scans of common table expressions (CTEs).
- Scans of temporary tables.
- Scans of foreign tables, unless the foreign data wrapper has an `IsForeignScanParallelSafe` API that indicates otherwise.
- Plan nodes to which an `InitPlan` is attached.
- Plan nodes that reference a correlated `SubPlan`.

### 15.4.1. Parallel Labeling for Functions and Aggregates

The planner cannot automatically determine whether a user-defined function or aggregate is parallel safe, parallel restricted, or parallel unsafe, because this would require predicting every operation that the function could possibly perform. In general, this is equivalent to the Halting Problem and therefore impossible. Even for simple functions where it could conceivably be done, we do not try, since this would be expensive and error-prone. Instead, all user-defined functions are assumed to be parallel unsafe unless otherwise marked. When using `CREATE FUNCTION` or `ALTER FUNCTION`, markings can be set by specifying `PARALLEL SAFE`, `PARALLEL RESTRICTED`, or `PARALLEL UNSAFE` as appropriate. When using `CREATE AGGREGATE`, the `PARALLEL` option can be specified with `SAFE`, `RESTRICTED`, or `UNSAFE` as the corresponding value.

Functions and aggregates must be marked `PARALLEL UNSAFE` if they write to the database, access sequences, change the transaction state even temporarily (e.g., a PL/pgSQL function that establishes an `EXCEPTION` block to catch errors), or make persistent changes to settings. Similarly, functions must be marked `PARALLEL RESTRICTED` if they access temporary tables, client connection state, cursors, prepared statements, or miscellaneous backend-local state that the system cannot synchronize across workers. For example, `setseed` and `random` are parallel restricted for this last reason.

In general, if a function is labeled as being safe when it is restricted or unsafe, or if it is labeled as being restricted when it is in fact unsafe, it may throw errors or produce wrong answers when used in a parallel query. C-language functions could in theory exhibit totally undefined behavior if mislabeled, since there is no way for the system to protect itself against arbitrary C code, but in most likely cases the result will be no worse than for any other function. If in doubt, it is probably best to label functions as `UNSAFE`.

If a function executed within a parallel worker acquires locks that are not held by the leader, for example by querying a table not referenced in the query, those locks will be released at worker exit, not end of transaction. If you write a function that does this, and this behavior difference is important to you, mark such functions as `PARALLEL RESTRICTED` to ensure that they execute only in the leader.

Note that the query planner does not consider deferring the evaluation of parallel-restricted functions or aggregates involved in the query in order to obtain a superior plan. So, for example, if a `WHERE` clause applied to a particular table is parallel restricted, the query planner will not consider performing a scan of that table in the parallel portion of a plan. In some cases, it would be possible (and perhaps even

efficient) to include the scan of that table in the parallel portion of the query and defer the evaluation of the `WHERE` clause so that it happens above the `Gather` node. However, the planner does not do this.

---

# Part III. Server Administration

This part covers topics that are of interest to a LightDB database administrator. This includes installation of the software, set up and configuration of the server, management of users and databases, and maintenance tasks. Anyone who runs a LightDB server, even for personal use, but especially in production, should be familiar with the topics covered in this part.

The information in this part is arranged approximately in the order in which a new user should read it. But the chapters are self-contained and can be read individually as desired. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

The first few chapters are written so they can be understood without prerequisite knowledge, so new users who need to set up their own server can begin their exploration with this part. The rest of this part is about tuning and management; that material assumes that the reader is familiar with the general use of the LightDB database system. Readers are encouraged to look at Part I and Part II for additional information.

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# Chapter 16. Server Setup and Operation

This chapter discusses how to set up and run the database server, and its interactions with the operating system.

The directions in this chapter assume that you are working with plain LightDB without any additional infrastructure, for example a copy that you built from source according to the directions in the preceding chapters. If you are working with a pre-packaged or vendor-supplied version of LightDB, it is likely that the packager has made special provisions for installing and starting the database server according to your system's conventions. Consult the package-level documentation for details.

## 16.1. The LightDB User Account

As with any server daemon that is accessible to the outside world, it is advisable to run LightDB under a separate user account. This user account should only own the data that is managed by the server, and should not be shared with other daemons. (For example, using the user `nobody` is a bad idea.) In particular, it is advisable that this user account not own the LightDB executable files, to ensure that a compromised server process could not modify those executables.

Pre-packaged versions of LightDB will typically create a suitable user account automatically during package installation.

To add a Unix user account to your system, look for a command `useradd` or `adduser`. The user name `lightdb` is often used, and is assumed throughout this book, but you can use another name if you like.

## 16.2. Creating a Database Cluster

Before you can do anything, you must initialize a database storage area on disk. We call this a *database cluster*. (The SQL standard uses the term *catalog cluster*.) A database cluster is a collection of databases that is managed by a single instance of a running database server. After initialization, a database cluster will contain a database named `postgres`, which is meant as a default database for use by utilities, users and third party applications. The database server itself does not require the `postgres` database to exist, but many external utility programs assume it exists. Another database created within each cluster during initialization is called `template1`. As the name suggests, this will be used as a template for subsequently created databases; it should not be used for actual work. (See Chapter 20 for information about creating new databases within a cluster.)

In file system terms, a database cluster is a single directory under which all data will be stored. We call this the *data directory* or *data area*. It is completely up to you where you choose to store your data. There is no default, although locations such as `/usr/local/lightdb-x/data` or `/var/lib/lightdb-x/data` are popular. The data directory must be initialized before being used, using the program `initdb` which is installed with LightDB.

If you are using a pre-packaged version of LightDB, it may well have a specific convention for where to place the data directory, and it may also provide a script for creating the data directory. In that case you should use that script in preference to running `initdb` directly. Consult the package-level documentation for details.

To initialize a database cluster manually, run `initdb` and specify the desired file system location of the database cluster with the `-D` option, for example:

```
$ initdb -D /usr/local/lightdb-x/data
```

Note that you must execute this command while logged into the LightDB user account, which is described in the previous section.

### Tip

As an alternative to the `-D` option, you can set the environment variable `LTDATA`.

Alternatively, you can run `initdb` via the `lt_ctl` program like so:

```
$ lt_ctl -D /usr/local/lightdb-x/data initdb
```

This may be more intuitive if you are using `lt_ctl` for starting and stopping the server (see Section 16.3), so that `lt_ctl` would be the sole command you use for managing the database server instance.

`initdb` will attempt to create the directory you specify if it does not already exist. Of course, this will fail if `initdb` does not have permissions to write in the parent directory. It's generally recommendable that the LightDB user own not just the data directory but its parent directory as well, so that this should not be a problem. If the desired parent directory doesn't exist either, you will need to create it first, using root privileges if the grandparent directory isn't writable. So the process might look like this:

```
root# mkdir /usr/local/pgsql
root# chown lightdb /usr/local/pgsql
root# su lightdb
lightdb$ initdb -D /usr/local/lightdb-x/data
```

`initdb` will refuse to run if the data directory exists and already contains files; this is to prevent accidentally overwriting an existing installation.

Because the data directory contains all the data stored in the database, it is essential that it be secured from unauthorized access. `initdb` therefore revokes access permissions from everyone but the LightDB user, and optionally, group. Group access, when enabled, is read-only. This allows an unprivileged user in the same group as the cluster owner to take a backup of the cluster data or perform other operations that only require read access.

Note that enabling or disabling group access on an existing cluster requires the cluster to be shut down and the appropriate mode to be set on all directories and files before restarting LightDB. Otherwise, a mix of modes might exist in the data directory. For clusters that allow access only by the owner, the appropriate modes are 0700 for directories and 0600 for files. For clusters that also allow reads by the group, the appropriate modes are 0750 for directories and 0640 for files.

However, while the directory contents are secure, the default client authentication setup allows any local user to connect to the database and even become the database superuser. If you do not trust other local users, we recommend you use one of `initdb`'s `-W`, `--pwprompt` or `--pwfile` options to assign a password to the database superuser. Also, specify `-A md5` or `-A password` so that the default `trust` authentication mode is not used; or modify the generated `lt_hba.conf` file after running `initdb`, but *before* you start the server for the first time. (Other reasonable approaches include using `peer` authentication or file system permissions to restrict connections. See Chapter 18 for more information.)

`initdb` also initializes the default locale for the database cluster. Normally, it will just take the locale settings in the environment and apply them to the initialized database. It is possible to specify a different locale for the database; more information about that can be found in Section 21.1. The default sort order used within the particular database cluster is set by `initdb`, and while you can create new databases using different sort order, the order used in the template databases that `initdb` creates cannot be changed without dropping and recreating them. There is also a performance impact for using locales other than `C` or `POSIX`. Therefore, it is important to make this choice correctly the first time.

`initdb` also sets the default character set encoding for the database cluster. Normally this should be chosen to match the locale setting. For details see Section 21.3.

Non-C and non-POSIX locales rely on the operating system's collation library for character set ordering. This controls the ordering of keys stored in indexes. For this reason, a cluster cannot switch to an incompatible collation library version, either through snapshot restore, binary streaming replication, a different operating system, or an operating system upgrade.

## 16.2.1. Use of Secondary File Systems

Many installations create their database clusters on file systems (volumes) other than the machine's "root" volume. If you choose to do this, it is not advisable to try to use the secondary volume's topmost directory (mount point) as the data directory. Best practice is to create a directory within the mount-point directory that is owned by the LightDB user, and then create the data directory within that. This avoids permissions problems, particularly for operations such as `lt_upgrade`, and it also ensures clean failures if the secondary volume is taken offline.

## 16.2.2. File Systems

Generally, any file system with POSIX semantics can be used for LightDB. Users prefer different file systems for a variety of reasons, including vendor support, performance, and familiarity. Experience suggests that, all other things being equal, one should not expect major performance or behavior changes merely from switching file systems or making minor file system configuration changes.

### 16.2.2.1. NFS

It is possible to use an NFS file system for storing the LightDB data directory. LightDB does nothing special for NFS file systems, meaning it assumes NFS behaves exactly like locally-connected drives. LightDB does not use any functionality that is known to have nonstandard behavior on NFS, such as file locking.

The only firm requirement for using NFS with LightDB is that the file system is mounted using the `hard` option. With the `hard` option, processes can "hang" indefinitely if there are network problems, so this configuration will require a careful monitoring setup. The `soft` option will interrupt system calls in case of network problems, but LightDB will not repeat system calls interrupted in this way, so any such interruption will result in an I/O error being reported.

It is not necessary to use the `sync` mount option. The behavior of the `async` option is sufficient, since LightDB issues `fsync` calls at appropriate times to flush the write caches. (This is analogous to how it works on a local file system.) However, it is strongly recommended to use the `sync` export option on the NFS *server* on systems where it exists (mainly Linux). Otherwise, an `fsync` or equivalent on the NFS client is not actually guaranteed to reach permanent storage on the server, which could cause corruption similar to running with the parameter `fsync off`. The defaults of these mount and export options differ between vendors and versions, so it is recommended to check and perhaps specify them explicitly in any case to avoid any ambiguity.

In some cases, an external storage product can be accessed either via NFS or a lower-level protocol such as iSCSI. In the latter case, the storage appears as a block device and any available file system can be created on it. That approach might relieve the DBA from having to deal with some of the idiosyncrasies of NFS, but of course the complexity of managing remote storage then happens at other levels.

## 16.3. Starting the Database Server

Before anyone can access the database, you must start the database server. The database server program is called `lightdb`.

If you are using a pre-packaged version of LightDB, it almost certainly includes provisions for running the server as a background task according to the conventions of your operating system. Using the

package's infrastructure to start the server will be much less work than figuring out how to do this yourself. Consult the package-level documentation for details.

The bare-bones way to start the server manually is just to invoke `lightdb` directly, specifying the location of the data directory with the `-D` option, for example:

```
$ lightdb -D /usr/local/lightdb-x/data
```

which will leave the server running in the foreground. This must be done while logged into the LightDB user account. Without `-D`, the server will try to use the data directory named by the environment variable `LTDATA`. If that variable is not provided either, it will fail.

Normally it is better to start `lightdb` in the background. For this, use the usual Unix shell syntax:

```
$ lightdb -D /usr/local/lightdb-x/data >logfile 2>&1 &
```

It is important to store the server's stdout and stderr output somewhere, as shown above. It will help for auditing purposes and to diagnose problems. (See Section 22.3 for a more thorough discussion of log file handling.)

The `lightdb` program also takes a number of other command-line options. For more information, see the `lightdb` reference page and Chapter 17 below.

This shell syntax can get tedious quickly. Therefore the wrapper program `lt_ctl` is provided to simplify some tasks. For example:

```
lt_ctl start -l logfile
```

will start the server in the background and put the output into the named log file. The `-D` option has the same meaning here as for `lightdb`. `lt_ctl` is also capable of stopping the server.

Normally, you will want to start the database server when the computer boots. Autostart scripts are operating-system-specific. There are a few example scripts distributed with LightDB in the `contrib/start-scripts` directory. Installing one will require root privileges.

Different systems have different conventions for starting up daemons at boot time. Many systems have a file `/etc/rc.local` or `/etc/rc.d/rc.local`. Others use `init.d` or `rc.d` directories. Whatever you do, the server must be run by the LightDB user account *and not by root* or any other user. Therefore you probably should form your commands using `su postgres -c '...'`. For example:

```
su lightdb -c 'lt_ctl start -D /usr/local/lightdb-x/data -l
serverlog'
```

Here are a few more operating-system-specific suggestions. (In each case be sure to use the proper installation directory and user name where we show generic values.)

- For FreeBSD, look at the file `contrib/start-scripts/freebsd` in the LightDB source distribution.
- On OpenBSD, add the following lines to the file `/etc/rc.local`:

```
if [ -x /usr/local/lightdb-x/bin/lt_ctl -a -x /usr/local/lightdb-x/bin/lightdb ]; then
    su -l lightdb -c '/usr/local/lightdb-x/bin/lt_ctl start -s -l /var/lightdb/log -D /usr/local/lightdb-x/data'
```

```
    echo -n ' lightdb'
fi
```

- On Linux systems either add

```
/usr/local/lightdb-x/bin/lt_ctl start -l logfile -D /usr/local/
lightdb-x/data
```

to `/etc/rc.d/rc.local` or `/etc/rc.local` or look at the file `contrib/start-scripts/linux` in the LightDB source distribution.

When using `systemd`, you can use the following service unit file (e.g., at `/etc/systemd/system/postgresql.service`):

```
[Unit]
Description=LightDB database server
Documentation=man:postgres(1)

[Service]
Type=notify
User=lightdb
ExecStart=/usr/local/lightdb-x/bin/lightdb -D /usr/local/lightdb-
x/data
ExecReload=/bin/kill -HUP $MAINPID
KillMode=mixed
KillSignal=SIGINT
TimeoutSec=infinity

[Install]
WantedBy=multi-user.target
```

Using `Type=notify` requires that the server binary was built with `configure --with-systemd`.

Consider carefully the timeout setting. `systemd` has a default timeout of 90 seconds as of this writing and will kill a process that does not report readiness within that time. But a LightDB server that might have to perform crash recovery at startup could take much longer to become ready. The suggested value of `infinity` disables the timeout logic.

- On NetBSD, use either the FreeBSD or Linux start scripts, depending on preference.
- On Solaris, create a file called `/etc/init.d/lightdb` that contains the following line:

```
su - lightdb -c "/usr/local/lightdb-x/bin/lt_ctl start -l logfile
-D /usr/local/lightdb-x/data"
```

Then, create a symbolic link to it in `/etc/rc3.d` as `S99lightdb`.

While the server is running, its PID is stored in the file `lightdb.pid` in the data directory. This is used to prevent multiple server instances from running in the same data directory and can also be used for shutting down the server.

## 16.3.1. Server Start-up Failures

There are several common reasons the server might fail to start. Check the server's log file, or start it by hand (without redirecting standard output or standard error) and see what error messages appear. Below we explain some of the most common error messages in more detail.

```
LOG:  could not bind IPv4 address "127.0.0.1": Address already in
      use
HINT:  Is another postmaster already running on port 5432? If not,
      wait a few seconds and retry.
FATAL: could not create any TCP/IP sockets
```

This usually means just what it suggests: you tried to start another server on the same port where one is already running. However, if the kernel error message is not `Address already in use` or some variant of that, there might be a different problem. For example, trying to start a server on a reserved port number might draw something like:

```
$ lightdb -p 666
LOG:  could not bind IPv4 address "127.0.0.1": Permission denied
HINT:  Is another postmaster already running on port 666? If not,
      wait a few seconds and retry.
FATAL: could not create any TCP/IP sockets
```

A message like:

```
FATAL: could not create shared memory segment: Invalid argument
DETAIL: Failed system call was shmget(key=5440001,
      size=4011376640, 03600).
```

probably means your kernel's limit on the size of shared memory is smaller than the work area LightDB is trying to create (4011376640 bytes in this example). This is only likely to happen if you have set `shared_memory_type` to `sysv`. In that case, you can try starting the server with a smaller-than-normal number of buffers (`shared_buffers`), or reconfigure your kernel to increase the allowed shared memory size. You might also see this message when trying to start multiple servers on the same machine, if their total space requested exceeds the kernel limit.

An error like:

```
FATAL: could not create semaphores: No space left on device
DETAIL: Failed system call was semget(5440126, 17, 03600).
```

does *not* mean you've run out of disk space. It means your kernel's limit on the number of System V semaphores is smaller than the number LightDB wants to create. As above, you might be able to work around the problem by starting the server with a reduced number of allowed connections (`max_connections`), but you'll eventually want to increase the kernel limit.

Details about configuring System V IPC facilities are given in Section 16.4.1.

## 16.3.2. Client Connection Problems

Although the error conditions possible on the client side are quite varied and application-dependent, a few of them might be directly related to how the server was started. Conditions other than those shown below should be documented with the respective client application.

```
ltsql: could not connect to server: Connection refused
        Is the server running on host "server.joe.com" and
        accepting
        TCP/IP connections on port 5432?
```

This is the generic “I couldn't find a server to talk to” failure. It looks like the above when TCP/IP communication is attempted. A common mistake is to forget to configure the server to allow TCP/IP connections.



Alternatively, you'll get this when attempting Unix-domain socket communication to a local server:

```
ltsql: could not connect to server: No such file or directory
       Is the server running locally and accepting
       connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

The last line is useful in verifying that the client is trying to connect to the right place. If there is in fact no server running there, the kernel error message will typically be either `Connection refused` or `No such file or directory`, as illustrated. (It is important to realize that `Connection refused` in this context does *not* mean that the server got your connection request and rejected it. That case will produce a different message, as shown in Section 18.15.) Other error messages such as `Connection timed out` might indicate more fundamental problems, like lack of network connectivity.

## 16.4. Managing Kernel Resources

LightDB can sometimes exhaust various operating system resource limits, especially when multiple copies of the server are running on the same system, or in very large installations. This section explains the kernel resources used by LightDB and the steps you can take to resolve problems related to kernel resource consumption.

### 16.4.1. Shared Memory and Semaphores

LightDB requires the operating system to provide inter-process communication (IPC) features, specifically shared memory and semaphores. Unix-derived systems typically provide “System V” IPC, “POSIX” IPC, or both. Windows has its own implementation of these features and is not discussed here.

By default, LightDB allocates a very small amount of System V shared memory, as well as a much larger amount of anonymous `mmap` shared memory. Alternatively, a single large System V shared memory region can be used (see `shared_memory_type`). In addition a significant number of semaphores, which can be either System V or POSIX style, are created at server startup. Currently, POSIX semaphores are used on Linux and FreeBSD systems while other platforms use System V semaphores.

System V IPC features are typically constrained by system-wide allocation limits. When LightDB exceeds one of these limits, the server will refuse to start and should leave an instructive error message describing the problem and what to do about it. (See also Section 16.3.1.) The relevant kernel parameters are named consistently across different systems; Table 16.1 gives an overview. The methods to set them, however, vary. Suggestions for some platforms are given below.

**Table 16.1. System V IPC Parameters**

Name	Description	Values needed to run one LightDB instance
SHMMAX	Maximum size of shared memory segment (bytes)	at least 1kB, but the default is usually much higher
SHMMIN	Minimum size of shared memory segment (bytes)	1
SHMALL	Total amount of shared memory available (bytes or pages)	same as SHMMAX if bytes, or <code>ceil ( SHMMAX / PAGE_SIZE )</code> if pages, plus room for other applications
SHMSEG	Maximum number of shared memory segments per process	only 1 segment is needed, but the default is much higher

Name	Description	Values needed to run one LightDB instance
SHMMNI	Maximum number of shared memory segments system-wide	like SHMSEG plus room for other applications
SEMMNI	Maximum number of semaphore identifiers (i.e., sets)	at least $\text{ceil}((\text{max\_connections} + \text{autovacuum\_max\_workers} + \text{max\_wal\_senders} + \text{max\_worker\_processes} + 5) / 16)$ plus room for other applications
SEMMNS	Maximum number of semaphores system-wide	$\text{ceil}((\text{max\_connections} + \text{autovacuum\_max\_workers} + \text{max\_wal\_senders} + \text{max\_worker\_processes} + 5) / 16) * 17$ plus room for other applications
SEMMSL	Maximum number of semaphores per set	at least 17
SEMMAP	Number of entries in semaphore map	see text
SEVMX	Maximum value of semaphore	at least 1000 (The default is often 32767; do not change unless necessary)

LightDB requires a few bytes of System V shared memory (typically 48 bytes, on 64-bit platforms) for each copy of the server. On most modern operating systems, this amount can easily be allocated. However, if you are running many copies of the server or you explicitly configure the server to use large amounts of System V shared memory (see `shared_memory_type` and `dynamic_shared_memory_type`), it may be necessary to increase `SHMALL`, which is the total amount of System V shared memory system-wide. Note that `SHMALL` is measured in pages rather than bytes on many systems.

Less likely to cause problems is the minimum size for shared memory segments (`SHMMIN`), which should be at most approximately 32 bytes for LightDB (it is usually just 1). The maximum number of segments system-wide (`SHMMNI`) or per-process (`SHMSEG`) are unlikely to cause a problem unless your system has them set to zero.

When using System V semaphores, LightDB uses one semaphore per allowed connection (`max_connections`), allowed autovacuum worker process (`autovacuum_max_workers`) and allowed background process (`max_worker_processes`), in sets of 16. Each such set will also contain a 17th semaphore which contains a “magic number”, to detect collision with semaphore sets used by other applications. The maximum number of semaphores in the system is set by `SEMMNS`, which consequently must be at least as high as `max_connections` plus `autovacuum_max_workers` plus `max_wal_senders`, plus `max_worker_processes`, plus one extra for each 16 allowed connections plus workers (see the formula in Table 16.1). The parameter `SEMMNI` determines the limit on the number of semaphore sets that can exist on the system at one time. Hence this parameter must be at least  $\text{ceil}((\text{max\_connections} + \text{autovacuum\_max\_workers} + \text{max\_wal\_senders} + \text{max\_worker\_processes} + 5) / 16)$ . Lowering the number of allowed connections is a temporary workaround for failures, which are usually confusingly worded “No space left on device”, from the function `semget`.

In some cases it might also be necessary to increase `SEMMAP` to be at least on the order of `SEMMNS`. If the system has this parameter (many do not), it defines the size of the semaphore resource map, in which each contiguous block of available semaphores needs an entry. When a semaphore set is freed it is either added to an existing entry that is adjacent to the freed block or it is registered under a new map entry. If the map is full, the freed semaphores get lost (until reboot). Fragmentation of the semaphore space could over time lead to fewer available semaphores than there should be.

Various other settings related to “semaphore undo”, such as `SEMMNU` and `SEMUME`, do not affect LightDB.

When using POSIX semaphores, the number of semaphores needed is the same as for System V, that is one semaphore per allowed connection (`max_connections`), allowed autovacuum worker process (`autovacuum_max_workers`) and allowed background process (`max_worker_processes`). On the platforms where this option is preferred, there is no specific kernel limit on the number of POSIX semaphores.

## AIX

It should not be necessary to do any special configuration for such parameters as `SHMMAX`, as it appears this is configured to allow all memory to be used as shared memory. That is the sort of configuration commonly used for other databases such as DB/2.

It might, however, be necessary to modify the global `ulimit` information in `/etc/security/limits`, as the default hard limits for file sizes (`fsize`) and numbers of files (`nofiles`) might be too low.

## FreeBSD

The default shared memory settings are usually good enough, unless you have set `shared_memory_type` to `sysv`. System V semaphores are not used on this platform.

The default IPC settings can be changed using the `sysctl` or `loader` interfaces. The following parameters can be set using `sysctl`:

```
# sysctl kern.ipc.shmall=32768
# sysctl kern.ipc.shmmax=134217728
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

If you have set `shared_memory_type` to `sysv`, you might also want to configure your kernel to lock System V shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

If running in a FreeBSD jail, you should set its `sysvshm` parameter to `new`, so that it has its own separate System V shared memory namespace. (Before FreeBSD 11.0, it was necessary to enable shared access to the host's IPC namespace from jails, and take measures to avoid collisions.)

## NetBSD

The default shared memory settings are usually good enough, unless you have set `shared_memory_type` to `sysv`. You will usually want to increase `kern.ipc.semnum` and `kern.ipc.semms`, as NetBSD's default settings for these are uncomfortably small.

IPC parameters can be adjusted using `sysctl`, for example:

```
# sysctl -w kern.ipc.semnum=100
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

If you have set `shared_memory_type` to `sysv`, you might also want to configure your kernel to lock System V shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

## OpenBSD

The default shared memory settings are usually good enough, unless you have set `shared_memory_type` to `sysv`. You will usually want to increase

`kern.seminfo.semmni` and `kern.seminfo.semmns`, as OpenBSD's default settings for these are uncomfortably small.

IPC parameters can be adjusted using `sysctl`, for example:

```
# sysctl kern.seminfo.semmni=100
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

## HP-UX

The default settings tend to suffice for normal installations.

IPC parameters can be set in the System Administration Manager (SAM) under Kernel Configuration → Configurable Parameters. Choose Create A New Kernel when you're done.

## Linux

The default shared memory settings are usually good enough, unless you have set `shared_memory_type` to `sysv`, and even then only on older kernel versions that shipped with low defaults. System V semaphores are not used on this platform.

The shared memory size settings can be changed via the `sysctl` interface. For example, to allow 16 GB:

```
$ sysctl -w kernel.shmmax=17179869184
$ sysctl -w kernel.shmall=4194304
```

To make these settings persist over reboots, see `/etc/sysctl.conf`.

## macOS

The default shared memory and semaphore settings are usually good enough, unless you have set `shared_memory_type` to `sysv`.

The recommended method for configuring shared memory in macOS is to create a file named `/etc/sysctl.conf`, containing variable assignments such as:

```
kern.sysv.shmmax=4194304
kern.sysv.shmmin=1
kern.sysv.shmmni=32
kern.sysv.shmseg=8
kern.sysv.shmall=1024
```

Note that in some macOS versions, *all five* shared-memory parameters must be set in `/etc/sysctl.conf`, else the values will be ignored.

SHMMAX can only be set to a multiple of 4096.

SHMALL is measured in 4 kB pages on this platform.

It is possible to change all but SHMMNI on the fly, using `sysctl`. But it's still best to set up your preferred values via `/etc/sysctl.conf`, so that the values will be kept across reboots.

## Solaris illumos

The default shared memory and semaphore settings are usually good enough for most LightDB applications. Solaris defaults to a SHMMAX of one-quarter of system RAM. To further adjust this

setting, use a project setting associated with the `lightdb` user. For example, run the following as root:

```
projadd -c "LightDB DB User" -K "project.max-shm-  
memory=(privileged,8GB,deny)" -U lightdb -G lightdb user.lightdb
```

This command adds the `user.lightdb` project and sets the shared memory maximum for the `lightdb` user to 8GB, and takes effect the next time that user logs in, or when you restart LightDB (not reload). The above assumes that LightDB is run by the `lightdb` user in the `lightdb` group. No server reboot is required.

Other recommended kernel setting changes for database servers which will have a large number of connections are:

```
project.max-shm-ids=(priv,32768,deny)  
project.max-sem-ids=(priv,4096,deny)  
project.max-msg-ids=(priv,4096,deny)
```

Additionally, if you are running LightDB inside a zone, you may need to raise the zone resource usage limits as well. See "Chapter2: Projects and Tasks" in the *System Administrator's Guide* for more information on `projects` and `prctl`.

## 16.4.2. systemd RemoveIPC

If `systemd` is in use, some care must be taken that IPC resources (including shared memory) are not prematurely removed by the operating system. This is especially of concern when installing LightDB from source. Users of distribution packages of LightDB are less likely to be affected, as the `lightdb` user is then normally created as a system user.

The setting `RemoveIPC` in `logind.conf` controls whether IPC objects are removed when a user fully logs out. System users are exempt. This setting defaults to on in stock `systemd`, but some operating system distributions default it to off.

A typical observed effect when this setting is on is that shared memory objects used for parallel query execution are removed at apparently random times, leading to errors and warnings while attempting to open and remove them, like

```
WARNING: could not remove shared memory segment "/  
LightDB.1450751626": No such file or directory
```

Different types of IPC objects (shared memory vs. semaphores, System V vs. POSIX) are treated slightly differently by `systemd`, so one might observe that some IPC resources are not removed in the same way as others. But it is not advisable to rely on these subtle differences.

A "user logging out" might happen as part of a maintenance job or manually when an administrator logs in as the `lightdb` user or something similar, so it is hard to prevent in general.

What is a "system user" is determined at `systemd` compile time from the `SYS_UID_MAX` setting in `/etc/login.defs`.

Packaging and deployment scripts should be careful to create the `lightdb` user as a system user by using `useradd -r, adduser --system`, or equivalent.

Alternatively, if the user account was created incorrectly or cannot be changed, it is recommended to set

RemoveIPC=no

in `/etc/systemd/logind.conf` or another appropriate configuration file.

### Caution

At least one of these two things has to be ensured, or the LightDB server will be very unreliable.

## 16.4.3. Resource Limits

Unix-like operating systems enforce various kinds of resource limits that might interfere with the operation of your LightDB server. Of particular importance are limits on the number of processes per user, the number of open files per process, and the amount of memory available to each process. Each of these have a “hard” and a “soft” limit. The soft limit is what actually counts but it can be changed by the user up to the hard limit. The hard limit can only be changed by the root user. The system call `setrlimit` is responsible for setting these parameters. The shell's built-in command `ulimit` (Bourne shells) or `limit` (csh) is used to control the resource limits from the command line. On BSD-derived systems the file `/etc/login.conf` controls the various resource limits set during login. See the operating system documentation for details. The relevant parameters are `maxproc`, `openfiles`, and `datasize`. For example:

```
default:\
...
      :datasize-cur=256M:\
      :maxproc-cur=256:\
      :openfiles-cur=256:\
...
```

(`-cur` is the soft limit. Append `-max` to set the hard limit.)

Kernels can also have system-wide limits on some resources.

- On Linux `/proc/sys/fs/file-max` determines the maximum number of open files that the kernel will support. It can be changed by writing a different number into the file or by adding an assignment in `/etc/sysctl.conf`. The maximum limit of files per process is fixed at the time the kernel is compiled; see `/usr/src/linux/Documentation/proc.txt` for more information.

The LightDB server uses one process per connection so you should provide for at least as many processes as allowed connections, in addition to what you need for the rest of your system. This is usually not a problem but if you run several servers on one machine things might get tight.

The factory default limit on open files is often set to “socially friendly” values that allow many users to coexist on a machine without using an inappropriate fraction of the system resources. If you run many servers on a machine this is perhaps what you want, but on dedicated servers you might want to raise this limit.

On the other side of the coin, some systems allow individual processes to open large numbers of files; if more than a few processes do so then the system-wide limit can easily be exceeded. If you find this happening, and you do not want to alter the system-wide limit, you can set LightDB's `max_files_per_process` configuration parameter to limit the consumption of open files.

## 16.4.4. Linux Memory Overcommit

The default virtual memory behavior on Linux is not optimal for LightDB. Because of the way that the kernel implements memory overcommit, the kernel might terminate the LightDB postmaster (the master server process) if the memory demands of either LightDB or another process cause the system to run out of virtual memory.

If this happens, you will see a kernel message that looks like this (consult your system documentation and configuration on where to look for such a message):

```
Out of Memory: Killed process 12345 (lightdb).
```

This indicates that the `lightdb` process has been terminated due to memory pressure. Although existing database connections will continue to function normally, no new connections will be accepted. To recover, LightDB will need to be restarted.

One way to avoid this problem is to run LightDB on a machine where you can be sure that other processes will not run the machine out of memory. If memory is tight, increasing the swap space of the operating system can help avoid the problem, because the out-of-memory (OOM) killer is invoked only when physical memory and swap space are exhausted.

If LightDB itself is the cause of the system running out of memory, you can avoid the problem by changing your configuration. In some cases, it may help to lower memory-related configuration parameters, particularly `shared_buffers`, `work_mem`, and `hash_mem_multiplier`. In other cases, the problem may be caused by allowing too many connections to the database server itself. In many cases, it may be better to reduce `max_connections` and instead make use of external connection-pooling software.

It is possible to modify the kernel's behavior so that it will not “overcommit” memory. Although this setting will not prevent the OOM killer<sup>1</sup> from being invoked altogether, it will lower the chances significantly and will therefore lead to more robust system behavior. This is done by selecting strict overcommit mode via `sysctl`:

```
sysctl -w vm.overcommit_memory=2
```

or placing an equivalent entry in `/etc/sysctl.conf`. You might also wish to modify the related setting `vm.overcommit_ratio`. For details see the kernel documentation file <https://www.kernel.org/doc/Documentation/vm/overcommit-accounting>.

Another approach, which can be used with or without altering `vm.overcommit_memory`, is to set the process-specific *OOM score adjustment* value for the postmaster process to `-1000`, thereby guaranteeing it will not be targeted by the OOM killer. The simplest way to do this is to execute

```
echo -1000 > /proc/self/oom_score_adj
```

in the postmaster's startup script just before invoking the postmaster. Note that this action must be done as root, or it will have no effect; so a root-owned startup script is the easiest place to do it. If you do this, you should also set these environment variables in the startup script before invoking the postmaster:

```
export PG_OOM_ADJUST_FILE=/proc/self/oom_score_adj
export PG_OOM_ADJUST_VALUE=0
```

These settings will cause postmaster child processes to run with the normal OOM score adjustment of zero, so that the OOM killer can still target them at need. You could use some other value for `LT_OOM_ADJUST_VALUE` if you want the child processes to run with some other OOM score adjustment. (`LT_OOM_ADJUST_VALUE` can also be omitted, in which case it defaults to zero.) If

---

<sup>1</sup> <https://lwn.net/Articles/104179/>

you do not set `LT_OOM_ADJUST_FILE`, the child processes will run with the same OOM score adjustment as the postmaster, which is unwise since the whole point is to ensure that the postmaster has a preferential setting.

## 16.4.5. Linux Huge Pages

Using huge pages reduces overhead when using large contiguous chunks of memory, as LightDB does, particularly when using large values of `shared_buffers`. To use this feature in LightDB you need a kernel with `CONFIG_HUGETLBFS=y` and `CONFIG_HUGETLB_PAGE=y`. You will also have to adjust the kernel setting `vm.nr_hugepages`. To estimate the number of huge pages needed, start LightDB without huge pages enabled and check the postmaster's anonymous shared memory segment size, as well as the system's huge page size, using the `/proc` file system. This might look like:

```
$ head -1 $SLTDATA/lightdb.pid
4170
$ pmap 4170 | awk '/rw-s/ && /zero/ {print $2}'
6490428K
$ grep ^Hugepagesize /proc/meminfo
Hugepagesize:          2048 kB
```

6490428 / 2048 gives approximately 3169.154, so in this example we need at least 3170 huge pages, which we can set with:

```
$ sysctl -w vm.nr_hugepages=3170
```

A larger setting would be appropriate if other programs on the machine also need huge pages. Don't forget to add this setting to `/etc/sysctl.conf` so that it will be reapplied after reboots.

Sometimes the kernel is not able to allocate the desired number of huge pages immediately, so it might be necessary to repeat the command or to reboot. (Immediately after a reboot, most of the machine's memory should be available to convert into huge pages.) To verify the huge page allocation situation, use:

```
$ grep Huge /proc/meminfo
```

It may also be necessary to give the database server's operating system user permission to use huge pages by setting `vm.hugetlb_shm_group` via `sysctl`, and/or give permission to lock memory with `ulimit -l`.

The default behavior for huge pages in LightDB is to use them when possible and to fall back to normal pages when failing. To enforce the use of huge pages, you can set `huge_pages` to `on` in `lightdb.conf`. Note that with this setting LightDB will fail to start if not enough huge pages are available.

For a detailed description of the Linux huge pages feature have a look at <https://www.kernel.org/doc/Documentation/vm/hugetlbpage.txt>.

## 16.5. Shutting Down the Server

There are several ways to shut down the database server. Under the hood, they all reduce to sending a signal to the supervisor `lightdb` process.

If you are using a pre-packaged version of LightDB, and you used its provisions for starting the server, then you should also use its provisions for stopping the server. Consult the package-level documentation for details.



When managing the server directly, you can control the type of shutdown by sending different signals to the `lightdb` process:

#### SIGTERM

This is the *Smart Shutdown* mode. After receiving SIGTERM, the server disallows new connections, but lets existing sessions end their work normally. It shuts down only after all of the sessions terminate. If the server is in online backup mode, it additionally waits until online backup mode is no longer active. While backup mode is active, new connections will still be allowed, but only to superusers (this exception allows a superuser to connect to terminate online backup mode). If the server is in recovery when a smart shutdown is requested, recovery and streaming replication will be stopped only after all regular sessions have terminated.

#### SIGINT

This is the *Fast Shutdown* mode. The server disallows new connections and sends all existing server processes SIGTERM, which will cause them to abort their current transactions and exit promptly. It then waits for all server processes to exit and finally shuts down. If the server is in online backup mode, backup mode will be terminated, rendering the backup useless.

#### SIGQUIT

This is the *Immediate Shutdown* mode. The server will send SIGQUIT to all child processes and wait for them to terminate. If any do not terminate within 5 seconds, they will be sent SIGKILL. The master server process exits as soon as all child processes have exited, without doing normal database shutdown processing. This will lead to recovery (by replaying the WAL log) upon next start-up. This is recommended only in emergencies.

The `lt_ctl` program provides a convenient interface for sending these signals to shut down the server. Alternatively, you can send the signal directly using `kill` on non-Windows systems. The PID of the `lightdb` process can be found using the `ps` program, or from the file `lightdb.pid` in the data directory. For example, to do a fast shutdown:

```
$ kill -INT `head -1 /usr/local/lightdb-x/data/lightdb.pid`
```

### Important

It is best not to use SIGKILL to shut down the server. Doing so will prevent the server from releasing shared memory and semaphores. Furthermore, SIGKILL kills the `lightdb` process without letting it relay the signal to its subprocesses, so it might be necessary to kill the individual subprocesses by hand as well.

To terminate an individual session while allowing other sessions to continue, use `pg_terminate_backend()` (see Table 9.85) or send a SIGTERM signal to the child process associated with the session.

## 16.6. Upgrading a LightDB Cluster

This section discusses how to upgrade your database data from one LightDB release to a newer one.

Current LightDB version numbers consist of a major and a minor version number. For example, in the version number 10.1, the 10 is the major version number and the 1 is the minor version number, meaning this would be the first minor release of the major release 10. For releases before LightDB version 10.0, version numbers consist of three numbers, for example, 9.5.3. In those cases, the major version consists of the first two digit groups of the version number, e.g., 9.5, and the minor version is the third number, e.g., 3, meaning this would be the third minor release of the major release 9.5.

Minor releases never change the internal storage format and are always compatible with earlier and later minor releases of the same major version number. For example, version 10.1 is compatible with version 10.0 and version 10.6. Similarly, for example, 9.5.3 is compatible with 9.5.0, 9.5.1, and 9.5.6. To update between compatible versions, you simply replace the executables while the server is down and restart the server. The data directory remains unchanged — minor upgrades are that simple.

For *major* releases of LightDB, the internal data storage format is subject to change, thus complicating upgrades. The traditional method for moving data to a new major version is to dump and restore the database, though this can be slow. A faster method is `lt_upgrade`. Replication methods are also available, as discussed below. (If you are using a pre-packaged version of LightDB, it may provide scripts to assist with major version upgrades. Consult the package-level documentation for details.)

New major versions also typically introduce some user-visible incompatibilities, so application programming changes might be required. pay particular attention to the section labeled "Migration". Though you can upgrade from one major version to another without upgrading to intervening versions, you should read the major release notes of all intervening versions.

Cautious users will want to test their client applications on the new version before switching over fully; therefore, it's often a good idea to set up concurrent installations of old and new versions. When testing a LightDB major upgrade, consider the following categories of possible changes:

#### Administration

The capabilities available for administrators to monitor and control the server often change and improve in each major release.

#### SQL

Typically this includes new SQL command capabilities and not changes in behavior, unless specifically mentioned in the release notes.

#### Library API

Typically libraries like `libpq` only add new functionality, again unless mentioned in the release notes.

#### System Catalogs

System catalog changes usually only affect database management tools.

#### Server C-language API

This involves changes in the backend function API, which is written in the C programming language. Such changes affect code that references backend functions deep inside the server.

## 16.6.1. Upgrading Data via `lt_dumpall`

One upgrade method is to dump data from one major version of LightDB and restore it in another — to do this, you must use a *logical* backup tool like `lt_dumpall`; file system level backup methods will not work. (There are checks in place that prevent you from using a data directory with an incompatible version of LightDB, so no great harm can be done by trying to start the wrong server version on a data directory.)

It is recommended that you use the `lt_dump` and `lt_dumpall` programs from the *newer* version of LightDB, to take advantage of enhancements that might have been made in these programs. Current releases of the dump programs can read data from any server version back to 8.0.

These instructions assume that your existing installation is under the `/usr/local/pgsql` directory, and that the data area is in `/usr/local/lightdb-x/data`. Substitute your paths appropriately.

1. If making a backup, make sure that your database is not being updated. This does not affect the integrity of the backup, but the changed data would of course not be included. If necessary, edit the permissions in the file `/usr/local/lightdb-x/data/lt_hba.conf` (or equivalent) to disallow access from everyone except you. See Chapter 18 for additional information on access control.

To back up your database installation, type:

```
lt_dumpall > outputfile
```

To make the backup, you can use the `lt_dumpall` command from the version you are currently running; see Section 23.1.2 for more details. For best results, however, try to use the `lt_dumpall` command from LightDB 13.8-23.4, since this version contains bug fixes and improvements over older versions. While this advice might seem idiosyncratic since you haven't installed the new version yet, it is advisable to follow it if you plan to install the new version in parallel with the old version. In that case you can complete the installation normally and transfer the data later. This will also decrease the downtime.

2. Shut down the old server:

```
lt_ctl stop
```

On systems that have LightDB started at boot time, there is probably a start-up file that will accomplish the same thing. For example, on a Red Hat Linux system one might find that this works:

```
/etc/rc.d/init.d/lightdb stop
```

See Chapter 16 for details about starting and stopping the server.

3. If restoring from backup, rename or delete the old installation directory if it is not version-specific. It is a good idea to rename the directory, rather than delete it, in case you have trouble and need to revert to it. Keep in mind the directory might consume significant disk space. To rename the directory, use a command like this:

```
mv /usr/local/pgsql /usr/local/pgsql.old
```

(Be sure to move the directory as a single unit so relative paths remain unchanged.)

4. Install the new version of LightDB.
5. Create a new database cluster if needed. Remember that you must execute these commands while logged in to the special database user account (which you already have if you are upgrading).

```
/usr/local/lightdb-x/bin/initdb -D /usr/local/lightdb-x/data
```

6. Restore your previous `lt_hba.conf` and any `lightdb.conf` modifications.
7. Start the database server, again using the special database user account:

```
/usr/local/lightdb-x/bin/lightdb -D /usr/local/lightdb-x/data
```

8. Finally, restore your data from backup with:

```
/usr/local/lightdb-x/bin/ltsql -d postgres -f outputfile
```

using the *new* ltsql.

The least downtime can be achieved by installing the new server in a different directory and running both the old and the new servers in parallel, on different ports. Then you can use something like:

```
lt_dumpall -p 5432 | ltsql -d postgres -p 5433
```

to transfer your data.

## 16.6.2. Upgrading Data via lt\_upgrade

The `lt_upgrade` module allows an installation to be migrated in-place from one major LightDB version to another. Upgrades can be performed in minutes, particularly with `--link` mode. It requires steps similar to `lt_dumpall` above, e.g., starting/stopping the server, running `initdb`. The `lt_upgrade` documentation outlines the necessary steps. It is strongly recommended to use `lt_upgrade_check` for pre-upgrade checks before performing the upgrade.

## 16.6.3. Upgrading Data via Replication

It is also possible to use logical replication methods to create a standby server with the updated version of LightDB. This is possible because logical replication supports replication between different major versions of LightDB. The standby can be on the same computer or a different computer. Once it has synced up with the master server (running the older version of LightDB), you can switch masters and make the standby the master and shut down the older database instance. Such a switch-over results in only several seconds of downtime for an upgrade.

This method of upgrading can be performed using the built-in logical replication facilities as well as using external logical replication systems such as `pglogical`, `Slony`, `Londiste`, and `Bucardo`.

## 16.7. Preventing Server Spoofing

While the server is running, it is not possible for a malicious user to take the place of the normal database server. However, when the server is down, it is possible for a local user to spoof the normal server by starting their own server. The spoof server could read passwords and queries sent by clients, but could not return any data because the `LTDATA` directory would still be secure because of directory permissions. Spoofing is possible because any user can start a database server; a client cannot identify an invalid server unless it is specially configured.

One way to prevent spoofing of `local` connections is to use a Unix domain socket directory (`unix_socket_directories`) that has write permission only for a trusted local user. This prevents a malicious user from creating their own socket file in that directory. If you are concerned that some applications might still reference `/tmp` for the socket file and hence be vulnerable to spoofing, during operating system startup create a symbolic link `/tmp/.s.PGSQL.5432` that points to the relocated socket file. You also might need to modify your `/tmp` cleanup script to prevent removal of the symbolic link.

Another option for `local` connections is for clients to use `requirepeer` to specify the required owner of the server process connected to the socket.

To prevent spoofing on TCP connections, either use SSL certificates and make sure that clients check the server's certificate, or use GSSAPI encryption (or both, if they're on separate connections).

To prevent spoofing with SSL, the server must be configured to accept only `hostssl` connections (Section 18.1) and have SSL key and certificate files (Section 16.9). The TCP client must connect using

`sslmode=verify-ca` or `verify-full` and have the appropriate root certificate file installed (Section 32.18.1).

To prevent spoofing with GSSAPI, the server must be configured to accept only `hostgssenc` connections (Section 18.1) and use `gss` authentication with them. The TCP client must connect using `gssencmode=require`.

## 16.8. Encryption Options

LightDB offers encryption at several levels, and provides flexibility in protecting data from disclosure due to database server theft, unscrupulous administrators, and insecure networks. Encryption might also be required to secure sensitive data such as medical records or financial transactions.

### Password Encryption

Database user passwords are stored as hashes (determined by the setting `password_encryption`), so the administrator cannot determine the actual password assigned to the user. If SCRAM or MD5 encryption is used for client authentication, the unencrypted password is never even temporarily present on the server because the client encrypts it before being sent across the network. SCRAM is preferred, because it is an Internet standard and is more secure than the LightDB-specific MD5 authentication protocol.

### Encryption For Specific Columns

The `ltpcrypto` module allows certain fields to be stored encrypted. This is useful if only some of the data is sensitive. The client supplies the decryption key and the data is decrypted on the server and then sent to the client.

The decrypted data and the decryption key are present on the server for a brief time while it is being decrypted and communicated between the client and server. This presents a brief moment where the data and keys can be intercepted by someone with complete access to the database server, such as the system administrator.

### Data Partition Encryption

Storage encryption can be performed at the file system level or the block level. Linux file system encryption options include `eCryptfs` and `EncFS`, while FreeBSD uses `PEFS`. Block level or full disk encryption options include `dm-crypt` + `LUKS` on Linux and `GEOM` modules `geli` and `gbde` on FreeBSD. Many other operating systems support this functionality, including Windows.

This mechanism prevents unencrypted data from being read from the drives if the drives or the entire computer is stolen. This does not protect against attacks while the file system is mounted, because when mounted, the operating system provides an unencrypted view of the data. However, to mount the file system, you need some way for the encryption key to be passed to the operating system, and sometimes the key is stored somewhere on the host that mounts the disk.

### Encrypting Data Across A Network

SSL connections encrypt all data sent across the network: the password, the queries, and the data returned. The `lt_hba.conf` file allows administrators to specify which hosts can use non-encrypted connections (`host`) and which require SSL-encrypted connections (`hostssl`). Also, clients can specify that they connect to servers only via SSL.

GSSAPI-encrypted connections encrypt all data sent across the network, including queries and data returned. (No password is sent across the network.) The `lt_hba.conf` file allows administrators to specify which hosts can use non-encrypted connections (`host`) and which require GSSAPI-encrypted connections (`hostgssenc`). Also, clients can specify that they connect to servers only on GSSAPI-encrypted connections (`gssencmode=require`).

Stunnel or SSH can also be used to encrypt transmissions.

### SSL Host Authentication

It is possible for both the client and server to provide SSL certificates to each other. It takes some extra configuration on each side, but this provides stronger verification of identity than the mere use of passwords. It prevents a computer from pretending to be the server just long enough to read the password sent by the client. It also helps prevent “man in the middle” attacks where a computer between the client and server pretends to be the server and reads and passes all data between the client and server.

### Client-Side Encryption

If the system administrator for the server's machine cannot be trusted, it is necessary for the client to encrypt the data; this way, unencrypted data never appears on the database server. Data is encrypted on the client before being sent to the server, and database results have to be decrypted on the client before being used.

## 16.9. Secure TCP/IP Connections with SSL

LightDB has native support for using SSL connections to encrypt client/server communications for increased security. This requires that OpenSSL is installed on both client and server systems and that support in LightDB is enabled at build time.

### 16.9.1. Basic Setup

With SSL support compiled in, the LightDB server can be started with SSL enabled by setting the parameter `ssl` to `on` in `lightdb.conf`. The server will listen for both normal and SSL connections on the same TCP port, and will negotiate with any connecting client on whether to use SSL. By default, this is at the client's option; see Section 18.1 about how to set up the server to require use of SSL for some or all connections.

To start in SSL mode, files containing the server certificate and private key must exist. By default, these files are expected to be named `server.crt` and `server.key`, respectively, in the server's data directory, but other names and locations can be specified using the configuration parameters `ssl_cert_file` and `ssl_key_file`.

On Unix systems, the permissions on `server.key` must disallow any access to world or group; achieve this by the command `chmod 0600 server.key`. Alternatively, the file can be owned by root and have group read access (that is, 0640 permissions). That setup is intended for installations where certificate and key files are managed by the operating system. The user under which the LightDB server runs should then be made a member of the group that has access to those certificate and key files.

If the data directory allows group read access then certificate files may need to be located outside of the data directory in order to conform to the security requirements outlined above. Generally, group access is enabled to allow an unprivileged user to backup the database, and in that case the backup software will not be able to read the certificate files and will likely error.

If the private key is protected with a passphrase, the server will prompt for the passphrase and will not start until it has been entered. Using a passphrase by default disables the ability to change the server's SSL configuration without a server restart, but see `ssl_passphrase_command_supports_reload`. Furthermore, passphrase-protected private keys cannot be used at all on Windows.

The first certificate in `server.crt` must be the server's certificate because it must match the server's private key. The certificates of “intermediate” certificate authorities can also be appended to the file. Doing this avoids the necessity of storing intermediate certificates on clients, assuming the root and intermediate certificates were created with `v3_ca` extensions. (This sets the certificate's basic constraint of `CA` to `true`.) This allows easier expiration of intermediate certificates.

It is not necessary to add the root certificate to `server.crt`. Instead, clients must have the root certificate of the server's certificate chain.

## 16.9.2. OpenSSL Configuration

LightDB reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

OpenSSL supports a wide range of ciphers and authentication algorithms, of varying strength. While a list of ciphers can be specified in the OpenSSL configuration file, you can specify ciphers specifically for use by the database server by modifying `ssl_ciphers` in `lightdb.conf`.

### Note

It is possible to have authentication without encryption overhead by using `NULL-SHA` or `NULL-MD5` ciphers. However, a man-in-the-middle could read and pass communications between client and server. Also, encryption overhead is minimal compared to the overhead of authentication. For these reasons `NULL` ciphers are not recommended.

## 16.9.3. Using Client Certificates

To require the client to supply a trusted certificate, place certificates of the root certificate authorities (CAs) you trust in a file in the data directory, set the parameter `ssl_ca_file` in `lightdb.conf` to the new file name, and add the authentication option `clientcert=verify-ca` or `clientcert=verify-full` to the appropriate `hostssl` line(s) in `lt_hba.conf`. A certificate will then be requested from the client during SSL connection startup. (See Section 32.18 for a description of how to set up certificates on the client.)

For a `hostssl` entry with `clientcert=verify-ca`, the server will verify that the client's certificate is signed by one of the trusted certificate authorities. If `clientcert=verify-full` is specified, the server will not only verify the certificate chain, but it will also check whether the username or its mapping matches the `cn` (Common Name) of the provided certificate. Note that certificate chain validation is always ensured when the `cert` authentication method is used (see Section 18.12).

Intermediate certificates that chain up to existing root certificates can also appear in the `ssl_ca_file` file if you wish to avoid storing them on clients (assuming the root and intermediate certificates were created with `v3_ca` extensions). Certificate Revocation List (CRL) entries are also checked if the parameter `ssl_crl_file` is set.

The `clientcert` authentication option is available for all authentication methods, but only in `lt_hba.conf` lines specified as `hostssl`. When `clientcert` is not specified or is set to `no-verify`, the server will still verify any presented client certificates against its CA file, if one is configured — but it will not insist that a client certificate be presented.

There are two approaches to enforce that users provide a certificate during login.

The first approach makes use of the `cert` authentication method for `hostssl` entries in `lt_hba.conf`, such that the certificate itself is used for authentication while also providing `ssl` connection security. See Section 18.12 for details. (It is not necessary to specify any `clientcert` options explicitly when using the `cert` authentication method.) In this case, the `cn` (Common Name) provided in the certificate is checked against the user name or an applicable mapping.

The second approach combines any authentication method for `hostssl` entries with the verification of client certificates by setting the `clientcert` authentication option to `verify-ca` or `verify-`

full. The former option only enforces that the certificate is valid, while the latter also ensures that the `cn` (Common Name) in the certificate matches the user name or an applicable mapping.

## 16.9.4. SSL Server File Usage

Table 16.2 summarizes the files that are relevant to the SSL setup on the server. (The shown file names are default names. The locally configured names could be different.)

**Table 16.2. SSL Server File Usage**

File	Contents	Effect
<code>ssl_cert_file</code> ( <code>\$LTDDATA/server.crt</code> )	server certificate	sent to client to indicate server's identity
<code>ssl_key_file</code> ( <code>\$LTDDATA/server.key</code> )	server private key	proves server certificate was sent by the owner; does not indicate certificate owner is trustworthy
<code>ssl_ca_file</code>	trusted certificate authorities	checks that client certificate is signed by a trusted certificate authority
<code>ssl_crl_file</code>	certificates revoked by certificate authorities	client certificate must not be on this list

The server reads these files at server start and whenever the server configuration is reloaded. On Windows systems, they are also re-read whenever a new backend process is spawned for a new client connection.

If an error in these files is detected at server start, the server will refuse to start. But if an error is detected during a configuration reload, the files are ignored and the old SSL configuration continues to be used. On Windows systems, if an error in these files is detected at backend start, that backend will be unable to establish an SSL connection. In all these cases, the error condition is reported in the server log.

## 16.9.5. Creating Certificates

To create a simple self-signed certificate for the server, valid for 365 days, use the following OpenSSL command, replacing `dbhost.yourdomain.com` with the server's host name:

```
openssl req -new -x509 -days 365 -nodes -text -out server.crt \
  -keyout server.key -subj "/CN=dbhost.yourdomain.com"
```

Then do:

```
chmod og-rwx server.key
```

because the server will reject the file if its permissions are more liberal than this. For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.

While a self-signed certificate can be used for testing, a certificate signed by a certificate authority (CA) (usually an enterprise-wide root CA) should be used in production.

To create a server certificate whose identity can be validated by clients, first create a certificate signing request (CSR) and a public/private key file:



```
openssl req -new -nodes -text -out root.csr \  
-keyout root.key -subj "/CN=root.yourdomain.com"  
chmod og-rwx root.key
```

Then, sign the request with the key to create a root certificate authority (using the default OpenSSL configuration file location on Linux):

```
openssl x509 -req -in root.csr -text -days 3650 \  
-extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
-signkey root.key -out root.crt
```

Finally, create a server certificate signed by the new root certificate authority:

```
openssl req -new -nodes -text -out server.csr \  
-keyout server.key -subj "/CN=dbhost.yourdomain.com"  
chmod og-rwx server.key  
  
openssl x509 -req -in server.csr -text -days 365 \  
-CA root.crt -CAkey root.key -CAcreateserial \  
-out server.crt
```

`server.crt` and `server.key` should be stored on the server, and `root.crt` should be stored on the client so the client can verify that the server's leaf certificate was signed by its trusted root certificate. `root.key` should be stored offline for use in creating future certificates.

It is also possible to create a chain of trust that includes intermediate certificates:

```
# root  
openssl req -new -nodes -text -out root.csr \  
-keyout root.key -subj "/CN=root.yourdomain.com"  
chmod og-rwx root.key  
openssl x509 -req -in root.csr -text -days 3650 \  
-extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
-signkey root.key -out root.crt  
  
# intermediate  
openssl req -new -nodes -text -out intermediate.csr \  
-keyout intermediate.key -subj "/CN=intermediate.yourdomain.com"  
chmod og-rwx intermediate.key  
openssl x509 -req -in intermediate.csr -text -days 1825 \  
-extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
-CA root.crt -CAkey root.key -CAcreateserial \  
-out intermediate.crt  
  
# leaf  
openssl req -new -nodes -text -out server.csr \  
-keyout server.key -subj "/CN=dbhost.yourdomain.com"  
chmod og-rwx server.key  
openssl x509 -req -in server.csr -text -days 365 \  
-CA intermediate.crt -CAkey intermediate.key -CAcreateserial \  
-out server.crt
```

`server.crt` and `intermediate.crt` should be concatenated into a certificate file bundle and stored on the server. `server.key` should also be stored on the server. `root.crt` should be stored on the client so the client can verify that the server's leaf certificate was signed by a chain of certificates linked to its trusted root certificate. `root.key` and `intermediate.key` should be stored offline for use in creating future certificates.

## 16.10. Secure TCP/IP Connections with GSSAPI Encryption

LightDB also has native support for using GSSAPI to encrypt client/server communications for increased security. Support requires that a GSSAPI implementation (such as MIT Kerberos) is installed on both client and server systems, and that support in LightDB is enabled at build time.

### 16.10.1. Basic Setup

The LightDB server will listen for both normal and GSSAPI-encrypted connections on the same TCP port, and will negotiate with any connecting client whether to use GSSAPI for encryption (and for authentication). By default, this decision is up to the client (which means it can be downgraded by an attacker); see Section 18.1 about setting up the server to require the use of GSSAPI for some or all connections.

When using GSSAPI for encryption, it is common to use GSSAPI for authentication as well, since the underlying mechanism will determine both client and server identities (according to the GSSAPI implementation) in any case. But this is not required; another LightDB authentication method can be chosen to perform additional verification.

Other than configuration of the negotiation behavior, GSSAPI encryption requires no setup beyond that which is necessary for GSSAPI authentication. (For more information on configuring that, see Section 18.6.)

## 16.11. Secure TCP/IP Connections with SSH Tunnels

It is possible to use SSH to encrypt the network connection between clients and a LightDB server. Done properly, this provides an adequately secure network connection, even for non-SSL-capable clients.

First make sure that an SSH server is running properly on the same machine as the LightDB server and that you can log in using `ssh` as some user; you then can establish a secure tunnel to the remote server. A secure tunnel listens on a local port and forwards all traffic to a port on the remote machine. Traffic sent to the remote port can arrive on its `localhost` address, or different bind address if desired; it does not appear as coming from your local machine. This command creates a secure tunnel from the client machine to the remote machine `foo.com`:

```
ssh -L 63333:localhost:5432 joe@foo.com
```

The first number in the `-L` argument, 63333, is the local port number of the tunnel; it can be any unused port. (IANA reserves ports 49152 through 65535 for private use.) The name or IP address after this is the remote bind address you are connecting to, i.e., `localhost`, which is the default. The second number, 5432, is the remote end of the tunnel, e.g., the port number your database server is using. In order to connect to the database server using this tunnel, you connect to port 63333 on the local machine:

```
ltsql -h localhost -p 63333 postgres
```

To the database server it will then look as though you are user `joe` on host `foo.com` connecting to the `localhost` bind address, and it will use whatever authentication procedure was configured for connections by that user to that bind address. Note that the server will not think the connection is SSL-encrypted, since in fact it is not encrypted between the SSH server and the LightDB server. This should not pose any extra security risk because they are on the same machine.

In order for the tunnel setup to succeed you must be allowed to connect via `ssh` as `joe@foo.com`, just as if you had attempted to use `ssh` to create a terminal session.

You could also have set up port forwarding as

```
ssh -L 63333:foo.com:5432 joe@foo.com
```

but then the database server will see the connection as coming in on its `foo.com` bind address, which is not opened by the default setting `listen_addresses = 'localhost'`. This is usually not what you want.

If you have to “hop” to the database server via some login host, one possible setup could look like this:

```
ssh -L 63333:db.foo.com:5432 joe@shell.foo.com
```

Note that this way the connection from `shell.foo.com` to `db.foo.com` will not be encrypted by the SSH tunnel. SSH offers quite a few configuration possibilities when the network is restricted in various ways. Please refer to the SSH documentation for details.

### Tip

Several other applications exist that can provide secure tunnels using a procedure similar in concept to the one just described.

## 16.12. Registering Event Log on Windows

To register a Windows event log library with the operating system, issue this command:

```
regsvr32 pgsql_library_directory/pgevent.dll
```

This creates registry entries used by the event viewer, under the default event source named `LightDB`.

To specify a different event source name (see `event_source`), use the `/n` and `/i` options:

```
regsvr32 /n /i:event_source_name pgsql_library_directory/pgevent.dll
```

To unregister the event log library from the operating system, issue this command:

```
regsvr32 /u [/i:event_source_name] pgsql_library_directory/pgevent.dll
```

### Note

To enable event logging in the database server, modify `log_destination` to include `eventlog` in `lightdb.conf`.

---

# Chapter 17. Server Configuration

There are many configuration parameters that affect the behavior of the database system. In the first section of this chapter we describe how to interact with configuration parameters. The subsequent sections discuss each parameter in detail.

## 17.1. Setting Parameters

### 17.1.1. Parameter Names and Values

All parameter names are case-insensitive. Every parameter takes a value of one of five types: boolean, string, integer, floating point, or enumerated (enum). The type determines the syntax for setting the parameter:

- *Boolean*: Values can be written as `on`, `off`, `true`, `false`, `yes`, `no`, `1`, `0` (all case-insensitive) or any unambiguous prefix of one of these.
- *String*: In general, enclose the value in single quotes, doubling any single quotes within the value. Quotes can usually be omitted if the value is a simple number or identifier, however. (Values that match a SQL keyword require quoting in some contexts.)
- *Numeric (integer and floating point)*: Numeric parameters can be specified in the customary integer and floating-point formats; fractional values are rounded to the nearest integer if the parameter is of integer type. Integer parameters additionally accept hexadecimal input (beginning with `0x`) and octal input (beginning with `0`), but these formats cannot have a fraction. Do not use thousands separators. Quotes are not required, except for hexadecimal input.
- *Numeric with Unit*: Some numeric parameters have an implicit unit, because they describe quantities of memory or time. The unit might be bytes, kilobytes, blocks (typically eight kilobytes), milliseconds, seconds, or minutes. An unadorned numeric value for one of these settings will use the setting's default unit, which can be learned from `pg_settings.unit`. For convenience, settings can be given with a unit specified explicitly, for example `'120 ms'` for a time value, and they will be converted to whatever the parameter's actual unit is. Note that the value must be written as a string (with quotes) to use this feature. The unit name is case-sensitive, and there can be whitespace between the numeric value and the unit.
  - Valid memory units are `B` (bytes), `kB` (kilobytes), `MB` (megabytes), `GB` (gigabytes), and `TB` (terabytes). The multiplier for memory units is 1024, not 1000.
  - Valid time units are `us` (microseconds), `ms` (milliseconds), `s` (seconds), `min` (minutes), `h` (hours), and `d` (days).

If a fractional value is specified with a unit, it will be rounded to a multiple of the next smaller unit if there is one. For example, `30.1 GB` will be converted to `30822 MB` not `32319628902 B`. If the parameter is of integer type, a final rounding to integer occurs after any unit conversion.
- *Enumerated*: Enumerated-type parameters are written in the same way as string parameters, but are restricted to have one of a limited set of values. The values allowable for such a parameter can be found from `pg_settings.enumvals`. Enum parameter values are case-insensitive.

### 17.1.2. Parameter Interaction via the Configuration File

The most fundamental way to set these parameters is to edit the file `lightdb.conf`, which is normally kept in the data directory. A default copy is installed when the database cluster directory is initialized. An example of what this file might look like is:

```
# This is a comment
log_connections = yes
```

```
log_destination = 'syslog'  
search_path = '"$user", public'  
shared_buffers = 128MB
```

One parameter is specified per line. The equal sign between name and value is optional. Whitespace is insignificant (except within a quoted parameter value) and blank lines are ignored. Hash marks (#) designate the remainder of the line as a comment. Parameter values that are not simple identifiers or numbers must be single-quoted. To embed a single quote in a parameter value, write either two quotes (preferred) or backslash-quote. If the file contains multiple entries for the same parameter, all but the last one are ignored.

Parameters set in this way provide default values for the cluster. The settings seen by active sessions will be these values unless they are overridden. The following sections describe ways in which the administrator or user can override these defaults.

The configuration file is reread whenever the main server process receives a SIGHUP signal; this signal is most easily sent by running `lt_ctl reload` from the command line or by calling the SQL function `pg_reload_conf()`. The main server process also propagates this signal to all currently running server processes, so that existing sessions also adopt the new values (this will happen after they complete any currently-executing client command). Alternatively, you can send the signal to a single server process directly. Some parameters can only be set at server start; any changes to their entries in the configuration file will be ignored until the server is restarted. Invalid parameter settings in the configuration file are likewise ignored (but logged) during SIGHUP processing.

In addition to `lightdb.conf`, a LightDB data directory contains a file `lightdb.auto.conf`, which has the same format as `lightdb.conf` but is intended to be edited automatically, not manually. This file holds settings provided through the `ALTER SYSTEM` command. This file is read whenever `lightdb.conf` is, and its settings take effect in the same way. Settings in `lightdb.auto.conf` override those in `lightdb.conf`.

External tools may also modify `lightdb.auto.conf`. It is not recommended to do this while the server is running, since a concurrent `ALTER SYSTEM` command could overwrite such changes. Such tools might simply append new settings to the end, or they might choose to remove duplicate settings and/or comments (as `ALTER SYSTEM` will).

The system view `pg_file_settings` can be helpful for pre-testing changes to the configuration files, or for diagnosing problems if a SIGHUP signal did not have the desired effects.

### 17.1.3. Parameter Interaction via SQL

LightDB provides three SQL commands to establish configuration defaults. The already-mentioned `ALTER SYSTEM` command provides a SQL-accessible means of changing global defaults; it is functionally equivalent to editing `lightdb.conf`. In addition, there are two commands that allow setting of defaults on a per-database or per-role basis:

- The `ALTER DATABASE` command allows global settings to be overridden on a per-database basis.
- The `ALTER ROLE` command allows both global and per-database settings to be overridden with user-specific values.

Values set with `ALTER DATABASE` and `ALTER ROLE` are applied only when starting a fresh database session. They override values obtained from the configuration files or server command line, and constitute defaults for the rest of the session. Note that some settings cannot be changed after server start, and so cannot be set with these commands (or the ones listed below).

The above three methods of modifying parameters will be recorded in detail in the log file (located in `$LTDATA/log/`), including the values before and after parameter modification, as well as the time of parameter modification, client program name to modify the parameter, user who modified the parameter, and specific SQL statements used to modify the parameter. Also the old and current value of the modified parameter will be prompted in the client program when issuing `ALTER SYSTEM`, `ALTER DATABASE` or `ALTER ROLE`.

Once a client is connected to the database, LightDB provides two additional SQL commands (and equivalent functions) to interact with session-local configuration settings:

- The `SHOW` command allows inspection of the current value of any parameter. The corresponding SQL function is `current_setting(setting_name text)` (see Section 9.27.1).
- The `SET` command allows modification of the current value of those parameters that can be set locally to a session; it has no effect on other sessions. The corresponding SQL function is `set_config(setting_name, new_value, is_local)` (see Section 9.27.1).

In addition, the system view `pg_settings` can be used to view and change session-local values:

- Querying this view is similar to using `SHOW ALL` but provides more detail. It is also more flexible, since it's possible to specify filter conditions or join against other relations.
- Using `UPDATE` on this view, specifically updating the `setting` column, is the equivalent of issuing `SET` commands. For example, the equivalent of

```
SET configuration_parameter TO DEFAULT;
```

is:

```
UPDATE pg_settings SET setting = reset_val WHERE name =  
'configuration_parameter';
```

## 17.1.4. Parameter Interaction via the Shell

In addition to setting global defaults or attaching overrides at the database or role level, you can pass settings to LightDB via shell facilities. Both the server and libpq client library accept parameter values via the shell.

- During server startup, parameter settings can be passed to the `lightdb` command via the `-c` command-line parameter. For example,

```
lightdb -c log_connections=yes -c log_destination='syslog'
```

Settings provided in this way override those set via `lightdb.conf` or `ALTER SYSTEM`, so they cannot be changed globally without restarting the server.

- When starting a client session via libpq, parameter settings can be specified using the `LTOPTIONS` environment variable. Settings established in this way constitute defaults for the life of the session, but do not affect other sessions. For historical reasons, the format of `LTOPTIONS` is similar to that used when launching the `lightdb` command; specifically, the `-c` flag must be specified. For example,

```
env PGOPTIONS="-c geco=off -c statement_timeout=5min" ltsql
```

Other clients and libraries might provide their own mechanisms, via the shell or otherwise, that allow the user to alter session settings without direct use of SQL commands.

## 17.1.5. Managing Configuration File Contents

LightDB provides several features for breaking down complex `lightdb.conf` files into sub-files. These features are especially useful when managing multiple servers with related, but not identical, configurations.

In addition to individual parameter settings, the `lightdb.conf` file can contain *include directives*, which specify another file to read and process as if it were inserted into the configuration file at this point. This feature allows a configuration file to be divided into physically separate parts. Include directives simply look like:

```
include 'filename'
```

If the file name is not an absolute path, it is taken as relative to the directory containing the referencing configuration file. Inclusions can be nested.

There is also an `include_if_exists` directive, which acts the same as the `include` directive, except when the referenced file does not exist or cannot be read. A regular `include` will consider this an error condition, but `include_if_exists` merely logs a message and continues processing the referencing configuration file.

The `lightdb.conf` file can also contain `include_dir` directives, which specify an entire directory of configuration files to include. These look like

```
include_dir 'directory'
```

Non-absolute directory names are taken as relative to the directory containing the referencing configuration file. Within the specified directory, only non-directory files whose names end with the suffix `.conf` will be included. File names that start with the `.` character are also ignored, to prevent mistakes since such files are hidden on some platforms. Multiple files within an include directory are processed in file name order (according to C locale rules, i.e., numbers before letters, and uppercase letters before lowercase ones).

Include files or directories can be used to logically separate portions of the database configuration, rather than having a single large `lightdb.conf` file. Consider a company that has two database servers, each with a different amount of memory. There are likely elements of the configuration both will share, for things such as logging. But memory-related parameters on the server will vary between the two. And there might be server specific customizations, too. One way to manage this situation is to break the custom configuration changes for your site into three files. You could add this to the end of your `lightdb.conf` file to include them:

```
include 'shared.conf'  
include 'memory.conf'  
include 'server.conf'
```

All systems would have the same `shared.conf`. Each server with a particular amount of memory could share the same `memory.conf`; you might have one for all servers with 8GB of RAM, another for those having 16GB. And finally `server.conf` could have truly server-specific configuration information in it.

Another possibility is to create a configuration file directory and put this information into files there. For example, a `conf.d` directory could be referenced at the end of `lightdb.conf`:

```
include_dir 'conf.d'
```

Then you could name the files in the `conf.d` directory like this:

```
00shared.conf  
01memory.conf  
02server.conf
```

This naming convention establishes a clear order in which these files will be loaded. This is important because only the last setting encountered for a particular parameter while the server is reading configuration files will be used. In this example, something set in `conf.d/02server.conf` would override a value set in `conf.d/01memory.conf`.

You might instead use this approach to naming the files descriptively:

```
00shared.conf
01memory-8GB.conf
02server-foo.conf
```

This sort of arrangement gives a unique name for each configuration file variation. This can help eliminate ambiguity when several servers have their configurations all stored in one place, such as in a version control repository. (Storing database configuration files under version control is another good practice to consider.)

## 17.2. File Locations

In addition to the `lightdb.conf` file already mentioned, LightDB uses two other manually-edited configuration files, which control client authentication (their use is discussed in Chapter 18). By default, all three configuration files are stored in the database cluster's data directory. The parameters described in this section allow the configuration files to be placed elsewhere. (Doing so can ease administration. In particular it is often easier to ensure that the configuration files are properly backed-up when they are kept separate.)

`data_directory` (string)

Specifies the directory to use for data storage. This parameter can only be set at server start.

`config_file` (string)

Specifies the main server configuration file (customarily called `lightdb.conf`). This parameter can only be set on the `lightdb` command line.

`hba_file` (string)

Specifies the configuration file for host-based authentication (customarily called `lt_hba.conf`). This parameter can only be set at server start.

`ident_file` (string)

Specifies the configuration file for user name mapping (customarily called `lt_ident.conf`). This parameter can only be set at server start. See also Section 18.2.

`external_pid_file` (string)

Specifies the name of an additional process-ID (PID) file that the server should create for use by server administration programs. This parameter can only be set at server start.

In a default installation, none of the above parameters are set explicitly. Instead, the data directory is specified by the `-D` command-line option or the `LTDATA` environment variable, and the configuration files are all found within the data directory.

If you wish to keep the configuration files elsewhere than the data directory, the `lightdb -D` command-line option or `LTDATA` environment variable must point to the directory containing the configuration files, and the `data_directory` parameter must be set in `lightdb.conf` (or on the command line) to show where the data directory is actually located. Notice that `data_directory`



overrides `-D` and `LTDATA` for the location of the data directory, but not for the location of the configuration files.

If you wish, you can specify the configuration file names and locations individually using the parameters `config_file`, `hba_file` and/or `ident_file`. `config_file` can only be specified on the `lightdb` command line, but the others can be set within the main configuration file. If all three parameters plus `data_directory` are explicitly set, then it is not necessary to specify `-D` or `LTDATA`.

When setting any of these parameters, a relative path will be interpreted with respect to the directory in which `lightdb` is started.

## 17.3. Connections and Authentication

### 17.3.1. Connection Settings

`listen_addresses` (string)

Specifies the TCP/IP address(es) on which the server is to listen for connections from client applications. The value takes the form of a comma-separated list of host names and/or numeric IP addresses. The special entry `*` corresponds to all available IP interfaces. The entry `0.0.0.0` allows listening for all IPv4 addresses and `::` allows listening for all IPv6 addresses. If the list is empty, the server does not listen on any IP interface at all, in which case only Unix-domain sockets can be used to connect to it. The default value is `localhost`, which allows only local TCP/IP “loopback” connections to be made. While client authentication (Chapter 18) allows fine-grained control over who can access the server, `listen_addresses` controls which interfaces accept connection attempts, which can help prevent repeated malicious connection requests on insecure network interfaces. This parameter can only be set at server start.

`port` (integer)

The TCP port the server listens on; 5432 by default. Note that the same port number is used for all IP addresses the server listens on. This parameter can only be set at server start.

`max_connections` (integer)

Determines the maximum number of concurrent connections to the database server. The default is typically 100 connections, but might be less if your kernel settings will not support it (as determined during `initdb`). This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`superuser_reserved_connections` (integer)

Determines the number of connection “slots” that are reserved for connections by LightDB superusers. At most `max_connections` connections can ever be active simultaneously. Whenever the number of active concurrent connections is at least `max_connections` minus `superuser_reserved_connections`, new connections will be accepted only for superusers, and no new replication connections will be accepted.

The default value is three connections. The value must be less than `max_connections`. This parameter can only be set at server start.

`unix_socket_directories` (string)

Specifies the directory of the Unix-domain socket(s) on which the server is to listen for connections from client applications. Multiple sockets can be created by listing multiple directories separated by commas. Whitespace between entries is ignored; surround a directory

name with double quotes if you need to include whitespace or commas in the name. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. On Windows, the default is empty, which means no Unix-domain socket is created by default. This parameter can only be set at server start.

In addition to the socket file itself, which is named `.s.PGSQL.nnnn` where `nnnn` is the server's port number, an ordinary file named `.s.PGSQL.nnnn.lock` will be created in each of the `unix_socket_directories` directories. Neither file should ever be removed manually.

`unix_socket_group` (string)

Sets the owning group of the Unix-domain socket(s). (The owning user of the sockets is always the user that starts the server.) In combination with the parameter `unix_socket_permissions` this can be used as an additional access control mechanism for Unix-domain connections. By default this is the empty string, which uses the default group of the server user. This parameter can only be set at server start.

This parameter is not supported on Windows. Any setting will be ignored.

`unix_socket_permissions` (integer)

Sets the access permissions of the Unix-domain socket(s). Unix-domain sockets use the usual Unix file system permission set. The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a 0 (zero).)

The default permissions are `0777`, meaning anyone can connect. Reasonable alternatives are `0770` (only user and group, see also `unix_socket_group`) and `0700` (only user). (Note that for a Unix-domain socket, only write permission matters, so there is no point in setting or revoking read or execute permissions.)

This access control mechanism is independent of the one described in Chapter 18.

This parameter can only be set at server start.

This parameter is irrelevant on systems, notably Solaris as of Solaris 10, that ignore socket permissions entirely. There, one can achieve a similar effect by pointing `unix_socket_directories` to a directory having search permission limited to the desired audience.

`bonjour` (boolean)

Enables advertising the server's existence via Bonjour. The default is off. This parameter can only be set at server start.

`bonjour_name` (string)

Specifies the Bonjour service name. The computer name is used if this parameter is set to the empty string `' '` (which is the default). This parameter is ignored if the server was not compiled with Bonjour support. This parameter can only be set at server start.

`tcp_keepalives_idle` (integer)

Specifies the amount of time with no network activity after which the operating system should send a TCP keepalive message to the client. If this value is specified without units, it is taken as seconds. A value of 0 selects the operating system's default. The default value is 300 seconds. This parameter is supported only on systems that support `TCP_KEEPIDLE` or an equivalent socket option, and on Windows; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

**Note**

On Windows, setting a value of 0 will set this parameter to 2 hours, since Windows does not provide a way to read the system default value.

`tcp_keepalives_interval` (integer)

Specifies the amount of time after which a TCP keepalive message that has not been acknowledged by the client should be retransmitted. If this value is specified without units, it is taken as seconds. A value of 0 selects the operating system's default. The default values is 30 seconds. This parameter is supported only on systems that support `TCP_KEEPINTVL` or an equivalent socket option, and on Windows; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

**Note**

On Windows, setting a value of 0 will set this parameter to 1 second, since Windows does not provide a way to read the system default value.

`tcp_keepalives_count` (integer)

Specifies the number of TCP keepalive messages that can be lost before the server's connection to the client is considered dead. A value of 0 selects the operating system's default. The default value is 5. This parameter is supported only on systems that support `TCP_KEEPCNT` or an equivalent socket option; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

**Note**

This parameter is not supported on Windows, and must be zero.

`tcp_user_timeout` (integer)

Specifies the amount of time that transmitted data may remain unacknowledged before the TCP connection is forcibly closed. If this value is specified without units, it is taken as milliseconds. A value of 0 (the default) selects the operating system's default. This parameter is supported only on systems that support `TCP_USER_TIMEOUT`; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

**Note**

This parameter is not supported on Windows, and must be zero.

## 17.3.2. Authentication

`authentication_timeout` (integer)

Maximum amount of time allowed to complete client authentication. If a would-be client has not completed the authentication protocol in this much time, the server closes the connection. This

prevents hung clients from occupying a connection indefinitely. If this value is specified without units, it is taken as seconds. The default is one minute (1m). This parameter can only be set in the `lightdb.conf` file or on the server command line.

`password_encryption` (enum)

When a password is specified in `CREATE ROLE` or `ALTER ROLE`, this parameter determines the algorithm to use to encrypt the password. The default value is `md5`, which stores the password as an MD5 hash (`on` is also accepted, as alias for `md5`). Setting this parameter to `scram-sha-256` will encrypt the password with SCRAM-SHA-256.

Note that older clients might lack support for the SCRAM authentication mechanism, and hence not work with passwords encrypted with SCRAM-SHA-256. See Section 18.5 for more details.

`krb_server_keyfile` (string)

Sets the location of the server's Kerberos key file. The default is `FILE:/usr/local/lightdb-x/etc/krb5.keytab` (where the directory part is whatever was specified as `sysconfdir` at build time; use `lt_config --sysconfdir` to determine that). If this parameter is set to an empty string, it is ignored and a system-dependent default is used. This parameter can only be set in the `lightdb.conf` file or on the server command line. See Section 18.6 for more information.

`krb_caseins_users` (boolean)

Sets whether GSSAPI user names should be treated case-insensitively. The default is `off` (case sensitive). This parameter can only be set in the `lightdb.conf` file or on the server command line.

`db_user_namespace` (boolean)

This parameter enables per-database user names. It is off by default. This parameter can only be set in the `lightdb.conf` file or on the server command line.

If this is on, you should create users as `username@dbname`. When `username` is passed by a connecting client, `@` and the database name are appended to the user name and that database-specific user name is looked up by the server. Note that when you create users with names containing `@` within the SQL environment, you will need to quote the user name.

With this parameter enabled, you can still create ordinary global users. Simply append `@` when specifying the user name in the client, e.g., `joe@`. The `@` will be stripped off before the user name is looked up by the server.

`db_user_namespace` causes the client's and server's user name representation to differ. Authentication checks are always done with the server's user name so authentication methods must be configured for the server's user name, not the client's. Because `md5` uses the user name as salt on both the client and server, `md5` cannot be used with `db_user_namespace`.

### Note

This feature is intended as a temporary measure until a complete solution is found. At that time, this option will be removed.

## 17.3.3. SSL

See Section 16.9 for more information about setting up SSL.

`ssl` (boolean)

Enables SSL connections. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `off`.

`ssl_ca_file` (string)

Specifies the name of the file containing the SSL server certificate authority (CA). Relative paths are relative to the data directory. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is empty, meaning no CA file is loaded, and client certificate verification is not performed.

`ssl_cert_file` (string)

Specifies the name of the file containing the SSL server certificate. Relative paths are relative to the data directory. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `server.crt`.

`ssl_crl_file` (string)

Specifies the name of the file containing the SSL client certificate revocation list (CRL). Relative paths are relative to the data directory. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is empty, meaning no CRL file is loaded.

`ssl_key_file` (string)

Specifies the name of the file containing the SSL server private key. Relative paths are relative to the data directory. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `server.key`.

`ssl_ciphers` (string)

Specifies a list of SSL cipher suites that are allowed to be used by SSL connections. See the ciphers manual page in the OpenSSL package for the syntax of this setting and a list of supported values. Only connections using TLS version 1.2 and lower are affected. There is currently no setting that controls the cipher choices used by TLS version 1.3 connections. The default value is `HIGH:MEDIUM:+3DES:!aNULL`. The default is usually a reasonable choice unless you have specific security requirements.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

Explanation of the default value:

HIGH

Cipher suites that use ciphers from HIGH group (e.g., AES, Camellia, 3DES)

MEDIUM

Cipher suites that use ciphers from MEDIUM group (e.g., RC4, SEED)

+3DES

The OpenSSL default order for HIGH is problematic because it orders 3DES higher than AES128. This is wrong because 3DES offers less security than AES128, and it is also much slower. +3DES reorders it after all other HIGH and MEDIUM ciphers.

!aNULL

Disables anonymous cipher suites that do no authentication. Such cipher suites are vulnerable to man-in-the-middle attacks and therefore should not be used.

Available cipher suite details will vary across OpenSSL versions. Use the command `openssl ciphers -v 'HIGH:MEDIUM:+3DES:!aNULL'` to see actual details for the currently installed OpenSSL version. Note that this list is filtered at run time based on the server key type.

`ssl_prefer_server_ciphers` (boolean)

Specifies whether to use the server's SSL cipher preferences, rather than the client's. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is on.

Older LightDB versions do not have this setting and always use the client's preferences. This setting is mainly for backward compatibility with those versions. Using the server's preferences is usually better because it is more likely that the server is appropriately configured.

`ssl_ecdh_curve` (string)

Specifies the name of the curve to use in ECDH key exchange. It needs to be supported by all clients that connect. It does not need to be the same curve used by the server's Elliptic Curve key. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `prime256v1`.

OpenSSL names for the most common curves are: `prime256v1` (NIST P-256), `secp384r1` (NIST P-384), `secp521r1` (NIST P-521). The full list of available curves can be shown with the command `openssl ecparam -list_curves`. Not all of them are usable in TLS though.

`ssl_min_protocol_version` (enum)

Sets the minimum SSL/TLS protocol version to use. Valid values are currently: `TLSv1`, `TLSv1.1`, `TLSv1.2`, `TLSv1.3`. Older versions of the OpenSSL library do not support all values; an error will be raised if an unsupported setting is chosen. Protocol versions before TLS 1.0, namely SSL version 2 and 3, are always disabled.

The default is `TLSv1.2`, which satisfies industry best practices as of this writing.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`ssl_max_protocol_version` (enum)

Sets the maximum SSL/TLS protocol version to use. Valid values are as for `ssl_min_protocol_version`, with addition of an empty string, which allows any protocol version. The default is to allow any version. Setting the maximum protocol version is mainly useful for testing or if some component has issues working with a newer protocol.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`ssl_dh_params_file` (string)

Specifies the name of the file containing Diffie-Hellman parameters used for so-called ephemeral DH family of SSL ciphers. The default is empty, in which case compiled-in default DH parameters used. Using custom DH parameters reduces the exposure if an attacker manages to crack the well-known compiled-in DH parameters. You can create your own DH parameters file with the command `openssl dhparam -out dhparams.pem 2048`.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`ssl_passphrase_command` (string)

Sets an external command to be invoked when a passphrase for decrypting an SSL file such as a private key needs to be obtained. By default, this parameter is empty, which means the built-in prompting mechanism is used.

The command must print the passphrase to the standard output and exit with code 0. In the parameter value, `%p` is replaced by a prompt string. (Write `%%` for a literal `%`.) Note that the prompt string will probably contain whitespace, so be sure to quote adequately. A single newline is stripped from the end of the output if present.

The command does not actually have to prompt the user for a passphrase. It can read it from a file, obtain it from a keychain facility, or similar. It is up to the user to make sure the chosen mechanism is adequately secure.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`ssl_passphrase_command_supports_reload` (boolean)

This parameter determines whether the passphrase command set by `ssl_passphrase_command` will also be called during a configuration reload if a key file needs a passphrase. If this parameter is off (the default), then `ssl_passphrase_command` will be ignored during a reload and the SSL configuration will not be reloaded if a passphrase is needed. That setting is appropriate for a command that requires a TTY for prompting, which might not be available when the server is running. Setting this parameter to on might be appropriate if the passphrase is obtained from a file, for example.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.4. Resource Consumption

### 17.4.1. Memory

`shared_buffers` (integer)

Sets the amount of memory the database server uses for shared memory buffers. The default is typically 128 megabytes (128MB), but might be less if your kernel settings will not support it (as determined during `initdb`). This setting must be at least 128 kilobytes. However, settings significantly higher than the minimum are usually needed for good performance. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. (Non-default values of `BLCKSZ` change the minimum value.) This parameter can only be set at server start.

If you have a dedicated database server with 1GB or more of RAM, a reasonable starting value for `shared_buffers` is 25% of the memory in your system. There are some workloads where even larger settings for `shared_buffers` are effective, but because LightDB also relies on the operating system cache, it is unlikely that an allocation of more than 40% of RAM to `shared_buffers` will work better than a smaller amount. Larger settings for `shared_buffers` usually require a corresponding increase in `max_wal_size`, in order to spread out the process of writing large quantities of new or changed data over a longer period of time.

On systems with less than 1GB of RAM, a smaller percentage of RAM is appropriate, so as to leave adequate space for the operating system.

`huge_pages` (enum)

Controls whether huge pages are requested for the main shared memory area. Valid values are `try` (the default), `on`, and `off`. With `huge_pages` set to `try`, the server will try to request huge pages, but fall back to the default if that fails. With `on`, failure to request huge pages will prevent the server from starting up. With `off`, huge pages will not be requested.

At present, this setting is supported only on Linux and Windows. The setting is ignored on other systems when set to `try`. On Linux, it is only supported when `shared_memory_type` is set to `mmap` (the default).

The use of huge pages results in smaller page tables and less CPU time spent on memory management, increasing performance. For more details about using huge pages on Linux, see Section 16.4.5.

Huge pages are known as large pages on Windows. To use them, you need to assign the user right Lock Pages in Memory to the Windows user account that runs LightDB. You can use Windows Group Policy tool (gpedit.msc) to assign the user right Lock Pages in Memory. To start the database server on the command prompt as a standalone process, not as a Windows service, the command prompt must be run as an administrator or User Access Control (UAC) must be disabled. When the UAC is enabled, the normal command prompt revokes the user right Lock Pages in Memory when started.

Note that this setting only affects the main shared memory area. Operating systems such as Linux, FreeBSD, and Illumos can also use huge pages (also known as “super” pages or “large” pages) automatically for normal memory allocation, without an explicit request from LightDB. On Linux, this is called “transparent huge pages” (THP). That feature has been known to cause performance degradation with LightDB for some users on some Linux versions, so its use is currently discouraged (unlike explicit use of `huge_pages`).

`lt_ring_buffers` (integer)

Sets the maximum amount of memory used for ring buffers within each database session. When running a sequential scan query that needs to access a large number of pages (more than a quarter of the total pages of `shared_buffers`) just once, a special access strategy called bulk-read is used. A page that has been touched only by such a scan is unlikely to be needed again soon, so instead of blowing out the entire buffer cache, a small ring of buffers that specified by `lt_ring_buffers` is allocated and those buffers are reused for the whole scan. This also implies that much of the write traffic caused by such a statement will be done by the backend itself and not pushed off onto other processes.

If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The default is 256 kilobytes (256kB). (If `BLCKSZ` is not 8kB, the default value scales proportionally to it.) This setting can be changed within individual sessions. However, please notice that the actual size of ring buffers is determined by  $\min(\text{shared\_buffers} / 8, \text{lt\_ring\_buffers})$ , and this is to ensure ring buffers isn't an undue fraction of shared buffers.

`temp_buffers` (integer)

Sets the maximum amount of memory used for temporary buffers within each database session. These are session-local buffers used only for access to temporary tables. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The default is eight megabytes (8MB). (If `BLCKSZ` is not 8kB, the default value scales proportionally to it.) This setting can be changed within individual sessions, but only before the first use of temporary tables within the session; subsequent attempts to change the value will have no effect on that session.

A session will allocate temporary buffers as needed up to the limit given by `temp_buffers`. The cost of setting a large value in sessions that do not actually need many temporary buffers is only a buffer descriptor, or about 64 bytes, per increment in `temp_buffers`. However if a buffer is actually used an additional 8192 bytes will be consumed for it (or in general, `BLCKSZ` bytes).

`max_prepared_transactions` (integer)

Sets the maximum number of transactions that can be in the “prepared” state simultaneously (see `PREPARE TRANSACTION`). Setting this parameter to zero (which is the default) disables the prepared-transaction feature. This parameter can only be set at server start.

If you are not planning to use prepared transactions, this parameter should be set to zero to prevent accidental creation of prepared transactions. If you are using prepared transactions, you will



probably want `max_prepared_transactions` to be at least as large as `max_connections`, so that every session can have a prepared transaction pending.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`work_mem (integer)`

Sets the base maximum amount of memory to be used by a query operation (such as a sort or hash table) before writing to temporary disk files. If this value is specified without units, it is taken as kilobytes. The default value is four megabytes (4MB). Note that for a complex query, several sort or hash operations might be running in parallel; each operation will generally be allowed to use as much memory as this value specifies before it starts to write data into temporary files. Also, several running sessions could be doing such operations concurrently. Therefore, the total memory used could be many times the value of `work_mem`; it is necessary to keep this fact in mind when choosing the value. Sort operations are used for `ORDER BY`, `DISTINCT`, and merge joins. Hash tables are used in hash joins, hash-based aggregation, and hash-based processing of `IN` subqueries.

Hash-based operations are generally more sensitive to memory availability than equivalent sort-based operations. The memory available for hash tables is computed by multiplying `work_mem` by `hash_mem_multiplier`. This makes it possible for hash-based operations to use an amount of memory that exceeds the usual `work_mem` base amount.

`lightdb_keep_temp_file (boolean)`

Allow temporary files to be retained when the base maximum amount of memory to be used by a query operation is not enough. `lt_list_temp_file` can be used for listing temporary file, for example: `select lt_list_temp_file('*')`. `lt_remove_temp_file` can be used for removing temporary file, for example: `select lt_remove_temp_file('*')`.

Note: 's' is used for the current session, '\*' is used for all session.

`hash_mem_multiplier (floating point)`

Used to compute the maximum amount of memory that hash-based operations can use. The final limit is determined by multiplying `work_mem` by `hash_mem_multiplier`. The default value is 1.0, which makes hash-based operations subject to the same simple `work_mem` maximum as sort-based operations.

Consider increasing `hash_mem_multiplier` in environments where spilling by query operations is a regular occurrence, especially when simply increasing `work_mem` results in memory pressure (memory pressure typically takes the form of intermittent out of memory errors). A setting of 1.5 or 2.0 may be effective with mixed workloads. Higher settings in the range of 2.0 - 8.0 or more may be effective in environments where `work_mem` has already been increased to 40MB or more.

`maintenance_work_mem (integer)`

Specifies the maximum amount of memory to be used by maintenance operations, such as `VACUUM`, `CREATE INDEX`, and `ALTER TABLE ADD FOREIGN KEY`. If this value is specified without units, it is taken as kilobytes. It defaults to 64 megabytes (64MB). Since only one of these operations can be executed at a time by a database session, and an installation normally doesn't have many of them running concurrently, it's safe to set this value significantly larger than `work_mem`. Larger settings might improve performance for vacuuming and for restoring database dumps.

Note that when autovacuum runs, up to `autovacuum_max_workers` times this memory may be allocated, so be careful not to set the default value too high. It may be useful to control for this by separately setting `autovacuum_work_mem`.

Note that for the collection of dead tuple identifiers, `VACUUM` is only able to utilize up to a maximum of 1GB of memory.

`autovacuum_work_mem` (integer)

Specifies the maximum amount of memory to be used by each autovacuum worker process. If this value is specified without units, it is taken as kilobytes. It defaults to -1, indicating that the value of `maintenance_work_mem` should be used instead. The setting has no effect on the behavior of `VACUUM` when run in other contexts. This parameter can only be set in the `lightdb.conf` file or on the server command line.

For the collection of dead tuple identifiers, autovacuum is only able to utilize up to a maximum of 1GB of memory, so setting `autovacuum_work_mem` to a value higher than that has no effect on the number of dead tuples that autovacuum can collect while scanning a table.

`logical_decoding_work_mem` (integer)

Specifies the maximum amount of memory to be used by logical decoding, before some of the decoded changes are written to local disk. This limits the amount of memory used by logical streaming replication connections. It defaults to 64 megabytes (64MB). Since each replication connection only uses a single buffer of this size, and an installation normally doesn't have many such connections concurrently (as limited by `max_wal_senders`), it's safe to set this value significantly higher than `work_mem`, reducing the amount of decoded changes written to disk.

`max_stack_depth` (integer)

Specifies the maximum safe depth of the server's execution stack. The ideal setting for this parameter is the actual stack size limit enforced by the kernel (as set by `ulimit -s` or local equivalent), less a safety margin of a megabyte or so. The safety margin is needed because the stack depth is not checked in every routine in the server, but only in key potentially-recursive routines. If this value is specified without units, it is taken as kilobytes. The default setting is two megabytes (2MB), which is conservatively small and unlikely to risk crashes. However, it might be too small to allow execution of complex functions. Only superusers can change this setting.

Setting `max_stack_depth` higher than the actual kernel limit will mean that a runaway recursive function can crash an individual backend process. On platforms where LightDB can determine the kernel limit, the server will not allow this variable to be set to an unsafe value. However, not all platforms provide the information, so caution is recommended in selecting a value.

`shared_memory_type` (enum)

Specifies the shared memory implementation that the server should use for the main shared memory region that holds LightDB's shared buffers and other shared data. Possible values are `mmap` (for anonymous shared memory allocated using `mmap`), `sysv` (for System V shared memory allocated via `shmget`) and `windows` (for Windows shared memory). Not all values are supported on all platforms; the first supported option is the default for that platform. The use of the `sysv` option, which is not the default on any platform, is generally discouraged because it typically requires non-default kernel settings to allow for large allocations (see Section 16.4.1).

`dynamic_shared_memory_type` (enum)

Specifies the dynamic shared memory implementation that the server should use. Possible values are `posix` (for POSIX shared memory allocated using `shm_open`), `sysv` (for System V shared memory allocated via `shmget`), `windows` (for Windows shared memory), and `mmap` (to simulate shared memory using memory-mapped files stored in the data directory). Not all values are supported on all platforms; the first supported option is the default for that platform. The use of the `mmap` option, which is not the default on any platform, is generally discouraged because the operating system may write modified pages back to disk repeatedly, increasing system I/O

load; however, it may be useful for debugging, when the `lt_dynshmem` directory is stored on a RAM disk, or when other shared memory facilities are not available.

## 17.4.2. Disk

`temp_file_limit` (integer)

Specifies the maximum amount of disk space that a process can use for temporary files, such as sort and hash temporary files, or the storage file for a held cursor. A transaction attempting to exceed this limit will be canceled. If this value is specified without units, it is taken as kilobytes. `-1` (the default) means no limit. Only superusers can change this setting.

This setting constrains the total space used at any instant by all temporary files used by a given LightDB process. It should be noted that disk space used for explicit temporary tables, as opposed to temporary files used behind-the-scenes in query execution, does *not* count against this limit.

## 17.4.3. Kernel Resource Usage

`max_files_per_process` (integer)

Sets the maximum number of simultaneously open files allowed to each server subprocess. The default is one thousand files. If the kernel is enforcing a safe per-process limit, you don't need to worry about this setting. But on some platforms (notably, most BSD systems), the kernel will allow individual processes to open many more files than the system can actually support if many processes all try to open that many files. If you find yourself seeing “Too many open files” failures, try reducing this setting. This parameter can only be set at server start.

## 17.4.4. Cost-based Vacuum Delay

During the execution of `VACUUM` and `ANALYZE` commands, the system maintains an internal counter that keeps track of the estimated cost of the various I/O operations that are performed. When the accumulated cost reaches a limit (specified by `vacuum_cost_limit`), the process performing the operation will sleep for a short period of time, as specified by `vacuum_cost_delay`. Then it will reset the counter and continue execution.

The intent of this feature is to allow administrators to reduce the I/O impact of these commands on concurrent database activity. There are many situations where it is not important that maintenance commands like `VACUUM` and `ANALYZE` finish quickly; however, it is usually very important that these commands do not significantly interfere with the ability of the system to perform other database operations. Cost-based vacuum delay provides a way for administrators to achieve this.

This feature is disabled by default for manually issued `VACUUM` commands. To enable it, set the `vacuum_cost_delay` variable to a nonzero value.

`vacuum_cost_delay` (floating point)

The amount of time that the process will sleep when the cost limit has been exceeded. If this value is specified without units, it is taken as milliseconds. The default value is zero, which disables the cost-based vacuum delay feature. Positive values enable cost-based vacuuming.

When using cost-based vacuuming, appropriate values for `vacuum_cost_delay` are usually quite small, perhaps less than 1 millisecond. While `vacuum_cost_delay` can be set to fractional-millisecond values, such delays may not be measured accurately on older platforms. On such platforms, increasing `VACUUM`'s throttled resource consumption above what you get at 1ms will require changing the other vacuum cost parameters. You should, nonetheless, keep `vacuum_cost_delay` as small as your platform will consistently measure; large delays are not helpful.

`vacuum_cost_page_hit` (integer)

The estimated cost for vacuuming a buffer found in the shared buffer cache. It represents the cost to lock the buffer pool, lookup the shared hash table and scan the content of the page. The default value is one.

`vacuum_cost_page_miss` (integer)

The estimated cost for vacuuming a buffer that has to be read from disk. This represents the effort to lock the buffer pool, lookup the shared hash table, read the desired block in from the disk and scan its content. The default value is 10.

`vacuum_cost_page_dirty` (integer)

The estimated cost charged when vacuum modifies a block that was previously clean. It represents the extra I/O required to flush the dirty block out to disk again. The default value is 20.

`vacuum_cost_limit` (integer)

The accumulated cost that will cause the vacuuming process to sleep. The default value is 200.

### Note

There are certain operations that hold critical locks and should therefore complete as quickly as possible. Cost-based vacuum delays do not occur during such operations. Therefore it is possible that the cost accumulates far higher than the specified limit. To avoid uselessly long delays in such cases, the actual delay is calculated as  $\text{vacuum\_cost\_delay} * \text{accumulated\_balance} / \text{vacuum\_cost\_limit}$  with a maximum of  $\text{vacuum\_cost\_delay} * 4$ .

## 17.4.5. Background Writer

There is a separate server process called the *background writer*, whose function is to issue writes of “dirty” (new or modified) shared buffers. When the number of clean shared buffers appears to be insufficient, the background writer writes some dirty buffers to the file system and marks them as clean. This reduces the likelihood that server processes handling user queries will be unable to find clean buffers and have to write dirty buffers themselves. However, the background writer does cause a net overall increase in I/O load, because while a repeatedly-dirtied page might otherwise be written only once per checkpoint interval, the background writer might write it several times as it is dirtied in the same interval. The parameters discussed in this subsection can be used to tune the behavior for local needs.

`bgwriter_delay` (integer)

Specifies the delay between activity rounds for the background writer. In each round the writer issues writes for some number of dirty buffers (controllable by the following parameters). It then sleeps for the length of `bgwriter_delay`, and repeats. When there are no dirty buffers in the buffer pool, though, it goes into a longer sleep regardless of `bgwriter_delay`. If this value is specified without units, it is taken as milliseconds. The default value is 200 milliseconds (200ms). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `bgwriter_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`bgwriter_lru_maxpages` (integer)

In each round, no more than this many buffers will be written by the background writer. Setting this to zero disables background writing. (Note that checkpoints, which are managed by a separate,

dedicated auxiliary process, are unaffected.) The default value is 100 buffers. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`bgwriter_lru_multiplier` (floating point)

The number of dirty buffers written in each round is based on the number of new buffers that have been needed by server processes during recent rounds. The average recent need is multiplied by `bgwriter_lru_multiplier` to arrive at an estimate of the number of buffers that will be needed during the next round. Dirty buffers are written until there are that many clean, reusable buffers available. (However, no more than `bgwriter_lru_maxpages` buffers will be written per round.) Thus, a setting of 1.0 represents a “just in time” policy of writing exactly the number of buffers predicted to be needed. Larger values provide some cushion against spikes in demand, while smaller values intentionally leave writes to be done by server processes. The default is 2.0. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`bgwriter_flush_after` (integer)

Whenever more than this amount of data has been written by the background writer, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of a checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 512kB on Linux, 0 elsewhere. (If `BLCKSZ` is not 8kB, the default and maximum values scale proportionally to it.) This parameter can only be set in the `lightdb.conf` file or on the server command line.

Smaller values of `bgwriter_lru_maxpages` and `bgwriter_lru_multiplier` reduce the extra I/O load caused by the background writer, but make it more likely that server processes will have to issue writes for themselves, delaying interactive queries.

## 17.4.6. Asynchronous Behavior

`effective_io_concurrency` (integer)

Sets the number of concurrent disk I/O operations that LightDB expects can be executed simultaneously. Raising this value will increase the number of I/O operations that any individual LightDB session attempts to initiate in parallel. The allowed range is 1 to 1000, or zero to disable issuance of asynchronous I/O requests. Currently, this setting only affects bitmap heap scans.

For magnetic drives, a good starting point for this setting is the number of separate drives comprising a RAID 0 stripe or RAID 1 mirror being used for the database. (For RAID 5 the parity drive should not be counted.) However, if the database is often busy with multiple queries issued in concurrent sessions, lower values may be sufficient to keep the disk array busy. A value higher than needed to keep the disks busy will only result in extra CPU overhead. SSDs and other memory-based storage can often process many concurrent requests, so the best value might be in the hundreds.

Asynchronous I/O depends on an effective `posix_fadvise` function, which some operating systems lack. If the function is not present then setting this parameter to anything but zero will result in an error. On some operating systems (e.g., Solaris), the function is present but does not actually do anything.

The default is 1 on supported systems, otherwise 0. This value can be overridden for tables in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

`maintenance_io_concurrency` (integer)

Similar to `effective_io_concurrency`, but used for maintenance work that is done on behalf of many client sessions.

The default is 10 on supported systems, otherwise 0. This value can be overridden for tables in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

`max_worker_processes` (integer)

Sets the maximum number of background processes that the system can support. This parameter can only be set at server start. The default is 8.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

When changing this value, consider also adjusting `max_parallel_workers`, `max_parallel_maintenance_workers`, and `max_parallel_workers_per_gather`.

`max_parallel_workers_per_gather` (integer)

Sets the maximum number of workers that can be started by a single `Gather` or `Gather Merge` node. Parallel workers are taken from the pool of processes established by `max_worker_processes`, limited by `max_parallel_workers`. Note that the requested number of workers may not actually be available at run time. If this occurs, the plan will run with fewer workers than expected, which may be inefficient. The default value is 2. Setting this value to 0 disables parallel query execution.

Note that parallel queries may consume very substantially more resources than non-parallel queries, because each worker process is a completely separate process which has roughly the same impact on the system as an additional user session. This should be taken into account when choosing a value for this setting, as well as when configuring other settings that control resource utilization, such as `work_mem`. Resource limits such as `work_mem` are applied individually to each worker, which means the total utilization may be much higher across all processes than it would normally be for any single process. For example, a parallel query using 4 workers may use up to 5 times as much CPU time, memory, I/O bandwidth, and so forth as a query which uses no workers at all.

For more information on parallel query, see Chapter 15.

`max_parallel_maintenance_workers` (integer)

Sets the maximum number of parallel workers that can be started by a single utility command. Currently, the parallel utility commands that support the use of parallel workers are `CREATE INDEX` only when building a B-tree index, and `VACUUM` without `FULL` option. Parallel workers are taken from the pool of processes established by `max_worker_processes`, limited by `max_parallel_workers`. Note that the requested number of workers may not actually be available at run time. If this occurs, the utility operation will run with fewer workers than expected. The default value is 2. Setting this value to 0 disables the use of parallel workers by utility commands.

Note that parallel utility commands should not consume substantially more memory than equivalent non-parallel operations. This strategy differs from that of parallel query, where resource limits generally apply per worker process. Parallel utility commands treat the resource limit `maintenance_work_mem` as a limit to be applied to the entire utility command, regardless of the number of parallel worker processes. However, parallel utility commands may still consume substantially more CPU resources and I/O bandwidth.

`max_parallel_workers` (integer)

Sets the maximum number of workers that the system can support for parallel operations. The default value is 8. When increasing or decreasing this value, consider also adjusting

`max_parallel_maintenance_workers` and `max_parallel_workers_per_gather`. Also, note that a setting for this value which is higher than `max_worker_processes` will have no effect, since parallel workers are taken from the pool of worker processes established by that setting.

`backend_flush_after` (integer)

Whenever more than this amount of data has been written by a single backend, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of a checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 0, i.e., no forced writeback. (If `BLCKSZ` is not 8kB, the maximum value scales proportionally to it.)

`old_snapshot_threshold` (integer)

Sets the minimum amount of time that a query snapshot can be used without risk of a “snapshot too old” error occurring when using the snapshot. Data that has been dead for longer than this threshold is allowed to be vacuumed away. This can help prevent bloat in the face of snapshots which remain in use for a long time. To prevent incorrect results due to cleanup of data which would otherwise be visible to the snapshot, an error is generated when the snapshot is older than this threshold and the snapshot is used to read a page which has been modified since the snapshot was built.

If this value is specified without units, it is taken as minutes. A value of `-1` (the default) disables this feature, effectively setting the snapshot age limit to infinity. This parameter can only be set at server start.

Useful values for production work probably range from a small number of hours to a few days. Small values (such as `0` or `1min`) are only allowed because they may sometimes be useful for testing. While a setting as high as `60d` is allowed, please note that in many workloads extreme bloat or transaction ID wraparound may occur in much shorter time frames.

When this feature is enabled, freed space at the end of a relation cannot be released to the operating system, since that could remove information needed to detect the “snapshot too old” condition. All space allocated to a relation remains associated with that relation for reuse only within that relation unless explicitly freed (for example, with `VACUUM FULL`).

This setting does not attempt to guarantee that an error will be generated under any particular circumstances. In fact, if the correct results can be generated from (for example) a cursor which has materialized a result set, no error will be generated even if the underlying rows in the referenced table have been vacuumed away. Some tables cannot safely be vacuumed early, and so will not be affected by this setting, such as system catalogs. For such tables this setting will neither reduce bloat nor create a possibility of a “snapshot too old” error on scanning.

## 17.5. Write Ahead Log

For additional information on tuning these settings, see Section 27.4.

### 17.5.1. Settings

`wal_level` (enum)

`wal_level` determines how much information is written to the WAL. The default value is `replica`, which writes enough data to support WAL archiving and replication, including running read-only queries on a standby server. `minimal` removes all logging except the

information required to recover from a crash or immediate shutdown. Finally, `logical` adds information necessary to support logical decoding. Each level includes the information logged at all lower levels. This parameter can only be set at server start.

In `minimal` level, no information is logged for permanent relations for the remainder of a transaction that creates or rewrites them. This can make operations much faster (see Section 14.4.7). Operations that initiate this optimization include:

```
ALTER ... SET TABLESPACE
CLUSTER
CREATE TABLE
REFRESH MATERIALIZED VIEW (without CONCURRENTLY)
REINDEX
TRUNCATE
```

But `minimal` WAL does not contain enough information to reconstruct the data from a base backup and the WAL logs, so `replica` or higher must be used to enable WAL archiving (`archive_mode`) and streaming replication.

In `logical` level, the same information is logged as with `replica`, plus information needed to allow extracting logical change sets from the WAL. Using a level of `logical` will increase the WAL volume, particularly if many tables are configured for `REPLICA IDENTITY FULL` and many `UPDATE` and `DELETE` statements are executed.

This parameter also allowed the values `archive` and `hot_standby`. But they are mapped to `replica`.

#### `fsync` (boolean)

If this parameter is on, the LightDB server will try to make sure that updates are physically written to disk, by issuing `fsync()` system calls or various equivalent methods (see `wal_sync_method`). This ensures that the database cluster can recover to a consistent state after an operating system or hardware crash.

While turning off `fsync` is often a performance benefit, this can result in unrecoverable data corruption in the event of a power failure or system crash. Thus it is only advisable to turn off `fsync` if you can easily recreate your entire database from external data.

Examples of safe circumstances for turning off `fsync` include the initial loading of a new database cluster from a backup file, using a database cluster for processing a batch of data after which the database will be thrown away and recreated, or for a read-only database clone which gets recreated frequently and is not used for failover. High quality hardware alone is not a sufficient justification for turning off `fsync`.

For reliable recovery when changing `fsync` off to on, it is necessary to force all modified buffers in the kernel to durable storage. This can be done while the cluster is shutdown or while `fsync` is on by running `initdb --sync-only`, running `sync`, unmounting the file system, or rebooting the server.

In many situations, turning off `synchronous_commit` for noncritical transactions can provide much of the potential performance benefit of turning off `fsync`, without the attendant risks of data corruption.

`fsync` can only be set in the `lightdb.conf` file or on the server command line. If you turn this parameter off, also consider turning off `full_page_writes`.

#### `synchronous_commit` (enum)

Specifies how much WAL processing must complete before the database server returns a “success” indication to the client. Valid values are `remote_apply`, `on` (the default), `remote_write`, `local`, and `off`.



If `synchronous_standby_names` is empty, the only meaningful settings are `on` and `off`; `remote_apply`, `remote_write` and `local` all provide the same local synchronization level as `on`. The local behavior of all non-`off` modes is to wait for local flush of WAL to disk. In `off` mode, there is no waiting, so there can be a delay between when success is reported to the client and when the transaction is later guaranteed to be safe against a server crash. (The maximum delay is three times `wal_writer_delay`.) Unlike `fsync`, setting this parameter to `off` does not create any risk of database inconsistency: an operating system or database crash might result in some recent allegedly-committed transactions being lost, but the database state will be just the same as if those transactions had been aborted cleanly. So, turning `synchronous_commit` off can be a useful alternative when performance is more important than exact certainty about the durability of a transaction. For more discussion see Section 27.3.

If `synchronous_standby_names` is non-empty, `synchronous_commit` also controls whether transaction commits will wait for their WAL records to be processed on the standby server(s).

When set to `remote_apply`, commits will wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and applied it, so that it has become visible to queries on the standby(s), and also written to durable storage on the standbys. This will cause much larger commit delays than previous settings since it waits for WAL replay. When set to `on`, commits wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and flushed it to durable storage. This ensures the transaction will not be lost unless both the primary and all synchronous standbys suffer corruption of their database storage. When set to `remote_write`, commits will wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and written it to their file systems. This setting ensures data preservation if a standby instance of LightDB crashes, but not if the standby suffers an operating-system-level crash because the data has not necessarily reached durable storage on the standby. The setting `local` causes commits to wait for local flush to disk, but not for replication. This is usually not desirable when synchronous replication is in use, but is provided for completeness.

This parameter can be changed at any time; the behavior for any one transaction is determined by the setting in effect when it commits. It is therefore possible, and useful, to have some transactions commit synchronously and others asynchronously. For example, to make a single multistatement transaction commit asynchronously when the default is the opposite, issue `SET LOCAL synchronous_commit TO OFF` within the transaction.

Table 17.1 summarizes the capabilities of the `synchronous_commit` settings.

**Table 17.1. synchronous\_commit Modes**

<b>synchronous_commit setting</b>	<b>local durable commit</b>	<b>standby durable commit after PG crash</b>	<b>standby durable commit after OS crash</b>	<b>standby query consistency</b>
<code>remote_apply</code>	•	•	•	•
<code>on</code>	•	•	•	
<code>remote_write</code>	•	•		
<code>local</code>	•			
<code>off</code>				

`wal_sync_method` (enum)

Method used for forcing WAL updates out to disk. If `fsync` is off then this setting is irrelevant, since WAL file updates will not be forced out at all. Possible values are:

- `open_datasync` (write WAL files with `open( )` option `O_DSYNC`)
- `fdasync` (call `fdasync( )` at each commit)

- `fsync` (call `fsync()` at each commit)
- `fsync_writethrough` (call `fsync()` at each commit, forcing write-through of any disk write cache)
- `open_sync` (write WAL files with `open()` option `O_SYNC`)
- `pmem_drain` (write WAL files with PMDK API, requiring `put_lwal` on Intel Optane PMEM)

The `open_*` options also use `O_DIRECT` if available. Not all of these choices are available on all platforms. The default is the first method in the above list that is supported by the platform, except that `fdatasync` is the default on Linux and FreeBSD. The default is not necessarily ideal; it might be necessary to change this setting or other aspects of your system configuration in order to create a crash-safe configuration or achieve optimal performance. These aspects are discussed in Section 27.1. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`full_page_writes` (boolean)

When this parameter is on, the LightDB server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint. This is needed because a page write that is in process during an operating system crash might be only partially completed, leading to an on-disk page that contains a mix of old and new data. The row-level change data normally stored in WAL will not be enough to completely restore such a page during post-crash recovery. Storing the full page image guarantees that the page can be correctly restored, but at the price of increasing the amount of data that must be written to WAL. (Because WAL replay always starts from a checkpoint, it is sufficient to do this during the first change of each page after a checkpoint. Therefore, one way to reduce the cost of full-page writes is to increase the checkpoint interval parameters.)

Turning this parameter off speeds normal operation, but might lead to either unrecoverable data corruption, or silent data corruption, after a system failure. The risks are similar to turning off `fsync`, though smaller, and it should be turned off only based on the same circumstances recommended for that parameter.

Turning off this parameter does not affect use of WAL archiving for point-in-time recovery (PITR) (see Section 23.3).

This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `on`.

`wal_log_hints` (boolean)

When this parameter is on, the LightDB server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint, even for non-critical modifications of so-called hint bits.

If data checksums are enabled, hint bit updates are always WAL-logged and this setting is ignored. You can use this setting to test how much extra WAL-logging would occur if your database had data checksums enabled.

This parameter can only be set at server start. The default value is `off`.

`wal_compression` (boolean)

When this parameter is on, the LightDB server compresses a full page image written to WAL when `full_page_writes` is on or during a base backup. A compressed page image will be decompressed during WAL replay. The default value is `off`. Only superusers can change this setting.

Turning this parameter on can reduce the WAL volume without increasing the risk of unrecoverable data corruption, but at the cost of some extra CPU spent on the compression during WAL logging and on the decompression during WAL replay.

`wal_init_zero` (boolean)

If set to `on` (the default), this option causes new WAL files to be filled with zeroes. On some file systems, this ensures that space is allocated before we need to write WAL records. However, *Copy-On-Write* (COW) file systems may not benefit from this technique, so the option is given to skip the unnecessary work. If set to `off`, only the final byte is written when the file is created so that it has the expected size.

`wal_recycle` (boolean)

If set to `on` (the default), this option causes WAL files to be recycled by renaming them, avoiding the need to create new ones. On COW file systems, it may be faster to create new ones, so the option is given to disable this behavior.

`wal_buffers` (integer)

The amount of shared memory used for WAL data that has not yet been written to disk. The default setting of `-1` selects a size equal to 1/32nd (about 3%) of `shared_buffers`, but not less than 64kB nor more than the size of one WAL segment, typically 16MB. This value can be set manually if the automatic choice is too large or too small, but any positive value less than 32kB will be treated as 32kB. If this value is specified without units, it is taken as WAL blocks, that is `XLOG_BLCKSZ` bytes, typically 8kB. This parameter can only be set at server start.

The contents of the WAL buffers are written out to disk at every transaction commit, so extremely large values are unlikely to provide a significant benefit. However, setting this value to at least a few megabytes can improve write performance on a busy server where many clients are committing at once. The auto-tuning selected by the default setting of `-1` should give reasonable results in most cases.

`wal_writer_delay` (integer)

Specifies how often the WAL writer flushes WAL, in time terms. After flushing WAL the writer sleeps for the length of time given by `wal_writer_delay`, unless woken up sooner by an asynchronously committing transaction. If the last flush happened less than `wal_writer_delay` ago and less than `wal_writer_flush_after` worth of WAL has been produced since, then WAL is only written to the operating system, not flushed to disk. If this value is specified without units, it is taken as milliseconds. The default value is 200 milliseconds (200ms). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `wal_writer_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`wal_writer_flush_after` (integer)

Specifies how often the WAL writer flushes WAL, in volume terms. If the last flush happened less than `wal_writer_delay` ago and less than `wal_writer_flush_after` worth of WAL has been produced since, then WAL is only written to the operating system, not flushed to disk. If `wal_writer_flush_after` is set to 0 then WAL data is always flushed immediately. If this value is specified without units, it is taken as WAL blocks, that is `XLOG_BLCKSZ` bytes, typically 8kB. The default is 1MB. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`wal_skip_threshold` (integer)

When `wal_level` is `minimal` and a transaction commits after creating or rewriting a permanent relation, this setting determines how to persist the new data. If the data is smaller than

this setting, write it to the WAL log; otherwise, use an `fsync` of affected files. Depending on the properties of your storage, raising or lowering this value might help if such commits are slowing concurrent transactions. If this value is specified without units, it is taken as kilobytes. The default is two megabytes (2MB).

`commit_delay` (integer)

Setting `commit_delay` adds a time delay before a WAL flush is initiated. This can improve group commit throughput by allowing a larger number of transactions to commit via a single WAL flush, if system load is high enough that additional transactions become ready to commit within the given interval. However, it also increases latency by up to the `commit_delay` for each WAL flush. Because the delay is just wasted if no other transactions become ready to commit, a delay is only performed if at least `commit_siblings` other transactions are active when a flush is about to be initiated. Also, no delays are performed if `fsync` is disabled. If this value is specified without units, it is taken as microseconds. The default `commit_delay` is zero (no delay). Only superusers can change this setting.

The first process that becomes ready to flush waits for the configured interval, while subsequent processes wait only until the leader completes the flush operation.

`commit_siblings` (integer)

Minimum number of concurrent open transactions to require before performing the `commit_delay` delay. A larger value makes it more probable that at least one other transaction will become ready to commit during the delay interval. The default is five transactions.

## 17.5.2. Checkpoints

`checkpoint_timeout` (integer)

Maximum time between automatic WAL checkpoints. If this value is specified without units, it is taken as seconds. The valid range is between 30 seconds and one day. The default is five minutes (5min). Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`checkpoint_completion_target` (floating point)

Specifies the target of checkpoint completion, as a fraction of total time between checkpoints. The default is 0.5. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`checkpoint_flush_after` (integer)

Whenever more than this amount of data has been written while performing a checkpoint, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of the checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 256kB on Linux, 0 elsewhere. (If `BLCKSZ` is not 8kB, the default and maximum values scale proportionally to it.) This parameter can only be set in the `lightdb.conf` file or on the server command line.

`checkpoint_warning` (integer)

Write a message to the server log if checkpoints caused by the filling of WAL segment files happen closer together than this amount of time (which suggests that `max_wal_size` ought to

be raised). If this value is specified without units, it is taken as seconds. The default is 30 seconds (30s). Zero disables the warning. No warnings will be generated if `checkpoint_timeout` is less than `checkpoint_warning`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`max_wal_size` (integer)

Maximum size to let the WAL grow during automatic checkpoints. This is a soft limit; WAL size can exceed `max_wal_size` under special circumstances, such as heavy load, a failing `archive_command`, or a high `wal_keep_size` setting. If this value is specified without units, it is taken as megabytes. The default is 1 GB. Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`min_wal_size` (integer)

As long as WAL disk usage stays below this setting, old WAL files are always recycled for future use at a checkpoint, rather than removed. This can be used to ensure that enough WAL space is reserved to handle spikes in WAL usage, for example when running large batch jobs. If this value is specified without units, it is taken as megabytes. The default is 80 MB. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`enable_incremental_checkpoint` (boolean)

Whether or not enable incremental checkpoint. Default: off. Means full checkpoint.

`incre_checkpoint_timeout` (boolean)

Maximum time between automatic WAL incremental checkpoints. If this value is specified without units, it is taken as seconds. The valid range is between 60 and 3600 seconds. The default is 60 seconds. Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_pagewriter` (boolean)

Enables pagewriter statistics log. The default is off. This parameter can only be set at server start.

`enable_candidate_buf_usage_count` (boolean)

Whether or not consider buf usage count when checking free page list. The default is off. This parameter can only be set at server start.

`enable_double_write` (boolean)

Whether or not enable double write. The default is off. This parameter can only be set at server start.

`dw_file_num` (integer)

Double writer file count, must between 1 and 16. The default is 2. This parameter can only be set at server start.

`dw_file_size` (integer)

Double writer file size, must between 32MB and 256MB. The default is 256MB. This parameter can only be set at server start.

`pagewriter_thread_num` (integer)

Page writer process count. The default is 2. This parameter can only be set at server start.

`pagewriter_sleep` (integer)

Page writer sleep time. The default is 1min. This parameter can only be set at server start.

`max_io_capacity` (integer)

The `max_io_capacity` variable defines the number of I/O operations per second (IOPS) available to pagewriter background tasks, such as flushing pages from the shared buffer.

### 17.5.3. Archiving

`archive_mode` (enum)

When `archive_mode` is enabled, completed WAL segments are sent to archive storage by setting `archive_command`. In addition to `off`, to disable, there are two modes: `on`, and `always`. During normal operation, there is no difference between the two modes, but when set to `always` the WAL archiver is enabled also during archive recovery or standby mode. In `always` mode, all files restored from the archive or streamed with streaming replication will be archived (again). See Section 24.2.9 for details.

`archive_mode` and `archive_command` are separate variables so that `archive_command` can be changed without leaving archiving mode. This parameter can only be set at server start. `archive_mode` cannot be enabled when `wal_level` is set to `minimal`.

`archive_command` (string)

The local shell command to execute to archive a completed WAL file segment. Any `%p` in the string is replaced by the path name of the file to archive, and any `%f` is replaced by only the file name. (The path name is relative to the working directory of the server, i.e., the cluster's data directory.) Use `%%` to embed an actual `%` character in the command. It is important for the command to return a zero exit status only if it succeeds. For more information see Section 23.3.1.

This parameter can only be set in the `lightdb.conf` file or on the server command line. It is ignored unless `archive_mode` was enabled at server start. If `archive_command` is an empty string (the default) while `archive_mode` is enabled, WAL archiving is temporarily disabled, but the server continues to accumulate WAL segment files in the expectation that a command will soon be provided. Setting `archive_command` to a command that does nothing but return true, e.g., `/bin/true` (REM on Windows), effectively disables archiving, but also breaks the chain of WAL files needed for archive recovery, so it should only be used in unusual circumstances.

`archive_command` cannot contain the string `'xargs -i rm'` which is usually used for archive cleanup. If it contains, `lightdb` will start fail.

`lightdb_archive_dir` (string)

Configuring archive dir for archive file clean up, it must be same with `dir` used in `archive_command`. The archive directory can only be a local directory, not a directory on another host. It is not recommended to use it with backup. It may clean up the archive files required for backup. When used with backup, you can set two archive directories, one for high availability and one for backup.

This parameter can only be set at server start. It is ignored unless `archive_mode` and `archive_command` was enabled at server start. If `lightdb_archive_dir` is an empty string (the default) while `archive_mode` and `archive_command` is enabled, WAL archiv clean up is disabled.

If `lightdb_archive_retention_size` is not zero, `lightdb_archive_dir` must be set, otherwise, `lightdb` will start fail.

lightdb will check if the `archive_command` contains the `'$lightdb_archive_dir/%f'` substring when `lightdb_archive_dir` is setted and `archive_command` has `'cp %p'` substring. `$lightdb_archive_dir` means the string in `lightdb_archive_retention_size`

`lightdb_archive_retention_size` (integer)

Clean up archive file older than (checkpoint file - `lightdb_archive_retention_size`). It is recommended to configure more than 10(max 10000), depending on the disk capacity and the synchronization rate between primary and standby.

This parameter can only be set at server start. It is ignored unless `lightdb_archive_dir` was enabled at server start. If `lightdb_archive_retention_size` is zero (the default) while `lightdb_archive_dir` is enabled, WAL archive clean up is disabled.

`archive_timeout` (integer)

The `archive_command` is only invoked for completed WAL segments. Hence, if your server generates little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To limit how old unarchived data can be, you can set `archive_timeout` to force the server to switch to a new WAL segment file periodically. When this parameter is greater than zero, the server will switch to a new segment file whenever this amount of time has elapsed since the last segment file switch, and there has been any database activity, including a single checkpoint (checkpoints are skipped if there is no database activity). Note that archived files that are closed early due to a forced switch are still the same length as completely full files. Therefore, it is unwise to use a very short `archive_timeout` — it will bloat your archive storage. `archive_timeout` settings of a minute or so are usually reasonable. You should consider using streaming replication, instead of archiving, if you want data to be copied off the master server more quickly than that. If this value is specified without units, it is taken as seconds. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.5.4. Archive Recovery

This section describes the settings that apply only for the duration of the recovery. They must be reset for any subsequent recovery you wish to perform.

“Recovery” covers using the server as a standby or for executing a targeted recovery. Typically, standby mode would be used to provide high availability and/or read scalability, whereas a targeted recovery is used to recover from data loss.

To start the server in standby mode, create a file called `standby.signal` in the data directory. The server will enter recovery and will not stop recovery when the end of archived WAL is reached, but will keep trying to continue recovery by connecting to the sending server as specified by the `primary_conninfo` setting and/or by fetching new WAL segments using `restore_command`. For this mode, the parameters from this section and Section 17.6.3 are of interest. Parameters from Section 17.5.5 will also be applied but are typically not useful in this mode.

To start the server in targeted recovery mode, create a file called `recovery.signal` in the data directory. If both `standby.signal` and `recovery.signal` files are created, standby mode takes precedence. Targeted recovery mode ends when the archived WAL is fully replayed, or when `recovery_target` is reached. In this mode, the parameters from both this section and Section 17.5.5 will be used.

`restore_command` (string)

The local shell command to execute to retrieve an archived segment of the WAL file series. This parameter is required for archive recovery, but optional for streaming replication. Any `%f` in the string is replaced by the name of the file to retrieve from the archive, and any `%p` is replaced by the copy destination path name on the server. (The path name is relative to the current

working directory, i.e., the cluster's data directory.) Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be kept to allow a restore to be restartable, so this information can be used to truncate the archive to just the minimum required to support restarting from the current restore. `%r` is typically only used by warm-standby configurations (see Section 24.2). Write `%%` to embed an actual `%` character.

It is important for the command to return a zero exit status only if it succeeds. The command *will* be asked for file names that are not present in the archive; it must return nonzero when so asked. Examples:

```
restore_command = 'cp /mnt/server/archivedir/%f "%p" '  
restore_command = 'copy "C:\\server\\archivedir\\%f" "%p" ' #  
Windows
```

An exception is that if the command was terminated by a signal (other than SIGTERM, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

This parameter can only be set at server start.

`archive_cleanup_command`(string)

This optional parameter specifies a shell command that will be executed at every restartpoint. The purpose of `archive_cleanup_command` is to provide a mechanism for cleaning up old archived WAL files that are no longer needed by the standby server. Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be *kept* to allow a restore to be restartable, and so all files earlier than `%r` may be safely removed. This information can be used to truncate the archive to just the minimum required to support restart from the current restore. The `lt_archivecleanup` module is often used in `archive_cleanup_command` for single-standby configurations, for example:

```
archive_cleanup_command = 'lt_archivecleanup /mnt/server/  
archivedir %r'
```

Note however that if multiple standby servers are restoring from the same archive directory, you will need to ensure that you do not delete WAL files until they are no longer needed by any of the servers. `archive_cleanup_command` would typically be used in a warm-standby configuration (see Section 24.2). Write `%%` to embed an actual `%` character in the command.

If the command returns a nonzero exit status then a warning log message will be written. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), a fatal error will be raised.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`recovery_end_command`(string)

This parameter specifies a shell command that will be executed once only at the end of recovery. This parameter is optional. The purpose of the `recovery_end_command` is to provide a mechanism for cleanup following replication or recovery. Any `%r` is replaced by the name of the file containing the last valid restart point, like in `archive_cleanup_command`.

If the command returns a nonzero exit status then a warning log message will be written and the database will proceed to start up anyway. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), the database will not proceed with startup.

This parameter can only be set in the `lightdb.conf` file or on the server command line.



## 17.5.5. Recovery Target

By default, recovery will recover to the end of the WAL log. The following parameters can be used to specify an earlier stopping point. At most one of `recovery_target`, `recovery_target_lsn`, `recovery_target_name`, `recovery_target_time`, or `recovery_target_xid` can be used; if more than one of these is specified in the configuration file, an error will be raised. These parameters can only be set at server start.

```
recovery_target = 'immediate'
```

This parameter specifies that recovery should end as soon as a consistent state is reached, i.e., as early as possible. When restoring from an online backup, this means the point where taking the backup ended.

Technically, this is a string parameter, but `'immediate'` is currently the only allowed value.

```
recovery_target_name (string)
```

This parameter specifies the named restore point (created with `pg_create_restore_point()`) to which recovery will proceed.

```
recovery_target_time (timestamp)
```

This parameter specifies the time stamp up to which recovery will proceed. The precise stopping point is also influenced by `recovery_target_inclusive`.

The value of this parameter is a time stamp in the same format accepted by the `timestamp with time zone` data type, except that you cannot use a time zone abbreviation (unless the `timezone_abbreviations` variable has been set earlier in the configuration file). Preferred style is to use a numeric offset from UTC, or you can write a full time zone name, e.g., `Europe/Helsinki` not `EEST`.

```
recovery_target_xid (string)
```

This parameter specifies the transaction ID up to which recovery will proceed. Keep in mind that while transaction IDs are assigned sequentially at transaction start, transactions can complete in a different numeric order. The transactions that will be recovered are those that committed before (and optionally including) the specified one. The precise stopping point is also influenced by `recovery_target_inclusive`.

```
recovery_target_lsn (pg_lsn)
```

This parameter specifies the LSN of the write-ahead log location up to which recovery will proceed. The precise stopping point is also influenced by `recovery_target_inclusive`. This parameter is parsed using the system data type `pg_lsn`.

The following options further specify the recovery target, and affect what happens when the target is reached:

```
recovery_target_inclusive (boolean)
```

Specifies whether to stop just after the specified recovery target (`on`), or just before the recovery target (`off`). Applies when `recovery_target_lsn`, `recovery_target_time`, or `recovery_target_xid` is specified. This setting controls whether transactions having exactly the target WAL location (LSN), commit time, or transaction ID, respectively, will be included in the recovery. Default is `on`.

```
recovery_target_timeline (string)
```

Specifies recovering into a particular timeline. The value can be a numeric timeline ID or a special value. The value `current` recovers along the same timeline that was current when the base

backup was taken. The value `latest` recovers to the latest timeline found in the archive, which is useful in a standby server. `latest` is the default.

You usually only need to set this parameter in complex re-recovery situations, where you need to return to a state that itself was reached after a point-in-time recovery. See Section 23.3.5 for discussion.

`recovery_target_action` (enum)

Specifies what action the server should take once the recovery target is reached. The default is `pause`, which means recovery will be paused. `promote` means the recovery process will finish and the server will start to accept connections. Finally `shutdown` will stop the server after reaching the recovery target.

The intended use of the `pause` setting is to allow queries to be executed against the database to check if this recovery target is the most desirable point for recovery. The paused state can be resumed by using `pg_wal_replay_resume()` (see Table 9.88), which then causes recovery to end. If this recovery target is not the desired stopping point, then shut down the server, change the recovery target settings to a later target and restart to continue recovery.

The `shutdown` setting is useful to have the instance ready at the exact replay point desired. The instance will still be able to replay more WAL records (and in fact will have to replay WAL records since the last checkpoint next time it is started).

Note that because `recovery.signal` will not be removed when `recovery_target_action` is set to `shutdown`, any subsequent start will end with immediate shutdown unless the configuration is changed or the `recovery.signal` file is removed manually.

This setting has no effect if no recovery target is set. If `hot_standby` is not enabled, a setting of `pause` will act the same as `shutdown`. If the recovery target is reached while a promotion is ongoing, a setting of `pause` will act the same as `promote`.

In any case, if a recovery target is configured but the archive recovery ends before the target is reached, the server will shut down with a fatal error.

## 17.6. Replication

These settings control the behavior of the built-in *streaming replication* feature (see Section 24.2.5). Servers will be either a master or a standby server. Masters can send data, while standbys are always receivers of replicated data. When cascading replication (see Section 24.2.7) is used, standby servers can also be senders, as well as receivers. Parameters are mainly for sending and standby servers, though some parameters have meaning only on the master server. Settings may vary across the cluster without problems if that is required.

### 17.6.1. Sending Servers

These parameters can be set on any server that is to send replication data to one or more standby servers. The master is always a sending server, so these parameters must always be set on the master. The role and meaning of these parameters does not change after a standby becomes the master.

`max_wal_senders` (integer)

Specifies the maximum number of concurrent connections from standby servers or streaming base backup clients (i.e., the maximum number of simultaneously running WAL sender processes). The default is 10. The value 0 means replication is disabled. Abrupt disconnection of a streaming client might leave an orphaned connection slot behind until a timeout is reached, so this parameter should be set slightly higher than the maximum number of expected clients so disconnected clients can immediately reconnect. This parameter can only be set at server start. Also, `wal_level` must be set to `replica` or higher to allow connections from standby servers.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`max_replication_slots` (integer)

Specifies the maximum number of replication slots (see Section 24.2.6) that the server can support. The default is 10. This parameter can only be set at server start. Setting it to a lower value than the number of currently existing replication slots will prevent the server from starting. Also, `wal_level` must be set to `replica` or higher to allow replication slots to be used.

On the subscriber side, specifies how many replication origins (see Chapter 46) can be tracked simultaneously, effectively limiting how many logical replication subscriptions can be created on the server. Setting it a lower value than the current number of tracked replication origins (reflected in `pg_replication_origin_status`, not `pg_replication_origin`) will prevent the server from starting.

`wal_keep_size` (integer)

Specifies the minimum size of past log file segments kept in the `lt_wal` directory, in case a standby server needs to fetch them for streaming replication. If a standby server connected to the sending server falls behind by more than `wal_keep_size` megabytes, the sending server might remove a WAL segment still needed by the standby, in which case the replication connection will be terminated. Downstream connections will also eventually fail as a result. (However, the standby server can recover by fetching the segment from archive, if WAL archiving is in use.)

This sets only the minimum size of segments retained in `lt_wal`; the system might need to retain more segments for WAL archival or to recover from a checkpoint. If `wal_keep_size` is zero (the default), the system doesn't keep any extra segments for standby purposes, so the number of old WAL segments available to standby servers is a function of the location of the previous checkpoint and status of WAL archiving. If this value is specified without units, it is taken as megabytes. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`max_slot_wal_keep_size` (integer)

Specify the maximum size of WAL files that replication slots are allowed to retain in the `lt_wal` directory at checkpoint time. If `max_slot_wal_keep_size` is -1 (the default), replication slots may retain an unlimited amount of WAL files. Otherwise, if `restart_lsn` of a replication slot falls behind the current LSN by more than the given size, the standby using the slot may no longer be able to continue replication due to removal of required WAL files. You can see the WAL availability of replication slots in `pg_replication_slots`. If this value is specified without units, it is taken as megabytes. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`wal_sender_timeout` (integer)

Terminate replication connections that are inactive for longer than this amount of time. This is useful for the sending server to detect a standby crash or network outage. If this value is specified without units, it is taken as milliseconds. The default value is 60 seconds. A value of zero disables the timeout mechanism.

With a cluster distributed across multiple geographic locations, using different values per location brings more flexibility in the cluster management. A smaller value is useful for faster failure detection with a standby having a low-latency network connection, and a larger value helps in judging better the health of a standby if located on a remote location, with a high-latency network connection.

`track_commit_timestamp` (boolean)

Record commit time of transactions. This parameter can only be set in `lightdb.conf` file or on the server command line. The default value is `off`.

## 17.6.2. Master Server

These parameters can be set on the master/primary server that is to send replication data to one or more standby servers. Note that in addition to these parameters, `wal_level` must be set appropriately on the master server, and optionally WAL archiving can be enabled as well (see Section 17.5.3). The values of these parameters on standby servers are irrelevant, although you may wish to set them there in preparation for the possibility of a standby becoming the master.

`synchronous_standby_names` (string)

Specifies a list of standby servers that can support *synchronous replication*, as described in Section 24.2.8. There will be one or more active synchronous standbys; transactions waiting for commit will be allowed to proceed after these standby servers confirm receipt of their data. The synchronous standbys will be those whose names appear in this list, and that are both currently connected and streaming data in real-time (as shown by a state of `streaming` in the `pg_stat_replication` view). Specifying more than one synchronous standby can allow for very high availability and protection against data loss.

The name of a standby server for this purpose is the `application_name` setting of the standby, as set in the standby's connection information. In case of a physical replication standby, this should be set in the `primary_conninfo` setting; the default is the setting of `cluster_name` if set, else `walreceiver`. For logical replication, this can be set in the connection information of the subscription, and it defaults to the subscription name. For other replication stream consumers, consult their documentation.

This parameter specifies a list of standby servers using either of the following syntaxes:

```
[FIRST] num_sync ( standby_name [ , ... ] )
ANY num_sync ( standby_name [ , ... ] )
standby_name [ , ... ]
```

where `num_sync` is the number of synchronous standbys that transactions need to wait for replies from, and `standby_name` is the name of a standby server. `FIRST` and `ANY` specify the method to choose synchronous standbys from the listed servers.

The keyword `FIRST`, coupled with `num_sync`, specifies a priority-based synchronous replication and makes transaction commits wait until their WAL records are replicated to `num_sync` synchronous standbys chosen based on their priorities. For example, a setting of `FIRST 3 (s1, s2, s3, s4)` will cause each commit to wait for replies from three higher-priority standbys chosen from standby servers `s1`, `s2`, `s3` and `s4`. The standbys whose names appear earlier in the list are given higher priority and will be considered as synchronous. Other standby servers appearing later in this list represent potential synchronous standbys. If any of the current synchronous standbys disconnects for whatever reason, it will be replaced immediately with the next-highest-priority standby. The keyword `FIRST` is optional.

The keyword `ANY`, coupled with `num_sync`, specifies a quorum-based synchronous replication and makes transaction commits wait until their WAL records are replicated to *at least* `num_sync` listed standbys. For example, a setting of `ANY 3 (s1, s2, s3, s4)` will cause each commit to proceed as soon as at least any three standbys of `s1`, `s2`, `s3` and `s4` reply.

`FIRST` and `ANY` are case-insensitive. If these keywords are used as the name of a standby server, its `standby_name` must be double-quoted.

The third syntax was used before LightDB version 9.6 and is still supported. It's the same as the first syntax with `FIRST` and `num_sync` equal to 1. For example, `FIRST 1 (s1, s2)` and `s1, s2` have the same meaning: either `s1` or `s2` is chosen as a synchronous standby.

The special entry `*` matches any standby name.

There is no mechanism to enforce uniqueness of standby names. In case of duplicates one of the matching standbys will be considered as higher priority, though exactly which one is indeterminate.

### Note

Each *standby\_name* should have the form of a valid SQL identifier, unless it is *\**. You can use double-quoting if necessary. But note that *standby\_names* are compared to standby application names case-insensitively, whether double-quoted or not.

If no synchronous standby names are specified here, then synchronous replication is not enabled and transaction commits will not wait for replication. This is the default configuration. Even when synchronous replication is enabled, individual transactions can be configured not to wait for replication by setting the `synchronous_commit` parameter to `local` or `off`.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`vacuum_defer_cleanup_age` (integer)

Specifies the number of transactions by which `VACUUM` and `HOT` updates will defer cleanup of dead row versions. The default is zero transactions, meaning that dead row versions can be removed as soon as possible, that is, as soon as they are no longer visible to any open transaction. You may wish to set this to a non-zero value on a primary server that is supporting hot standby servers, as described in Section 24.5. This allows more time for queries on the standby to complete without incurring conflicts due to early cleanup of rows. However, since the value is measured in terms of number of write transactions occurring on the primary server, it is difficult to predict just how much additional grace time will be made available to standby queries. This parameter can only be set in the `lightdb.conf` file or on the server command line.

You should also consider setting `hot_standby_feedback` on standby server(s) as an alternative to using this parameter.

This does not prevent cleanup of dead rows which have reached the age specified by `old_snapshot_threshold`.

## 17.6.3. Standby Servers

These settings control the behavior of a standby server that is to receive replication data. Their values on the master server are irrelevant.

`primary_conninfo` (string)

Specifies a connection string to be used for the standby server to connect with a sending server. This string is in the format described in Section 32.1.1. If any option is unspecified in this string, then the corresponding environment variable (see Section 32.14) is checked. If the environment variable is not set either, then defaults are used.

The connection string should specify the host name (or address) of the sending server, as well as the port number if it is not the same as the standby server's default. Also specify a user name corresponding to a suitably-privileged role on the sending server (see Section 24.2.5.1). A password needs to be provided too, if the sender demands password authentication. It can be provided in the `primary_conninfo` string, or in a separate `~/.pgpass` file on the standby server (use `replication` as the database name). Do not specify a database name in the `primary_conninfo` string.

This parameter can only be set in the `lightdb.conf` file or on the server command line. If this parameter is changed while the WAL receiver process is running, that process is signaled to shut

down and expected to restart with the new setting (except if `primary_conninfo` is an empty string). This setting has no effect if the server is not in standby mode.

`primary_slot_name` (string)

Optionally specifies an existing replication slot to be used when connecting to the sending server via streaming replication to control resource removal on the upstream node (see Section 24.2.6). This parameter can only be set in the `lightdb.conf` file or on the server command line. If this parameter is changed while the WAL receiver process is running, that process is signaled to shut down and expected to restart with the new setting. This setting has no effect if `primary_conninfo` is not set or the server is not in standby mode.

`promote_trigger_file` (string)

Specifies a trigger file whose presence ends recovery in the standby. Even if this value is not set, you can still promote the standby using `lt_ctl promote` or calling `pg_promote()`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`hot_standby` (boolean)

Specifies whether or not you can connect and run queries during recovery, as described in Section 24.5. The default value is `on`. This parameter can only be set at server start. It only has effect during archive recovery or in standby mode.

`max_standby_archive_delay` (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 24.5.2. `max_standby_archive_delay` applies when WAL data is being read from WAL archive (and is therefore not current). If this value is specified without units, it is taken as milliseconds. The default is 30 seconds. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the `lightdb.conf` file or on the server command line.

Note that `max_standby_archive_delay` is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply any one WAL segment's data. Thus, if one query has resulted in significant delay earlier in the WAL segment, subsequent conflicting queries will have much less grace time.

`max_standby_streaming_delay` (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 24.5.2. `max_standby_streaming_delay` applies when WAL data is being received via streaming replication. If this value is specified without units, it is taken as milliseconds. The default is 30 seconds. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the `lightdb.conf` file or on the server command line.

Note that `max_standby_streaming_delay` is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply WAL data once it has been received from the primary server. Thus, if one query has resulted in significant delay, subsequent conflicting queries will have much less grace time until the standby server has caught up again.

`wal_receiver_create_temp_slot` (boolean)

Specifies whether the WAL receiver process should create a temporary replication slot on the remote instance when no permanent replication slot to use has been configured (using `primary_slot_name`). The default is `off`. This parameter can only be set in the `lightdb.conf`

file or on the server command line. If this parameter is changed while the WAL receiver process is running, that process is signaled to shut down and expected to restart with the new setting.

`wal_receiver_status_interval` (integer)

Specifies the minimum frequency for the WAL receiver process on the standby to send information about replication progress to the primary or upstream standby, where it can be seen using the `pg_stat_replication` view. The standby will report the last write-ahead log location it has written, the last position it has flushed to disk, and the last position it has applied. This parameter's value is the maximum amount of time between reports. Updates are sent each time the write or flush positions change, or at least as often as specified by this parameter. Thus, the apply position may lag slightly behind the true position. If this value is specified without units, it is taken as seconds. The default value is 10 seconds. Setting this parameter to zero disables status updates completely. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`hot_standby_feedback` (boolean)

Specifies whether or not a hot standby will send feedback to the primary or upstream standby about queries currently executing on the standby. This parameter can be used to eliminate query cancels caused by cleanup records, but can cause database bloat on the primary for some workloads. Feedback messages will not be sent more frequently than once per `wal_receiver_status_interval`. The default value is `off`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

If cascaded replication is in use the feedback is passed upstream until it eventually reaches the primary. Standbys make no other use of feedback they receive other than to pass upstream.

This setting does not override the behavior of `old_snapshot_threshold` on the primary; a snapshot on the standby which exceeds the primary's age threshold can become invalid, resulting in cancellation of transactions on the standby. This is because `old_snapshot_threshold` is intended to provide an absolute limit on the time which dead rows can contribute to bloat, which would otherwise be violated because of the configuration of a standby.

`wal_receiver_timeout` (integer)

Terminate replication connections that are inactive for longer than this amount of time. This is useful for the receiving standby server to detect a primary node crash or network outage. If this value is specified without units, it is taken as milliseconds. The default value is 60 seconds. A value of zero disables the timeout mechanism. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`wal_retrieve_retry_interval` (integer)

Specifies how long the standby server should wait when WAL data is not available from any sources (streaming replication, local `lt_wal` or WAL archive) before trying again to retrieve WAL data. If this value is specified without units, it is taken as milliseconds. The default value is 5 seconds. This parameter can only be set in the `lightdb.conf` file or on the server command line.

This parameter is useful in configurations where a node in recovery needs to control the amount of time to wait for new WAL data to be available. For example, in archive recovery, it is possible to make the recovery more responsive in the detection of a new WAL log file by reducing the value of this parameter. On a system with low WAL activity, increasing it reduces the amount of requests necessary to access WAL archives, something useful for example in cloud environments where the amount of times an infrastructure is accessed is taken into account.

`recovery_min_apply_delay` (integer)

By default, a standby server restores WAL records from the sending server as soon as possible. It may be useful to have a time-delayed copy of the data, offering opportunities to correct data loss

errors. This parameter allows you to delay recovery by a specified amount of time. For example, if you set this parameter to 5min, the standby will replay each transaction commit only when the system time on the standby is at least five minutes past the commit time reported by the master. If this value is specified without units, it is taken as milliseconds. The default is zero, adding no delay.

It is possible that the replication delay between servers exceeds the value of this parameter, in which case no delay is added. Note that the delay is calculated between the WAL time stamp as written on master and the current time on the standby. Delays in transfer because of network lag or cascading replication configurations may reduce the actual wait time significantly. If the system clocks on master and standby are not synchronized, this may lead to recovery applying records earlier than expected; but that is not a major issue because useful settings of this parameter are much larger than typical time deviations between servers.

The delay occurs only on WAL records for transaction commits. Other records are replayed as quickly as possible, which is not a problem because MVCC visibility rules ensure their effects are not visible until the corresponding commit record is applied.

The delay occurs once the database in recovery has reached a consistent state, until the standby is promoted or triggered. After that the standby will end recovery without further waiting.

This parameter is intended for use with streaming replication deployments; however, if the parameter is specified it will be honored in all cases except crash recovery. `hot_standby_feedback` will be delayed by use of this feature which could lead to bloat on the master; use both together with care.

### Warning

Synchronous replication is affected by this setting when `synchronous_commit` is set to `remote_apply`; every COMMIT will need to wait to be applied.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.6.4. Subscribers

These settings control the behavior of a logical replication subscriber. Their values on the publisher are irrelevant.

Note that `wal_receiver_timeout`, `wal_receiver_status_interval` and `wal_retrieve_retry_interval` configuration parameters affect the logical replication workers as well.

`max_logical_replication_workers` (int)

Specifies maximum number of logical replication workers. This includes both apply workers and table synchronization workers.

Logical replication workers are taken from the pool defined by `max_worker_processes`.

The default value is 4. This parameter can only be set at server start.

`max_sync_workers_per_subscription` (integer)

Maximum number of synchronization workers per subscription. This parameter controls the amount of parallelism of the initial data copy during the subscription initialization or when new tables are added.

Currently, there can be only one synchronization worker per table.



The synchronization workers are taken from the pool defined by `max_logical_replication_workers`.

The default value is 2. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.7. Query Planning

### 17.7.1. Planner Method Configuration

These configuration parameters provide a crude method of influencing the query plans chosen by the query optimizer. If the default plan chosen by the optimizer for a particular query is not optimal, a *temporary* solution is to use one of these configuration parameters to force the optimizer to choose a different plan. Better ways to improve the quality of the plans chosen by the optimizer include adjusting the planner cost constants (see Section 17.7.2), running `ANALYZE` manually, increasing the value of the `default_statistics_target` configuration parameter, and increasing the amount of statistics collected for specific columns using `ALTER TABLE SET STATISTICS`.

`enable_bitmapscan` (boolean)

Enables or disables the query planner's use of bitmap-scan plan types. The default is on.

`enable_gathermerge` (boolean)

Enables or disables the query planner's use of gather merge plan types. The default is on.

`enable_hashagg` (boolean)

Enables or disables the query planner's use of hashed aggregation plan types. The default is on.

`lightdb_enable_sorted_group` (boolean)

Enables or disables the query planner's use of sorted aggregation or group(sorted) plan types. The default is on.

`enable_hashjoin` (boolean)

Enables or disables the query planner's use of hash-join plan types. The default is on.

`enable_incremental_sort` (boolean)

Enables or disables the query planner's use of incremental sort steps. The default is on.

`enable_indexscan` (boolean)

Enables or disables the query planner's use of index-scan plan types. The default is on.

`enable_indexonlyscan` (boolean)

Enables or disables the query planner's use of index-only-scan plan types (see Section 11.9). The default is on.

`enable_material` (boolean)

Enables or disables the query planner's use of materialization. It is impossible to suppress materialization entirely, but turning this variable off prevents the planner from inserting materialize nodes except in cases where it is required for correctness. The default is on.

`enable_mergejoin` (boolean)

Enables or disables the query planner's use of merge-join plan types. The default is on.

`enable_nestloop` (boolean)

Enables or disables the query planner's use of nested-loop join plans. It is impossible to suppress nested-loop joins entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_parallel_append` (boolean)

Enables or disables the query planner's use of parallel-aware append plan types. The default is `on`.

`enable_parallel_hash` (boolean)

Enables or disables the query planner's use of hash-join plan types with parallel hash. Has no effect if hash-join plans are not also enabled. The default is `on`.

`enable_partition_pruning` (boolean)

Enables or disables the query planner's ability to eliminate a partitioned table's partitions from query plans. This also controls the planner's ability to generate query plans which allow the query executor to remove (ignore) partitions during query execution. The default is `on`. See Section 5.11.4 for details.

`enable_partitionwise_join` (boolean)

Enables or disables the query planner's use of partitionwise join, which allows a join between partitioned tables to be performed by joining the matching partitions. Partitionwise join currently applies only when the join conditions include all the partition keys, which must be of the same data type and have one-to-one matching sets of child partitions. Because partitionwise join planning can use significantly more CPU time and memory during planning, the default is `off`.

`enable_partitionwise_aggregate` (boolean)

Enables or disables the query planner's use of partitionwise grouping or aggregation, which allows grouping or aggregation on a partitioned tables performed separately for each partition. If the `GROUP BY` clause does not include the partition keys, only partial aggregation can be performed on a per-partition basis, and finalization must be performed later. Because partitionwise grouping or aggregation can use significantly more CPU time and memory during planning, the default is `off`.

`enable_seqscan` (boolean)

Enables or disables the query planner's use of sequential scan plan types. It is impossible to suppress sequential scans entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_sort` (boolean)

Enables or disables the query planner's use of explicit sort steps. It is impossible to suppress explicit sorts entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_tidscan` (boolean)

Enables or disables the query planner's use of TID scan plan types. The default is `on`.

## 17.7.2. Planner Cost Constants

The *cost* variables described in this section are measured on an arbitrary scale. Only their relative values matter, hence scaling them all up or down by the same factor will result in no change in the

planner's choices. By default, these cost variables are based on the cost of sequential page fetches; that is, `seq_page_cost` is conventionally set to 1.0 and the other cost variables are set with reference to that. But you can use a different scale if you prefer, such as actual execution times in milliseconds on a particular machine.

### Note

Unfortunately, there is no well-defined method for determining ideal values for the cost variables. They are best treated as averages over the entire mix of queries that a particular installation will receive. This means that changing them on the basis of just a few experiments is very risky.

`seq_page_cost` (floating point)

Sets the planner's estimate of the cost of a disk page fetch that is part of a series of sequential fetches. The default is 1.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

`random_page_cost` (floating point)

Sets the planner's estimate of the cost of a non-sequentially-fetched disk page. The default is 4.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

Reducing this value relative to `seq_page_cost` will cause the system to prefer index scans; raising it will make index scans look relatively more expensive. You can raise or lower both values together to change the importance of disk I/O costs relative to CPU costs, which are described by the following parameters.

Random access to mechanical disk storage is normally much more expensive than four times sequential access. However, a lower default is used (4.0) because the majority of random accesses to disk, such as indexed reads, are assumed to be in cache. The default value can be thought of as modeling random access as 40 times slower than sequential, while expecting 90% of random reads to be cached.

If you believe a 90% cache rate is an incorrect assumption for your workload, you can increase `random_page_cost` to better reflect the true cost of random storage reads. Correspondingly, if your data is likely to be completely in cache, such as when the database is smaller than the total server memory, decreasing `random_page_cost` can be appropriate. Storage that has a low random read cost relative to sequential, e.g., solid-state drives, might also be better modeled with a lower value for `random_page_cost`, e.g., 1.1.

### Tip

Although the system will let you set `random_page_cost` to less than `seq_page_cost`, it is not physically sensible to do so. However, setting them equal makes sense if the database is entirely cached in RAM, since in that case there is no penalty for touching pages out of sequence. Also, in a heavily-cached database you should lower both values relative to the CPU parameters, since the cost of fetching a page already in RAM is much smaller than it would normally be.

`cpu_tuple_cost` (floating point)

Sets the planner's estimate of the cost of processing each row during a query. The default is 0.01.

`cpu_index_tuple_cost` (floating point)

Sets the planner's estimate of the cost of processing each index entry during an index scan. The default is 0.005.

`cpu_operator_cost` (floating point)

Sets the planner's estimate of the cost of processing each operator or function executed during a query. The default is 0.0025.

`parallel_setup_cost` (floating point)

Sets the planner's estimate of the cost of launching parallel worker processes. The default is 1000.

`parallel_tuple_cost` (floating point)

Sets the planner's estimate of the cost of transferring one tuple from a parallel worker process to another process. The default is 0.1.

`min_parallel_table_scan_size` (integer)

Sets the minimum amount of table data that must be scanned in order for a parallel scan to be considered. For a parallel sequential scan, the amount of table data scanned is always equal to the size of the table, but when indexes are used the amount of table data scanned will normally be less. If this value is specified without units, it is taken as blocks, that is BLCKSZ bytes, typically 8kB. The default is 8 megabytes (8MB).

`min_parallel_index_scan_size` (integer)

Sets the minimum amount of index data that must be scanned in order for a parallel scan to be considered. Note that a parallel index scan typically won't touch the entire index; it is the number of pages which the planner believes will actually be touched by the scan which is relevant. This parameter is also used to decide whether a particular index can participate in a parallel vacuum. See VACUUM. If this value is specified without units, it is taken as blocks, that is BLCKSZ bytes, typically 8kB. The default is 512 kilobytes (512kB).

`effective_cache_size` (integer)

Sets the planner's assumption about the effective size of the disk cache that is available to a single query. This is factored into estimates of the cost of using an index; a higher value makes it more likely index scans will be used, a lower value makes it more likely sequential scans will be used. When setting this parameter you should consider both LightDB's shared buffers and the portion of the kernel's disk cache that will be used for LightDB data files, though some data might exist in both places. Also, take into account the expected number of concurrent queries on different tables, since they will have to share the available space. This parameter has no effect on the size of shared memory allocated by LightDB, nor does it reserve kernel disk cache; it is used only for estimation purposes. The system also does not assume data remains in the disk cache between queries. If this value is specified without units, it is taken as blocks, that is BLCKSZ bytes, typically 8kB. The default is 4 gigabytes (4GB). (If BLCKSZ is not 8kB, the default value scales proportionally to it.)

`jit_above_cost` (floating point)

Sets the query cost above which JIT compilation is activated, if enabled (see Chapter 29). Performing JIT costs planning time but can accelerate query execution. Setting this to -1 disables JIT compilation. The default is 100000.

`jit_inline_above_cost` (floating point)

Sets the query cost above which JIT compilation attempts to inline functions and operators. Inlining adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`. Setting this to -1 disables inlining. The default is 500000.

`jit_optimize_above_cost` (floating point)

Sets the query cost above which JIT compilation applies expensive optimizations. Such optimization adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`, and it is unlikely to be beneficial to set it to more than `jit_inline_above_cost`. Setting this to `-1` disables expensive optimizations. The default is `500000`.

### 17.7.3. Genetic Query Optimizer

The genetic query optimizer (GEO) is an algorithm that does query planning using heuristic searching. This reduces planning time for complex queries (those joining many relations), at the cost of producing plans that are sometimes inferior to those found by the normal exhaustive-search algorithm. For more information see Chapter 56.

`geqo` (boolean)

Enables or disables genetic query optimization. This is on by default. It is usually best not to turn it off in production; the `geqo_threshold` variable provides more granular control of GEO.

`geqo_threshold` (integer)

Use genetic query optimization to plan queries with at least this many FROM items involved. (Note that a `FULL OUTER JOIN` construct counts as only one FROM item.) The default is `12`. For simpler queries it is usually best to use the regular, exhaustive-search planner, but for queries with many tables the exhaustive search takes too long, often longer than the penalty of executing a suboptimal plan. Thus, a threshold on the size of the query is a convenient way to manage use of GEO.

`geqo_effort` (integer)

Controls the trade-off between planning time and query plan quality in GEO. This variable must be an integer in the range from `1` to `10`. The default value is `five`. Larger values increase the time spent doing query planning, but also increase the likelihood that an efficient query plan will be chosen.

`geqo_effort` doesn't actually do anything directly; it is only used to compute the default values for the other variables that influence GEO behavior (described below). If you prefer, you can set the other parameters by hand instead.

`geqo_pool_size` (integer)

Controls the pool size used by GEO, that is the number of individuals in the genetic population. It must be at least two, and useful values are typically `100` to `1000`. If it is set to zero (the default setting) then a suitable value is chosen based on `geqo_effort` and the number of tables in the query.

`geqo_generations` (integer)

Controls the number of generations used by GEO, that is the number of iterations of the algorithm. It must be at least one, and useful values are in the same range as the pool size. If it is set to zero (the default setting) then a suitable value is chosen based on `geqo_pool_size`.

`geqo_selection_bias` (floating point)

Controls the selection bias used by GEO. The selection bias is the selective pressure within the population. Values can be from `1.50` to `2.00`; the latter is the default.

`geqo_seed` (floating point)

Controls the initial value of the random number generator used by GEO to select random paths through the join order search space. The value can range from zero (the default) to one. Varying

the value changes the set of join paths explored, and may result in a better or worse best path being found.

## 17.7.4. Other Planner Options

`default_statistics_target` (integer)

Sets the default statistics target for table columns without a column-specific target set via `ALTER TABLE SET STATISTICS`. Larger values increase the time needed to do `ANALYZE`, but might improve the quality of the planner's estimates. The default is 100. For more information on the use of statistics by the LightDB query planner, refer to Section 14.2.

`lightdb_enable_indexautoanalyze` (integer)

Enables or disables automatic collection of statistics immediately after index creation. This is on by default.

`constraint_exclusion` (enum)

Controls the query planner's use of table constraints to optimize queries. The allowed values of `constraint_exclusion` are `on` (examine constraints for all tables), `off` (never examine constraints), and `partition` (examine constraints only for inheritance child tables and `UNION ALL` subqueries). `partition` is the default setting. It is often used with traditional inheritance trees to improve performance.

When this parameter allows it for a particular table, the planner compares query conditions with the table's `CHECK` constraints, and omits scanning tables for which the conditions contradict the constraints. For example:

```
CREATE TABLE parent(key integer, ...);
CREATE TABLE child1000(check (key between 1000 and 1999))
  INHERITS(parent);
CREATE TABLE child2000(check (key between 2000 and 2999))
  INHERITS(parent);
...
SELECT * FROM parent WHERE key = 2400;
```

With constraint exclusion enabled, this `SELECT` will not scan `child1000` at all, improving performance.

Currently, constraint exclusion is enabled by default only for cases that are often used to implement table partitioning via inheritance trees. Turning it on for all tables imposes extra planning overhead that is quite noticeable on simple queries, and most often will yield no benefit for simple queries. If you have no tables that are partitioned using traditional inheritance, you might prefer to turn it off entirely. (Note that the equivalent feature for partitioned tables is controlled by a separate parameter, `enable_partition_pruning`.)

Refer to Section 5.11.5 for more information on using constraint exclusion to implement partitioning.

`cursor_tuple_fraction` (floating point)

Sets the planner's estimate of the fraction of a cursor's rows that will be retrieved. The default is 0.1. Smaller values of this setting bias the planner towards using "fast start" plans for cursors, which will retrieve the first few rows quickly while perhaps taking a long time to fetch all rows. Larger values put more emphasis on the total estimated time. At the maximum setting of 1.0, cursors are planned exactly like regular queries, considering only the total estimated time and not how soon the first rows might be delivered.

`from_collapse_limit` (integer)

The planner will merge sub-queries into upper queries if the resulting FROM list would have no more than this many items. Smaller values reduce planning time but might yield inferior query plans. The default is eight. For more information see Section 14.3.

Setting this value to `geqo_threshold` or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 17.7.3.

`jit` (boolean)

Determines whether JIT compilation may be used by LightDB, if available (see Chapter 29). The default is on.

`join_collapse_limit` (integer)

The planner will rewrite explicit JOIN constructs (except FULL JOINS) into lists of FROM items whenever a list of no more than this many items would result. Smaller values reduce planning time but might yield inferior query plans.

By default, this variable is set the same as `from_collapse_limit`, which is appropriate for most uses. Setting it to 1 prevents any reordering of explicit JOINS. Thus, the explicit join order specified in the query will be the actual order in which the relations are joined. Because the query planner does not always choose the optimal join order, advanced users can elect to temporarily set this variable to 1, and then specify the join order they desire explicitly. For more information see Section 14.3.

Setting this value to `geqo_threshold` or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 17.7.3.

`parallel_leader_participation` (boolean)

Allows the leader process to execute the query plan under Gather and Gather Merge nodes instead of waiting for worker processes. The default is on. Setting this value to off reduces the likelihood that workers will become blocked because the leader is not reading tuples fast enough, but requires the leader process to wait for worker processes to start up before the first tuples can be produced. The degree to which the leader can help or hinder performance depends on the plan type, number of workers and query duration.

`force_parallel_mode` (enum)

Allows the use of parallel queries for testing purposes even in cases where no performance benefit is expected. The allowed values of `force_parallel_mode` are `off` (use parallel mode only when it is expected to improve performance), `on` (force parallel query for all queries for which it is thought to be safe), and `regress` (like on, but with additional behavior changes as explained below).

More specifically, setting this value to `on` will add a Gather node to the top of any query plan for which this appears to be safe, so that the query runs inside of a parallel worker. Even when a parallel worker is not available or cannot be used, operations such as starting a subtransaction that would be prohibited in a parallel query context will be prohibited unless the planner believes that this will cause the query to fail. If failures or unexpected results occur when this option is set, some functions used by the query may need to be marked PARALLEL UNSAFE (or, possibly, PARALLEL RESTRICTED).

Setting this value to `regress` has all of the same effects as setting it to `on` plus some additional effects that are intended to facilitate automated regression testing. Normally, messages from a parallel worker include a context line indicating that, but a setting of `regress` suppresses this line so that the output is the same as in non-parallel execution. Also, the Gather nodes added

to plans by this setting are hidden in EXPLAIN output so that the output matches what would be obtained if this setting were turned off.

`plan_cache_mode` (enum)

Prepared statements (either explicitly prepared or implicitly generated, for example by PL/pgSQL) can be executed using custom or generic plans. Custom plans are made afresh for each execution using its specific set of parameter values, while generic plans do not rely on the parameter values and can be re-used across executions. Thus, use of a generic plan saves planning time, but if the ideal plan depends strongly on the parameter values then a generic plan may be inefficient. The choice between these options is normally made automatically, but it can be overridden with `plan_cache_mode`. The allowed values are `auto` (the default), `force_custom_plan` and `force_generic_plan`. This setting is considered when a cached plan is to be executed, not when it is prepared. For more information see PREPARE.

## 17.8. Error Reporting and Logging

### 17.8.1. Where to Log

`log_destination` (string)

LightDB supports several methods for logging server messages, including `stderr`, `csvlog` and `syslog`. On Windows, `eventlog` is also supported. Set this parameter to a list of desired log destinations separated by commas. The default is to log to `stderr` only. This parameter can only be set in the `lightdb.conf` file or on the server command line.

If `csvlog` is included in `log_destination`, log entries are output in “comma separated value” (CSV) format, which is convenient for loading logs into programs. See Section 17.8.4 for details. `logging_collector` must be enabled to generate CSV-format log output.

When either `stderr` or `csvlog` are included, the file `current_logfiles` is created to record the location of the log file(s) currently in use by the logging collector and the associated logging destination. This provides a convenient way to find the logs currently in use by the instance. Here is an example of this file's content:

```
stderr log/lightdb.log
csvlog log/lightdb.csv
```

`current_logfiles` is recreated when a new log file is created as an effect of rotation, and when `log_destination` is reloaded. It is removed when neither `stderr` nor `csvlog` are included in `log_destination`, and when the logging collector is disabled.

#### Note

On most Unix systems, you will need to alter the configuration of your system's `syslog` daemon in order to make use of the `syslog` option for `log_destination`. LightDB can log to `syslog` facilities LOCAL0 through LOCAL7 (see `syslog_facility`), but the default `syslog` configuration on most platforms will discard all such messages. You will need to add something like:

```
local0.*    /var/log/lightdb
```

to the `syslog` daemon's configuration file to make it work.

On Windows, when you use the `eventlog` option for `log_destination`, you should register an event source and its library with the operating system so



that the Windows Event Viewer can display event log messages cleanly. See Section 16.12 for details.

`logging_collector` (boolean)

This parameter enables the *logging collector*, which is a background process that captures log messages sent to `stderr` and redirects them into log files. This approach is often more useful than logging to `syslog`, since some types of messages might not appear in `syslog` output. (One common example is dynamic-linker failure messages; another is error messages produced by scripts such as `archive_command`.) This parameter can only be set at server start.

### Note

It is possible to log to `stderr` without using the logging collector; the log messages will just go to wherever the server's `stderr` is directed. However, that method is only suitable for low log volumes, since it provides no convenient way to rotate log files. Also, on some platforms not using the logging collector can result in lost or garbled log output, because multiple processes writing concurrently to the same log file can overwrite each other's output.

### Note

The logging collector is designed to never lose messages. This means that in case of extremely high load, server processes could be blocked while trying to send additional log messages when the collector has fallen behind. In contrast, `syslog` prefers to drop messages if it cannot write them, which means it may fail to log some messages in such cases but it will not block the rest of the system.

`log_directory` (string)

When `logging_collector` is enabled, this parameter determines the directory in which log files will be created. It can be specified as an absolute path, or relative to the cluster data directory. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `log`.

`log_filename` (string)

When `logging_collector` is enabled, this parameter sets the file names of the created log files. The value is treated as a `strftime` pattern, so `%`-escapes can be used to specify time-varying file names. (Note that if there are any time-zone-dependent `%`-escapes, the computation is done in the zone specified by `log_timezone`.) The supported `%`-escapes are similar to those listed in the Open Group's `strftime`<sup>1</sup> specification. Note that the system's `strftime` is not used directly, so platform-specific (nonstandard) extensions do not work. The default is `lightdb-%Y-%m-%d_%H%M%S.log`.

If you specify a file name without escapes, you should plan to use a log rotation utility to avoid eventually filling the entire disk.

If CSV-format output is enabled in `log_destination`, `.csv` will be appended to the timestamped log file name to create the file name for CSV-format output. (If `log_filename` ends in `.log`, the suffix is replaced instead.)

<sup>1</sup> <https://pubs.opengroup.org/onlinepubs/009695399/functions/strftime.html>

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_file_mode` (integer)

On Unix systems this parameter sets the permissions for log files when `logging_collector` is enabled. (On Microsoft Windows this parameter is ignored.) The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a 0 (zero).)

The default permissions are 0600, meaning only the server owner can read or write the log files. The other commonly useful setting is 0640, allowing members of the owner's group to read the files. Note however that to make use of such a setting, you'll need to alter `log_directory` to store the files somewhere outside the cluster data directory. In any case, it's unwise to make the log files world-readable, since they might contain sensitive data.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_rotation_age` (integer)

When `logging_collector` is enabled, this parameter determines the maximum amount of time to use an individual log file, after which a new log file will be created. If this value is specified without units, it is taken as minutes. The default is 24 hours. Set to zero to disable time-based creation of new log files. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`lightdb_log_retention_age` (integer)

When `logging_collector` is enabled, This parameter determines the maximum time to keep the log file, the log longer than this time will be cleaned up when switching the log file. If this value is specified without units, it is taken as minutes. The default is 0. Set to zero to disable time-based delete of log files. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_rotation_size` (integer)

When `logging_collector` is enabled, this parameter determines the maximum size of an individual log file. After this amount of data has been emitted into a log file, a new log file will be created. If this value is specified without units, it is taken as kilobytes. The default is 10 megabytes. Set to zero to disable size-based creation of new log files. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_truncate_on_rotation` (boolean)

When `logging_collector` is enabled, this parameter will cause LightDB to truncate (overwrite), rather than append to, any existing log file of the same name. However, truncation will occur only when a new file is being opened due to time-based rotation, not during server startup or size-based rotation. When off, pre-existing files will be appended to in all cases. For example, using this setting in combination with a `log_filename` like `lightdb-%H.log` would result in generating twenty-four hourly log files and then cyclically overwriting them. This parameter can only be set in the `lightdb.conf` file or on the server command line.

Example: To keep 7 days of logs, one log file per day named `server_log.Mon`, `server_log.Tue`, etc, and automatically overwrite last week's log with this week's log, set `log_filename` to `server_log.%a`, `log_truncate_on_rotation` to `on`, and `log_rotation_age` to 1440.

Example: To keep 24 hours of logs, one log file per hour, but also rotate sooner if the log file size exceeds 1GB, set `log_filename` to `server_log.%H%M`, `log_truncate_on_rotation` to `on`, `log_rotation_age` to 60, and `log_rotation_size` to 1000000. Including `%M` in `log_filename` allows any size-driven rotations that might occur to select a file name different from the hour's initial file name.

`syslog_facility` (enum)

When logging to syslog is enabled, this parameter determines the syslog “facility” to be used. You can choose from LOCAL0, LOCAL1, LOCAL2, LOCAL3, LOCAL4, LOCAL5, LOCAL6, LOCAL7; the default is LOCAL0. See also the documentation of your system’s syslog daemon. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`syslog_ident` (string)

When logging to syslog is enabled, this parameter determines the program name used to identify LightDB messages in syslog logs. The default is `postgres`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`syslog_sequence_numbers` (boolean)

When logging to syslog and this is on (the default), then each message will be prefixed by an increasing sequence number (such as [2]). This circumvents the “--- last message repeated N times ---” suppression that many syslog implementations perform by default. In more modern syslog implementations, repeated message suppression can be configured (for example, `$RepeatedMsgReduction` in `rsyslog`), so this might not be necessary. Also, you could turn this off if you actually want to suppress repeated messages.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`syslog_split_messages` (boolean)

When logging to syslog is enabled, this parameter determines how messages are delivered to syslog. When on (the default), messages are split by lines, and long lines are split so that they will fit into 1024 bytes, which is a typical size limit for traditional syslog implementations. When off, LightDB server log messages are delivered to the syslog service as is, and it is up to the syslog service to cope with the potentially bulky messages.

If syslog is ultimately logging to a text file, then the effect will be the same either way, and it is best to leave the setting on, since most syslog implementations either cannot handle large messages or would need to be specially configured to handle them. But if syslog is ultimately writing into some other medium, it might be necessary or more useful to keep messages logically together.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`event_source` (string)

When logging to event log is enabled, this parameter determines the program name used to identify LightDB messages in the log. The default is `LightDB`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.8.2. When to Log

`log_min_messages` (enum)

Controls which message levels are written to the server log. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, ERROR, LOG, FATAL, and PANIC. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log. The default is WARNING. Note that LOG has a different rank here than in `client_min_messages`. Only superusers can change this setting.

`log_min_error_statement` (enum)

Controls which SQL statements that cause an error condition are recorded in the server log. The current SQL statement is included in the log entry for any message of the specified severity or higher. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE,

WARNING, ERROR, LOG, FATAL, and PANIC. The default is ERROR, which means statements causing errors, log messages, fatal errors, or panics will be logged. To effectively turn off logging of failing statements, set this parameter to PANIC. Only superusers can change this setting.

`log_min_duration_statement` (integer)

Causes the duration of each completed statement to be logged if the statement ran for at least the specified amount of time. For example, if you set it to 250ms then all SQL statements that run 250ms or longer will be logged. Enabling this parameter can be helpful in tracking down unoptimized queries in your applications. If this value is specified without units, it is taken as milliseconds. Setting this to zero prints all statement durations. -1 (the default) disables logging statement durations. Only superusers can change this setting.

This overrides `log_min_duration_sample`, meaning that queries with duration exceeding this setting are not subject to sampling and are always logged.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

**Note**

When using this option together with `log_statement`, the text of statements that are logged because of `log_statement` will not be repeated in the duration log message. If you are not using syslog, it is recommended that you log the PID or session ID using `log_line_prefix` so that you can link the statement message to the later duration message using the process ID or session ID.

`log_min_duration_sample` (integer)

Allows sampling the duration of completed statements that ran for at least the specified amount of time. This produces the same kind of log entries as `log_min_duration_statement`, but only for a subset of the executed statements, with sample rate controlled by `log_statement_sample_rate`. For example, if you set it to 100ms then all SQL statements that run 100ms or longer will be considered for sampling. Enabling this parameter can be helpful when the traffic is too high to log all queries. If this value is specified without units, it is taken as milliseconds. Setting this to zero samples all statement durations. -1 (the default) disables sampling statement durations. Only superusers can change this setting.

This setting has lower priority than `log_min_duration_statement`, meaning that statements with durations exceeding `log_min_duration_statement` are not subject to sampling and are always logged.

Other notes for `log_min_duration_statement` apply also to this setting.

`log_statement_sample_rate` (floating point)

Determines the fraction of statements with duration exceeding `log_min_duration_sample` that will be logged. Sampling is stochastic, for example 0.5 means there is statistically one chance in two that any given statement will be logged. The default is 1.0, meaning to log all sampled statements. Setting this to zero disables sampled statement-duration logging, the same as setting `log_min_duration_sample` to -1. Only superusers can change this setting.

`log_transaction_sample_rate` (floating point)

Sets the fraction of transactions whose statements are all logged, in addition to statements logged for other reasons. It applies to each new transaction regardless of its statements' durations. Sampling is stochastic, for example 0.1 means there is statistically one chance in ten that any given transaction will be logged. `log_transaction_sample_rate` can be helpful to

construct a sample of transactions. The default is 0, meaning not to log statements from any additional transactions. Setting this to 1 logs all statements of all transactions. Only superusers can change this setting.

### Note

Like all statement-logging options, this option can add significant overhead.

Table 17.2 explains the message severity levels used by LightDB. If logging output is sent to syslog or Windows' eventlog, the severity levels are translated as shown in the table.

**Table 17.2. Message Severity Levels**

Severity	Usage	syslog	eventlog
DEBUG1 . . DEBUG5	Provides successively-more-detailed information for use by developers.	DEBUG	INFORMATION
INFO	Provides information implicitly requested by the user, e.g., output from VACUUM VERBOSE.	INFO	INFORMATION
NOTICE	Provides information that might be helpful to users, e.g., notice of truncation of long identifiers.	NOTICE	INFORMATION
WARNING	Provides warnings of likely problems, e.g., COMMIT outside a transaction block.	NOTICE	WARNING
ERROR	Reports an error that caused the current command to abort.	WARNING	ERROR
LOG	Reports information of interest to administrators, e.g., checkpoint activity.	INFO	INFORMATION
FATAL	Reports an error that caused the current session to abort.	ERR	ERROR
PANIC	Reports an error that caused all database sessions to abort.	CRIT	ERROR

## 17.8.3. What to Log

`application_name` (string)

The `application_name` can be any string of less than `NAMEDATALEN` characters (64 characters in a standard build). It is typically set by an application upon connection to the server. The name will be displayed in the `pg_stat_activity` view and included in CSV log entries. It can also be included in regular log entries via the `log_line_prefix` parameter. Only printable ASCII characters may be used in the `application_name` value. Other characters will be replaced with question marks (?).

`debug_print_parse` (boolean)

`debug_print_rewritten` (boolean)

`debug_print_plan` (boolean)

These parameters enable various debugging output to be emitted. When set, they print the resulting parse tree, the query rewriter output, or the execution plan for each executed query. These messages are emitted at LOG message level, so by default they will appear in the server log

but will not be sent to the client. You can change that by adjusting `client_min_messages` and/or `log_min_messages`. These parameters are off by default.

`debug_pretty_print` (boolean)

When set, `debug_pretty_print` indents the messages produced by `debug_print_parse`, `debug_print_rewritten`, or `debug_print_plan`. This results in more readable but much longer output than the “compact” format used when it is off. It is on by default.

`log_checkpoints` (boolean)

Causes checkpoints and restartpoints to be logged in the server log. Some statistics are included in the log messages, including the number of buffers written and the time spent writing them. This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is off.

`log_connections` (boolean)

Causes each attempted connection to the server to be logged, as well as successful completion of client authentication. Only superusers can change this parameter at session start, and it cannot be changed at all within a session. The default is off.

**Note**

Some client programs, like `ltsql`, attempt to connect twice while determining if a password is required, so duplicate “connection received” messages do not necessarily indicate a problem.

`log_disconnections` (boolean)

Causes session terminations to be logged. The log output provides information similar to `log_connections`, plus the duration of the session. Only superusers can change this parameter at session start, and it cannot be changed at all within a session. The default is off.

`log_duration` (boolean)

Causes the duration of every completed statement to be logged. The default is off. Only superusers can change this setting.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

**Note**

The difference between enabling `log_duration` and setting `log_min_duration_statement` to zero is that exceeding `log_min_duration_statement` forces the text of the query to be logged, but this option doesn't. Thus, if `log_duration` is on and `log_min_duration_statement` has a positive value, all durations are logged but the query text is included only for statements exceeding the threshold. This behavior can be useful for gathering statistics in high-load installations.

`log_error_verbosity` (enum)

Controls the amount of detail written in the server log for each message that is logged. Valid values are `TERSE`, `DEFAULT`, and `VERBOSE`, each adding more fields to displayed messages. `TERSE`

excludes the logging of `DETAIL`, `HINT`, `QUERY`, and `CONTEXT` error information. `VERBOSE` output includes the `SQLSTATE` error code (see also Appendix A) and the source code file name, function name, and line number that generated the error. Only superusers can change this setting.

`log_hostname` (boolean)

By default, connection log messages only show the IP address of the connecting host. Turning this parameter on causes logging of the host name as well. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`log_line_prefix` (string)

This is a `printf`-style string that is output at the beginning of each log line. `%` characters begin “escape sequences” that are replaced with status information as outlined below. Unrecognized escapes are ignored. Other characters are copied straight to the log line. Some escapes are only recognized by session processes, and will be treated as empty by background processes such as the main server process. Status information may be aligned either left or right by specifying a numeric literal after the `%` and before the option. A negative value will cause the status information to be padded on the right with spaces to give it a minimum width, whereas a positive value will pad on the left. Padding can be useful to aid human readability in log files.

This parameter can only be set in the `lightdb.conf` file or on the server command line. The default is `'%m [%p] '` which logs a time stamp and the process ID.

Escape	Effect	Session only
<code>%a</code>	Application name	yes
<code>%u</code>	User name	yes
<code>%d</code>	Database name	yes
<code>%r</code>	Remote host name or IP address, and remote port	yes
<code>%h</code>	Remote host name or IP address	yes
<code>%b</code>	Backend type	no
<code>%p</code>	Process ID	no
<code>%t</code>	Time stamp without milliseconds	no
<code>%m</code>	Time stamp with milliseconds	no
<code>%n</code>	Time stamp with milliseconds (as a Unix epoch)	no
<code>%i</code>	Command tag: type of session's current command	yes
<code>%e</code>	<code>SQLSTATE</code> error code	no
<code>%c</code>	Session ID: see below	no
<code>%l</code>	Number of the log line for each session or process, starting at 1	no
<code>%s</code>	Process start time stamp	no
<code>%v</code>	Virtual transaction ID (backendID/localXID)	no
<code>%x</code>	Transaction ID (0 if none is assigned)	no

Escape	Effect	Session only
<code>%q</code>	Produces no output, but tells non-session processes to stop at this point in the string; ignored by session processes	no
<code>%%</code>	Literal <code>%</code>	no

The backend type corresponds to the column `backend_type` in the view `pg_stat_activity`, but additional types can appear in the log that don't show in that view.

The `%c` escape prints a quasi-unique session identifier, consisting of two 4-byte hexadecimal numbers (without leading zeros) separated by a dot. The numbers are the process start time and the process ID, so `%c` can also be used as a space saving way of printing those items. For example, to generate the session identifier from `pg_stat_activity`, use this query:

```
SELECT to_hex(trunc(EXTRACT(EPOCH FROM backend_start))::integer)
|| '.' ||
       to_hex(pid)
FROM pg_stat_activity;
```

### Tip

If you set a nonempty value for `log_line_prefix`, you should usually make its last character be a space, to provide visual separation from the rest of the log line. A punctuation character can be used too.

### Tip

Syslog produces its own time stamp and process ID information, so you probably do not want to include those escapes if you are logging to syslog.

### Tip

The `%q` escape is useful when including information that is only available in session (backend) context like user or database name. For example:

```
log_line_prefix = '%m [%p] %q%u@d/%a '
```

`log_lock_waits` (boolean)

Controls whether a log message is produced when a session waits longer than `deadlock_timeout` to acquire a lock. This is useful in determining if lock waits are causing poor performance. The default is `off`. Only superusers can change this setting.

`log_parameter_max_length` (integer)

If greater than zero, each bind parameter value logged with a non-error statement-logging message is trimmed to this many bytes. Zero disables logging of bind parameters for non-error statement logs. `-1` (the default) allows bind parameters to be logged in full. If this value is specified without units, it is taken as bytes. Only superusers can change this setting.



This setting only affects log messages printed as a result of `log_statement`, `log_duration`, and related settings. Non-zero values of this setting add some overhead, particularly if parameters are sent in binary form, since then conversion to text is required.

`log_parameter_max_length_on_error` (integer)

If greater than zero, each bind parameter value reported in error messages is trimmed to this many bytes. Zero (the default) disables including bind parameters in error messages. -1 allows bind parameters to be printed in full. If this value is specified without units, it is taken as bytes.

Non-zero values of this setting add overhead, as LightDB will need to store textual representations of parameter values in memory at the start of each statement, whether or not an error eventually occurs. The overhead is greater when bind parameters are sent in binary form than when they are sent as text, since the former case requires data conversion while the latter only requires copying the string.

`log_statement` (enum)

Controls which SQL statements are logged. Valid values are `none` (off), `ddl`, `mod`, and `all` (all statements). `ddl` logs all data definition statements, such as `CREATE`, `ALTER`, and `DROP` statements. `mod` logs all `ddl` statements, plus data-modifying statements such as `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, and `COPY FROM`. `PREPARE`, `EXECUTE`, and `EXPLAIN ANALYZE` statements are also logged if their contained command is of an appropriate type. For clients using extended query protocol, logging occurs when an `Execute` message is received, and values of the Bind parameters are included (with any embedded single-quote marks doubled).

The default is `none`. Only superusers can change this setting.

**Note**

Statements that contain simple syntax errors are not logged even by the `log_statement = all` setting, because the log message is emitted only after basic parsing has been done to determine the statement type. In the case of extended query protocol, this setting likewise does not log statements that fail before the `Execute` phase (i.e., during parse analysis or planning). Set `log_min_error_statement` to `ERROR` (or lower) to log such statements.

`log_replication_commands` (boolean)

Causes each replication command to be logged in the server log. See Section 49.4 for more information about replication command. The default value is `off`. Only superusers can change this setting.

`log_temp_files` (integer)

Controls logging of temporary file names and sizes. Temporary files can be created for sorts, hashes, and temporary query results. If enabled by this setting, a log entry is emitted for each temporary file when it is deleted. A value of zero logs all temporary file information, while positive values log only files whose size is greater than or equal to the specified amount of data. If this value is specified without units, it is taken as kilobytes. The default setting is -1, which disables such logging. Only superusers can change this setting.

`log_timezone` (string)

Sets the time zone used for timestamps written in the server log. Unlike `TimeZone`, this value is cluster-wide, so that all sessions will report timestamps consistently. The built-in default is `GMT`, but that is typically overridden in `lightdb.conf`; `initdb` will install a setting there

corresponding to its system environment. See Section 8.5.3 for more information. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.8.4. Using CSV-Format Log Output

Including `csvlog` in the `log_destination` list provides a convenient way to import log files into a database table. This option emits log lines in comma-separated-values (CSV) format, with these columns: time stamp with milliseconds, user name, database name, process ID, client host:port number, session ID, per-session line number, command tag, session start time, virtual transaction ID, regular transaction ID, error severity, SQLSTATE code, error message, error message detail, hint, internal query that led to the error (if any), character count of the error position therein, error context, user query that led to the error (if any and enabled by `log_min_error_statement`), character count of the error position therein, location of the error in the LightDB source code (if `log_error_verbosity` is set to `verbose`), application name, and backend type. Here is a sample table definition for storing CSV-format log output:

```
CREATE TABLE lightdb_log
(
  log_time timestamp(3) with time zone,
  user_name text,
  database_name text,
  process_id integer,
  connection_from text,
  session_id text,
  session_line_num bigint,
  command_tag text,
  session_start_time timestamp with time zone,
  virtual_transaction_id text,
  transaction_id bigint,
  error_severity text,
  sql_state_code text,
  message text,
  detail text,
  hint text,
  internal_query text,
  internal_query_pos integer,
  context text,
  query text,
  query_pos integer,
  location text,
  application_name text,
  backend_type text,
  PRIMARY KEY (session_id, session_line_num)
);
```

To import a log file into this table, use the `COPY FROM` command:

```
COPY lightdb_log FROM '/full/path/to/logfile.csv' WITH csv;
```

It is also possible to access the file as a foreign table, using the supplied `file_fdw` module.

There are a few things you need to do to simplify importing CSV log files:

1. Set `log_filename` and `log_rotation_age` to provide a consistent, predictable naming scheme for your log files. This lets you predict what the file name will be and know when an individual log file is complete and therefore ready to be imported.

2. Set `log_rotation_size` to 0 to disable size-based log rotation, as it makes the log file name difficult to predict.
3. Set `log_truncate_on_rotation` to `on` so that old log data isn't mixed with the new in the same file.
4. The table definition above includes a primary key specification. This is useful to protect against accidentally importing the same information twice. The `COPY` command commits all of the data it imports at one time, so any error will cause the entire import to fail. If you import a partial log file and later import the file again when it is complete, the primary key violation will cause the import to fail. Wait until the log is complete and closed before importing. This procedure will also protect against accidentally importing a partial line that hasn't been completely written, which would also cause `COPY` to fail.

## 17.8.5. Process Title

These settings control how process titles of server processes are modified. Process titles are typically viewed using programs like `ps` or, on Windows, Process Explorer. See Section 25.1 for details.

`cluster_name` (string)

Sets a name that identifies this database cluster (instance) for various purposes. The cluster name appears in the process title for all server processes in this cluster. Moreover, it is the default application name for a standby connection (see `synchronous_standby_names`.)

The name can be any string of less than `NAMEDATALEN` characters (64 characters in a standard build). Only printable ASCII characters may be used in the `cluster_name` value. Other characters will be replaced with question marks (?). No name is shown if this parameter is set to the empty string '' (which is the default). This parameter can only be set at server start.

`update_process_title` (boolean)

Enables updating of the process title every time a new SQL command is received by the server. This setting defaults to `on` on most platforms, but it defaults to `off` on Windows due to that platform's larger overhead for updating the process title. Only superusers can change this setting.

## 17.9. Run-time Statistics

### 17.9.1. Query and Index Statistics Collector

These parameters control server-wide statistics collection features. When statistics collection is enabled, the data that is produced can be accessed via the `lt_stat` and `pg_statio` family of system views. Refer to Chapter 25 for more information.

`track_activities` (boolean)

Enables the collection of information on the currently executing command of each session, along with the time when that command began execution. This parameter is `on` by default. Note that even when enabled, this information is not visible to all users, only to superusers, roles with privileges of the `pg_read_all_stats` role and the user owning the sessions being reported on (including sessions belonging to a role they have the privileges of), so it should not represent a security risk. Only superusers can change this setting.

`track_activity_query_size` (integer)

Specifies the amount of memory reserved to store the text of the currently executing command for each active session, for the `pg_stat_activity.query` field. If this value is specified without units, it is taken as bytes. The default value is 1024 bytes. This parameter can only be set at server start.

`track_counts` (boolean)

Enables collection of statistics on database activity. This parameter is on by default, because the autovacuum daemon needs the collected information. Only superusers can change this setting.

`track_io_timing` (boolean)

Enables timing of database I/O calls. This parameter is off by default, because it will repeatedly query the operating system for the current time, which may cause significant overhead on some platforms. You can use the `lt_test_timing` tool to measure the overhead of timing on your system. I/O timing information is displayed in `pg_stat_database`, in the output of `EXPLAIN` when the `BUFFERS` option is used, and by `lt_stat_statements`. Only superusers can change this setting.

`track_functions` (enum)

Enables tracking of function call counts and time used. Specify `p1` to track only procedural-language functions, `a11` to also track SQL and C language functions. The default is `none`, which disables function statistics tracking. Only superusers can change this setting.

### Note

SQL-language functions that are simple enough to be “inlined” into the calling query will not be tracked, regardless of this setting.

`stats_temp_directory` (string)

Sets the directory to store temporary statistics data in. This can be a path relative to the data directory or an absolute path. The default is `lt_stat_tmp`. Pointing this at a RAM-based file system will decrease physical I/O requirements and can lead to improved performance. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.9.2. Statistics Monitoring

`log_statement_stats` (boolean)

`log_parser_stats` (boolean)

`log_planner_stats` (boolean)

`log_executor_stats` (boolean)

For each query, output performance statistics of the respective module to the server log. This is a crude profiling instrument, similar to the Unix `getrusage()` operating system facility. `log_statement_stats` reports total statement statistics, while the others report per-module statistics. `log_statement_stats` cannot be enabled together with any of the per-module options. All of these options are disabled by default. Only superusers can change these settings.

## 17.10. Automatic Vacuuming

These settings control the behavior of the *autovacuum* feature. Refer to Section 22.1.6 for more information. Note that many of these settings can be overridden on a per-table basis; see Storage Parameters.

`autovacuum` (boolean)

Controls whether the server should run the autovacuum launcher daemon. This is on by default; however, `track_counts` must also be enabled for autovacuum to work. This parameter can only be set in the `lightdb.conf` file or on the server command line; however, autovacuuming can be disabled for individual tables by changing table storage parameters.

Note that even when this parameter is disabled, the system will launch autovacuum processes if necessary to prevent transaction ID wraparound. See Section 22.1.5 for more information.

`log_autovacuum_min_duration` (integer)

Causes each action executed by autovacuum to be logged if it ran for at least the specified amount of time. Setting this to zero logs all autovacuum actions. -1 (the default) disables logging autovacuum actions. If this value is specified without units, it is taken as milliseconds. For example, if you set this to 250ms then all automatic vacuums and analyzes that run 250ms or longer will be logged. In addition, when this parameter is set to any value other than -1, a message will be logged if an autovacuum action is skipped due to a conflicting lock or a concurrently dropped relation. Enabling this parameter can be helpful in tracking autovacuum activity. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_max_workers` (integer)

Specifies the maximum number of autovacuum processes (other than the autovacuum launcher) that may be running at any one time. The default is three. This parameter can only be set at server start.

`autovacuum_naptime` (integer)

Specifies the minimum delay between autovacuum runs on any given database. In each round the daemon examines the database and issues `VACUUM` and `ANALYZE` commands as needed for tables in that database. If this value is specified without units, it is taken as seconds. The default is one minute (1min). This parameter can only be set in the `lightdb.conf` file or on the server command line.

`autovacuum_vacuum_threshold` (integer)

Specifies the minimum number of updated or deleted tuples needed to trigger a `VACUUM` in any one table. The default is 50 tuples. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_insert_threshold` (integer)

Specifies the number of inserted tuples needed to trigger a `VACUUM` in any one table. The default is 1000 tuples. If -1 is specified, autovacuum will not trigger a `VACUUM` operation on any tables based on the number of inserts. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_analyze_threshold` (integer)

Specifies the minimum number of inserted, updated or deleted tuples needed to trigger an `ANALYZE` in any one table. The default is 50 tuples. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_scale_factor` (floating point)

Specifies a fraction of the table size to add to `autovacuum_vacuum_threshold` when deciding whether to trigger a `VACUUM`. The default is 0.2 (20% of table size). This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_insert_scale_factor` (floating point)

Specifies a fraction of the table size to add to `autovacuum_vacuum_insert_threshold` when deciding whether to trigger a `VACUUM`. The default is 0.2 (20% of table size). This parameter

can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_analyze_scale_factor` (floating point)

Specifies a fraction of the table size to add to `autovacuum_analyze_threshold` when deciding whether to trigger an `ANALYZE`. The default is 0.1 (10% of table size). This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_freeze_max_age` (integer)

Specifies the maximum age (in transactions) that a table's `pg_class.relFrozenxid` field can attain before a `VACUUM` operation is forced to prevent transaction ID wraparound within the table. Note that the system will launch autovacuum processes to prevent wraparound even when autovacuum is otherwise disabled.

Vacuum also allows removal of old files from the `lt_xact` subdirectory, which is why the default is a relatively low 200 million transactions. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing table storage parameters. For more information see Section 22.1.5.

`autovacuum_multixact_freeze_max_age` (integer)

Specifies the maximum age (in multixacts) that a table's `pg_class.relminmxid` field can attain before a `VACUUM` operation is forced to prevent multixact ID wraparound within the table. Note that the system will launch autovacuum processes to prevent wraparound even when autovacuum is otherwise disabled.

Vacuuming multixacts also allows removal of old files from the `lt_multixact/members` and `lt_multixact/offsets` subdirectories, which is why the default is a relatively low 400 million multixacts. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing table storage parameters. For more information see Section 22.1.5.1.

`autovacuum_vacuum_cost_delay` (floating point)

Specifies the cost delay value that will be used in automatic `VACUUM` operations. If -1 is specified, the regular `vacuum_cost_delay` value will be used. If this value is specified without units, it is taken as milliseconds. The default value is 2 milliseconds. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_cost_limit` (integer)

Specifies the cost limit value that will be used in automatic `VACUUM` operations. If -1 is specified (which is the default), the regular `vacuum_cost_limit` value will be used. Note that the value is distributed proportionally among the running autovacuum workers, if there is more than one, so that the sum of the limits for each worker does not exceed the value of this variable. This parameter can only be set in the `lightdb.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

## 17.11. Client Connection Defaults

### 17.11.1. Statement Behavior

`client_min_messages` (enum)

Controls which message levels are sent to the client. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, `LOG`, `NOTICE`, `WARNING`, and `ERROR`. Each level includes all

the levels that follow it. The later the level, the fewer messages are sent. The default is `NOTICE`. Note that `LOG` has a different rank here than in `log_min_messages`.

`INFO` level messages are always sent to the client.

`search_path` (string)

This variable specifies the order in which schemas are searched when an object (table, data type, function, etc.) is referenced by a simple name with no schema specified. When there are objects of identical names in different schemas, the one found first in the search path is used. An object that is not in any of the schemas in the search path can only be referenced by specifying its containing schema with a qualified (dotted) name.

The value for `search_path` must be a comma-separated list of schema names. Any name that is not an existing schema, or is a schema for which the user does not have `USAGE` permission, is silently ignored.

If one of the list items is the special name `$user`, then the schema having the name returned by `CURRENT_USER` is substituted, if there is such a schema and the user has `USAGE` permission for it. (If not, `$user` is ignored.)

If one of the list items is the special name `$lt_syntax_compatible_type` and `lightdb_dblevel_syntax_compatible_type` is not `off`, then the schema having the name returned by `lt_syntax_compatible_type` is substituted, if there is such a schema and the user has `USAGE` permission for it. (If `lightdb_dblevel_syntax_compatible_type` is `off`, `$lt_syntax_compatible_type` is ignored.)

The system catalog schema, `pg_catalog`, is always searched, whether it is mentioned in the path or not. If it is mentioned in the path then it will be searched in the specified order. If `pg_catalog` is not in the path then it will be searched *before* searching any of the path items.

Likewise, the current session's temporary-table schema, `pg_temp_nnn`, is always searched if it exists. It can be explicitly listed in the path by using the alias `pg_temp`. If it is not listed in the path then it is searched first (even before `pg_catalog`). However, the temporary schema is only searched for relation (table, view, sequence, etc) and data type names. It is never searched for function or operator names.

When objects are created without specifying a particular target schema, they will be placed in the first valid schema named in `search_path`. An error is reported if the search path is empty.

The default value for this parameter is `"$user", public, $lt_syntax_compatible_type, lt_catalog`. This setting supports shared use of a database (where no users have private schemas, and all share use of `public`), private per-user schemas, and combinations of these. Other effects can be obtained by altering the default search path setting, either globally or per-user.

For more information on schema handling, see Section 5.9. In particular, the default configuration is suitable only when the database has a single user or a few mutually-trusting users.

The current effective value of the search path can be examined via the SQL function `current_schemas` (see Section 9.26). This is not quite the same as examining the value of `search_path`, since `current_schemas` shows how the items appearing in `search_path` were resolved.

`mysql` and `oracle` are special schemas, which can only be include in the specified `lightdb_dblevel_syntax_compatible_type`.

`row_security` (boolean)

This variable controls whether to raise an error in lieu of applying a row security policy. When set to `on`, policies apply normally. When set to `off`, queries fail which would otherwise apply at least one policy. The default is `on`. Change to `off` where limited row visibility could cause incorrect

results; for example, `lt_dump` makes that change by default. This variable has no effect on roles which bypass every row security policy, to wit, superusers and roles with the `BYPASSRLS` attribute.

For more information on row security policies, see `CREATE POLICY`.

`default_table_access_method` (string)

This parameter specifies the default table access method to use when creating tables or materialized views if the `CREATE` command does not explicitly specify an access method, or when `SELECT . . . INTO` is used, which does not allow specifying a table access method. The default is `heap`.

`default_tablespace` (string)

This variable specifies the default tablespace in which to create objects (tables and indexes) when a `CREATE` command does not explicitly specify a tablespace.

The value is either the name of a tablespace, or an empty string to specify using the default tablespace of the current database. If the value does not match the name of any existing tablespace, LightDB will automatically use the default tablespace of the current database. If a nondefault tablespace is specified, the user must have `CREATE` privilege for it, or creation attempts will fail.

This variable is not used for temporary tables; for them, `temp_tablespaces` is consulted instead.

This variable is also not used when creating databases. By default, a new database inherits its tablespace setting from the template database it is copied from.

If this parameter is set to a value other than the empty string when a partitioned table is created, the partitioned table's tablespace will be set to that value, which will be used as the default tablespace for partitions created in the future, even if `default_tablespace` has changed since then.

For more information on tablespaces, see Section 20.6.

`temp_tablespaces` (string)

This variable specifies tablespaces in which to create temporary objects (temp tables and indexes on temp tables) when a `CREATE` command does not explicitly specify a tablespace. Temporary files for purposes such as sorting large data sets are also created in these tablespaces.

The value is a list of names of tablespaces. When there is more than one name in the list, LightDB chooses a random member of the list each time a temporary object is to be created; except that within a transaction, successively created temporary objects are placed in successive tablespaces from the list. If the selected element of the list is an empty string, LightDB will automatically use the default tablespace of the current database instead.

When `temp_tablespaces` is set interactively, specifying a nonexistent tablespace is an error, as is specifying a tablespace for which the user does not have `CREATE` privilege. However, when using a previously set value, nonexistent tablespaces are ignored, as are tablespaces for which the user lacks `CREATE` privilege. In particular, this rule applies when using a value set in `lightdb.conf`.

The default value is an empty string, which results in all temporary objects being created in the default tablespace of the current database.

See also `default_tablespace`.

`check_function_bodies` (boolean)

This parameter is normally on. When set to `off`, it disables validation of the function body string during `CREATE FUNCTION`. Disabling validation avoids side effects of the validation process and avoids false positives due to problems such as forward references. Set this parameter to `off` before loading functions on behalf of other users; `lt_dump` does so automatically.



`default_transaction_isolation` (enum)

Each SQL transaction has an isolation level, which can be either “read uncommitted”, “read committed”, “repeatable read”, or “serializable”. This parameter controls the default isolation level of each new transaction. The default is “read committed”.

Consult Chapter 13 and `SET TRANSACTION` for more information.

`default_transaction_read_only` (boolean)

A read-only SQL transaction cannot alter non-temporary tables. This parameter controls the default read-only status of each new transaction. The default is `off` (read/write).

Consult `SET TRANSACTION` for more information.

`default_transaction_deferrable` (boolean)

When running at the `serializable` isolation level, a deferrable read-only SQL transaction may be delayed before it is allowed to proceed. However, once it begins executing it does not incur any of the overhead required to ensure serializability; so serialization code will have no reason to force it to abort because of concurrent updates, making this option suitable for long-running read-only transactions.

This parameter controls the default deferrable status of each new transaction. It currently has no effect on read-write transactions or those operating at isolation levels lower than `serializable`. The default is `off`.

Consult `SET TRANSACTION` for more information.

`transaction_isolation` (enum)

This parameter reflects the current transaction's isolation level. At the beginning of each transaction, it is set to the current value of `default_transaction_isolation`. Any subsequent attempt to change it is equivalent to a `SET TRANSACTION` command.

`transaction_read_only` (boolean)

This parameter reflects the current transaction's read-only status. At the beginning of each transaction, it is set to the current value of `default_transaction_read_only`. Any subsequent attempt to change it is equivalent to a `SET TRANSACTION` command.

`transaction_deferrable` (boolean)

This parameter reflects the current transaction's deferrability status. At the beginning of each transaction, it is set to the current value of `default_transaction_deferrable`. Any subsequent attempt to change it is equivalent to a `SET TRANSACTION` command.

`session_replication_role` (enum)

Controls firing of replication-related triggers and rules for the current session. Setting this variable requires superuser privilege and results in discarding any previously cached query plans. Possible values are `origin` (the default), `replica` and `local`.

The intended use of this setting is that logical replication systems set it to `replica` when they are applying replicated changes. The effect of that will be that triggers and rules (that have not been altered from their default configuration) will not fire on the replica. See the `ALTER TABLE` clauses `ENABLE TRIGGER` and `ENABLE RULE` for more information.

LightDB treats the settings `origin` and `local` the same internally. Third-party replication systems may use these two values for their internal purposes, for example using `local` to designate a session whose changes should not be replicated.

Since foreign keys are implemented as triggers, setting this parameter to `replica` also disables all foreign key checks, which can leave data in an inconsistent state if improperly used.

`statement_timeout (integer)`

Abort any statement that takes more than the specified amount of time. If `log_min_error_statement` is set to `ERROR` or lower, the statement that timed out will also be logged. If this value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

The timeout is measured from the time a command arrives at the server until it is completed by the server. If multiple SQL statements appear in a single simple-Query message, the timeout is applied to each statement separately. (LightDB versions before 13 usually treated the timeout as applying to the whole query string.) In extended query protocol, the timeout starts running when any query-related message (Parse, Bind, Execute, Describe) arrives, and it is canceled by completion of an Execute or Sync message.

Setting `statement_timeout` in `lightdb.conf` is not recommended because it would affect all sessions.

`lock_timeout (integer)`

Abort any statement that waits longer than the specified amount of time while attempting to acquire a lock on a table, index, row, or other database object. The time limit applies separately to each lock acquisition attempt. The limit applies both to explicit locking requests (such as `LOCK TABLE`, or `SELECT FOR UPDATE` without `NOWAIT`) and to implicitly-acquired locks. If this value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

Unlike `statement_timeout`, this timeout can only occur while waiting for locks. Note that if `statement_timeout` is nonzero, it is rather pointless to set `lock_timeout` to the same or larger value, since the statement timeout would always trigger first. If `log_min_error_statement` is set to `ERROR` or lower, the statement that timed out will be logged.

Setting `lock_timeout` in `lightdb.conf` is not recommended because it would affect all sessions.

`idle_in_transaction_session_timeout (integer)`

Terminate any session with an open transaction that has been idle for longer than the specified amount of time. This allows any locks held by that session to be released and the connection slot to be reused; it also allows tuples visible only to this transaction to be vacuumed. See Section 22.1 for more details about this.

If this value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

`vacuum_freeze_table_age (integer)`

`VACUUM` performs an aggressive scan if the table's `pg_class.relfrozensid` field has reached the age specified by this setting. An aggressive scan differs from a regular `VACUUM` in that it visits every page that might contain unfrozen XIDs or MXIDs, not just those that might contain dead tuples. The default is 150 million transactions. Although users can set this value anywhere from zero to two billion, `VACUUM` will silently limit the effective value to 95% of `autovacuum_freeze_max_age`, so that a periodic manual `VACUUM` has a chance to run before an anti-wraparound autovacuum is launched for the table. For more information see Section 22.1.5.

`vacuum_freeze_min_age (integer)`

Specifies the cutoff age (in transactions) that `VACUUM` should use to decide whether to freeze row versions while scanning a table. The default is 50 million transactions. Although users can set this

value anywhere from zero to one billion, `VACUUM` will silently limit the effective value to half the value of `autovacuum_freeze_max_age`, so that there is not an unreasonably short time between forced autovacua. For more information see Section 22.1.5.

`vacuum_multixact_freeze_table_age` (integer)

`VACUUM` performs an aggressive scan if the table's `pg_class.relminmxid` field has reached the age specified by this setting. An aggressive scan differs from a regular `VACUUM` in that it visits every page that might contain unfrozen XIDs or MXIDs, not just those that might contain dead tuples. The default is 150 million multixacts. Although users can set this value anywhere from zero to two billion, `VACUUM` will silently limit the effective value to 95% of `autovacuum_multixact_freeze_max_age`, so that a periodic manual `VACUUM` has a chance to run before an anti-wraparound is launched for the table. For more information see Section 22.1.5.1.

`vacuum_multixact_freeze_min_age` (integer)

Specifies the cutoff age (in multixacts) that `VACUUM` should use to decide whether to replace multixact IDs with a newer transaction ID or multixact ID while scanning a table. The default is 5 million multixacts. Although users can set this value anywhere from zero to one billion, `VACUUM` will silently limit the effective value to half the value of `autovacuum_multixact_freeze_max_age`, so that there is not an unreasonably short time between forced autovacua. For more information see Section 22.1.5.1.

`bytea_output` (enum)

Sets the output format for values of type `bytea`. Valid values are `hex` (the default) and `escape` (the traditional LightDB format). See Section 8.4 for more information. The `bytea` type always accepts both formats on input, regardless of this setting.

`xmlbinary` (enum)

Sets how binary values are to be encoded in XML. This applies for example when `bytea` values are converted to XML by the functions `xmlelement` or `xmlforest`. Possible values are `base64` and `hex`, which are both defined in the XML Schema standard. The default is `base64`. For further information about XML-related functions, see Section 9.15.

The actual choice here is mostly a matter of taste, constrained only by possible restrictions in client applications. Both methods support all possible values, although the hex encoding will be somewhat larger than the base64 encoding.

`xmloption` (enum)

Sets whether `DOCUMENT` or `CONTENT` is implicit when converting between XML and character string values. See Section 8.13 for a description of this. Valid values are `DOCUMENT` and `CONTENT`. The default is `CONTENT`.

According to the SQL standard, the command to set this option is

```
SET XML OPTION { DOCUMENT | CONTENT };
```

This syntax is also available in LightDB.

`gin_pending_list_limit` (integer)

Sets the maximum size of a GIN index's pending list, which is used when `fastupdate` is enabled. If the list grows larger than this maximum size, it is cleaned up by moving the entries in it to the index's main GIN data structure in bulk. If this value is specified without units, it is taken as kilobytes. The default is four megabytes (4MB). This setting can be overridden for individual GIN indexes by changing index storage parameters. See Section 62.4.1 and Section 62.5 for more information.

`lightdb_syntax_compatible_type` (enum)

Valid values are Oracle, MySQL, off. The default value is off. Set the default value of the create database command. For example, when the value is oracle, "create database test" is equivalent to "create database test with lightdb\_syntax\_compatible\_type oracle".

`lightdb_dblevel_syntax_compatible_type` (enum)

report the syntax compatible type for current database. It is determined by the value of `lightdb_syntax_compatible_type` when database is created.

When the value is set to Oracle, the following features are different:

- When the operator is '/' and the data type of both operands is integer, the return value type is numeric.
- The empty string is considered as NULL, When type of an expression is text, varchar(n), varchar2(n), nvarchar2(n) or char(n).
- When type of an expression is char(n), convert to text or varchar(n) without removing the trailing space.
- Empty strings can be converted to integer types, floating-point types, numeric, date, time, timestamp with time zone and timestamp without time zone, and the value is NULL
- rowid is supported.
- ROWNUM is supported.
- SYSDATE and SYSTIMESTAMP used in plpgsql will get different value in different statement, otherwise get same value.
- search\_path can included oracle. When search\_path include oracle, Call oracle schema's functions first.
- transform\_null\_equals does not work.

When the value is set to MySQL, the following features are different:

- search\_path can included mysql. When search\_path include mysql, Call mysql schema's functions first.
- User variable is supported. See Section 4.2.14.
- transform\_null\_equals does not work.
- Same as mysql, the value of integer type can be used as a boolean. For example, "select \* from test where 1" is equivalent to "select \* form test where true".
- In insert and update statements, you can use varchar, char(n) and text to assign values to timestamp with time zone and datetime type attributes
- When converting characters (including only text, varchar, char) to numeric values (including only int, bigint, numeric, small int), the invalid characters at the end are ignored. A string without valid characters is a special case and is converted to 0. For example, '1a' is converted to 1.
- Support for comparison of date type (including only date,datetime and timestamp with time zone) expressions and character type value expressions.
- CAST(expr AS char[(n)]) (see Section 4.2.9) takes an expression of any type and produces a string with the VARCHAR data type.

- The result set of the case expression (see Section 9.18.1) supports more types of combinations

`lightdb_mysql_lower_case_table_names` (boolean)

In MySQL compatibility mode, whether to enable the all-lowercase feature of table names. The value is true or false, the default value is true. true: enable false: disable

`lightdb_ascii_zero_store_value` (integer)

It is determined by the value of `lightdb_ascii_zero_store_value` when the database is created, this value only make means when the database compatible type is set to Oracle or MySQL.

Lightdb 23.3 introduced a new database level GUC parameter `lightdb_ascii_zero_store_value`, the value must be within the valid range of 0 to 32, inclusive of both 0 and 32, and the value can not be changed once the database be created.

If the database compatible type is set to Oracle or MySQL, and `lightdb_ascii_zero_store_value` is set to non-zero ASCII value, ASCII value `E'\0'` and `CHR(0)` would result in the ASCII value equal to `lightdb_ascii_zero_store_value`, if we do a query by JDBC and send the bind parameter in text type, ASCII value `\0'` would be replaced into ASCII value `lightdb_ascii_zero_store_value` on server side, as for Libpq in this bind parameter case, the ASCII value replacement happens on Libpq side. Please also note that, if ASCII value `\0'` is replaced by ASCII value `lightdb_ascii_zero_store_value`, the later behaviors (after ASCII value `\0'` be replaced) of ASCII value `\0'` character in the system would be the same as ASCII value of `lightdb_ascii_zero_store_value`, such as order compare, function call of `concat`, `length`, `ascii`, and other function that accept character as input parameter.

`lightdb_convert_chinese_char` (boolean)

In Oracle compatibility mode, convert Chinese commas and Chinese spaces in SQL statements to English commas and spaces. The value is true or false, the default value is true. true: enable false: disable

`lightdb_ignore_template_compatible_type_mismatch` (boolean)

This GUC parameter is introduced in Lightdb 23.4. It is used to decide how to process the conflict of `TEMPLATE` and `LIGHTDB_SYNTAX_COMPATIBLE_TYPE` options in `CREATE DATABASE`. When the two options are conflict, an error will be reported when its value is false, otherwise the `TEMPLATE` option will be ignored. The value is true or false, the default value is false.

## 17.11.2. Locale and Formatting

`DateStyle` (string)

Sets the display format for date and time values, as well as the rules for interpreting ambiguous date input values. For historical reasons, this variable contains two independent components: the output format specification (`ISO`, `Postgres`, `SQL`, or `German`) and the input/output specification for year/month/day ordering (`DMY`, `MDY`, or `YMD`). These can be set separately or together. The keywords `Euro` and `European` are synonyms for `DMY`; the keywords `US`, `NonEuro`, and `NonEuropean` are synonyms for `MDY`. See Section 8.5 for more information. The built-in default is `ISO, MDY`, but `initdb` will initialize the configuration file with a setting that corresponds to the behavior of the chosen `lc_time` locale.

`IntervalStyle` (enum)

Sets the display format for interval values. The value `sql_standard` will produce output matching SQL standard interval literals. The value `postgres` (which is the default) will produce output matching postgres releases prior to 8.4 when the `DateStyle` parameter was set to `ISO`. The

value `postgres_verbose` will produce output matching postgres releases prior to 8.4 when the `DateStyle` parameter was set to non-ISO output. The value `iso_8601` will produce output matching the time interval “format with designators” defined in section 4.4.3.2 of ISO 8601.

The `IntervalStyle` parameter also affects the interpretation of ambiguous interval input. See Section 8.5.4 for more information.

`TimeZone` (string)

Sets the time zone for displaying and interpreting time stamps. The built-in default is GMT, but that is typically overridden in `lightdb.conf`; `initdb` will install a setting there corresponding to its system environment. See Section 8.5.3 for more information.

`timezone_abbreviations` (string)

Sets the collection of time zone abbreviations that will be accepted by the server for datetime input. The default is 'Default', which is a collection that works in most of the world; there are also 'Australia' and 'India', and other collections can be defined for a particular installation. See Section B.4 for more information.

`extra_float_digits` (integer)

This parameter adjusts the number of digits used for textual output of floating-point values, including `float4`, `float8`, and geometric data types.

If the value is 1 (the default) or above, float values are output in shortest-precise format; see Section 8.1.3. The actual number of digits generated depends only on the value being output, not on the value of this parameter. At most 17 digits are required for `float8` values, and 9 for `float4` values. This format is both fast and precise, preserving the original binary float value exactly when correctly read. For historical compatibility, values up to 3 are permitted.

If the value is zero or negative, then the output is rounded to a given decimal precision. The precision used is the standard number of digits for the type (`FLT_DIG` or `DBL_DIG` as appropriate) reduced according to the value of this parameter. (For example, specifying -1 will cause `float4` values to be output rounded to 5 significant digits, and `float8` values rounded to 14 digits.) This format is slower and does not preserve all the bits of the binary float value, but may be more human-readable.

**Note**

The meaning of this parameter, and its default value, changed in LightDB 12; see Section 8.1.3 for further discussion.

`client_encoding` (string)

Sets the client-side encoding (character set). The default is to use the database encoding. The character sets supported by the LightDB server are described in Section 21.3.1.

`lc_messages` (string)

Sets the language in which messages are displayed. Acceptable values are system-dependent; see Section 21.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

On some systems, this locale category does not exist. Setting this variable will still work, but there will be no effect. Also, there is a chance that no translated messages for the desired language exist. In that case you will continue to see the English messages.

Only superusers can change this setting, because it affects the messages sent to the server log as well as to the client, and an improper value might obscure the readability of the server logs.

`lc_monetary` (string)

Sets the locale to use for formatting monetary amounts, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 21.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`lc_numeric` (string)

Sets the locale to use for formatting numbers, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 21.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`lc_time` (string)

Sets the locale to use for formatting dates and times, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 21.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`default_text_search_config` (string)

Selects the text search configuration that is used by those variants of the text search functions that do not have an explicit argument specifying the configuration. See Chapter 12 for further information. The built-in default is `pg_catalog.simple`, but `initdb` will initialize the configuration file with a setting that corresponds to the chosen `lc_ctype` locale, if a configuration matching that locale can be identified.

`lightdb_tsearch_non_stopwords` (string)

LightDB full text search has many built-in stop words. Words connected by stop words will be split into multiple independent words by `to_tsvector` function, for example, "2022-04-10" will be split into "2022", "04" and "10". `lightdb_tsearch_non_stopwords` is used to customize non-stop words, which is just the opposite of stop words, that is, non-stop words are considered to be an integral part of a word and thus will not be split into multiple independent words by `to_tsvector` function any more. Still the above example, if you set '-' as non-stop words, you will only get a result of "2022-04-10". The following characters can be used as non stop words in LightDB. Choose freely from the following characters to improve the accuracy and ease of use of full text search by this. Supported nonstopwords list:

```
! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [ \ ] ^ _ `
{ | } ~
```

See Chapter 12 for further information.

The built-in default value is "", you can update `lightdb_tsearch_non_stopwords` values in `lightdb.conf`. but if you update `lightdb_tsearch_non_stopwords` in `lightdb.conf`, you must restart the server to take effect. You can also update `lightdb_tsearch_non_stopwords` by set `lightdb_tsearch_non_stopwords` during session without restart server. Selects any combination of characters from the nonstopwords list , For example:

```
lightdb@postgres=# set lightdb_tsearch_non_stopwords =
'@-=:_';
SET
```

```
lightdb@postgres=# select to_tsvector('this is
from lt_hs_tab table logged at 2020-12-21 00:22:32,
username=zjh&pwd=balabala www.hs.net ');

to_tsvector

-----
'00:22:32':9 '2020-12-21':8 'log':6 'lt_hs_tab':4
'pwd=balabala':11 'tabl':5 'username=zjh':10 'www.hs.net':12
(1 row)

lightdb@postgres=# set lightdb_tsearch_non_stopwords =
'';
SET
lightdb@postgres=# select to_tsvector('this is
from lt_hs_tab table logged at 2020-12-21 00:22:32,
username=zjh&pwd=balabala www.hs.net ');

to_tsvector

-----
'-12':11 '-21':12 '00':13 '2020':10 '22':14 '32':15
'balabala':19 'hs':5 'log':8 'lt':4 'pwd':18 'tab':6 'tabl':7
'usernam':16 'www.hs.net':20 'zjh':17
(1 row)
```

If the configuration `lightdb_tsearch_non_stopwords` parameter is invalid, an error will be reported. For example:

```
lightdb@postgres=# set lightdb_tsearch_non_stopwords =
'l@';
ERROR:  invalid value for parameter
"lightdb_tsearch_non_stopwords": "l@"
DETAIL:  lightdb_tsearch_non_stopwords not support 'l@'
as non stopword.
```

`lightdb_tsearch_word_superpose` (boolean)

`lightdb_tsearch_word_superpose` is used to overlay the effect of using stop words and non-stop words. For example, if you set `lightdb_tsearch_word_superpose` to on and set `lightdb_tsearch_non_stopwords` to '-', you will get the results including "2022", "04", "10" and "2022-04-10" at the same time when using `to_tsvector("2022-04-10")`. See Chapter 12 for further information.

The built-in default value is off, you can update `lightdb_tsearch_word_superpose` value in `lightdb.conf`, but if you update `lightdb_tsearch_word_superpose` in `lightdb.conf`, you must restart the server to take effect. You can also update `lightdb_tsearch_word_superpose` by set `lightdb_tsearch_word_superpose` during session without restart server. Chinese text is not supported. For example:

```
lightdb@postgres=# set lightdb_tsearch_word_superpose =
off;
SET
```



```
lightdb@postgres=# select to_tsvector('this is
from lt_hs_tab table logged at 2020-12-21 00:22:32,
username=zjh&pwd=balabala www.hs.net');
```

to\_tsvector

```
-----
'-12':11 '-21':12 '00':13 '2020':10 '22':14 '32':15
'balabala':19 'hs':5 'log':8 'lt':4 'pwd':18 'tab':6 'tabl':7
'usernam':16 'www.hs.net':20 'zjh':17
(1 row)
```

```
lightdb@postgres=# set lightdb_tsearch_word_superpose =
on;
```

SET

```
lightdb@postgres=# select to_tsvector('this is
from lt_hs_tab table logged at 2020-12-21 00:22:32,
username=zjh&pwd=balabala www.hs.net');
```

to\_tsvector

```
-----
'-12':33 '-21':34 '00':13,35 '12':11 '2020':10,32
'21':12 '22':14,36 '32':15,37 'balabala':19,41 'hs':5,21,27
'log':8,30 'lt':4,26 'net':22 'pwd':18,40 'tab':6,28
'tabl':7,29 'usernam':16
,38 'www':20 'www.hs.net':42 'zjh':17,39
(1 row)
```

`lightdb_encryption_key_command` (string)

The key path used to store Transparent Data Encryption, which ensures that the TDE key will be read again after each restart of the data.

See Chapter 31 for further information.

When Transparent Data Encryption is not used, this parameter is null. Only when Transparent Data Encryption is configured, this parameter stores the tde key. A setting example using the SET statement is shown below.

```
show lightdb_encryption_key_command;
lightdb_encryption_key_command
-----
/home/lightdb/stage/provide_key.sh
(1 row)
```

`nls_date_format` (string)

Only in Oracle compatible mode, `lightdb` can configure `nls_date_format` parameter sets the display output format of `sysdate` and type `timestamp`.

See Section 9.9 for further information.

You must set a sysdate format for the nls\_date\_format variable in advance. A setting example using the SET statement is shown below.

```
SET nls_date_format = 'YYYY/MM/DD HH24:MI:SS';
```

```
select sysdate;
      sysdate
-----
2022/09/15 10:03:29
(1 row)
```

```
select to_char(sysdate);
      to_char
-----
2022/09/15 10:08:46
(1 row)
```

nls\_timestamp\_format (string)

Only in Oracle compatible mode, lightdb can configure nls\_timestamp\_format parameter sets the display output format of systimestamp and type timestamptz.

See Section 9.9 for further information.

You must set a systimestamp format for the nls\_timestamp\_format variable in advance. A setting example using the SET statement is shown below.

```
SET nls_timestamp_format = 'YYYY/MM/DD HH24:MI:SS.FF6TZH';
```

```
select systimestamp;
      systimestamp
-----
2022/09/15 10:05:56.884814+08
(1 row)
```

lightdb\_only\_full\_group\_by (boolean)

Only in MySQL compatibility mode, this parameter is used to control whether the SELECT DISTINCT...ORDER BY syntax of msql is compatible with that of msql other than ONLY\_FULL\_GROUP\_BY. The default value of this parameter is on.

By default, lightdb will report errors for inconsistent columns in the SELECT DISTINCT...ORDER BY syntax:

```
select distinct a from test_distinct_order_tbl order by d;
ERROR:  for SELECT DISTINCT, ORDER BY expressions must appear in
select list
LINE 1: select distinct a from test_distinct_order_tbl order by
d;
^
```

Only in MySQL compatibility mode and `lightdb_only_full_group_by` setting off, the above SQL can be executed normally:

```
set lightdb_only_full_group_by = off;
SET

select distinct a from test_distinct_order_tbl order by d;
a
---
3
1
2
(3 rows)
```

Note that this behavior is only a nonstandard syntax compatible with MySQL. It is used to ensure that the execution in LightDB will not report errors, but the results cannot be guaranteed to be completely consistent with MySQL. It is not recommended to use this feature. Please use the standard syntax format.

### 17.11.3. Shared Library Preloading

Several settings are available for preloading shared libraries into the server, in order to load additional functionality or achieve performance benefits. For example, a setting of `'$libdir/mylib'` would cause `mylib.so` (or on some platforms, `mylib.sl`) to be preloaded from the installation's standard library directory. The differences between the settings are when they take effect and what privileges are required to change them.

LightDB procedural language libraries can be preloaded in this way, typically by using the syntax `'$libdir/plXXX'` where XXX is `pgsql`, `plorasql`.

Only shared libraries specifically intended to be used with LightDB can be loaded this way. Every LightDB-supported library has a “magic block” that is checked to guarantee compatibility. For this reason, non-LightDB libraries cannot be loaded in this way. You might be able to use operating-system facilities such as `LD_PRELOAD` for that.

In general, refer to the documentation of a specific module for the recommended way to load that module.

`local_preload_libraries` (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. The parameter value only takes effect at the start of the connection. Subsequent changes have no effect. If a specified library is not found, the connection attempt will fail.

This option can be set by any user. Because of that, the libraries that can be loaded are restricted to those appearing in the `plugins` subdirectory of the installation's standard library directory. (It is the database administrator's responsibility to ensure that only “safe” libraries are installed there.) Entries in `local_preload_libraries` can specify this directory explicitly, for example `$libdir/plugins/mylib`, or just specify the library name — `mylib` would have the same effect as `$libdir/plugins/mylib`.

The intent of this feature is to allow unprivileged users to load debugging or performance-measurement libraries into specific sessions without requiring an explicit `LOAD` command. To that end, it would be typical to set this parameter using the `LTOPTIONS` environment variable on the client or by using `ALTER ROLE SET`.

However, unless a module is specifically designed to be used in this way by non-superusers, this is usually not the right setting to use. Look at `session_preload_libraries` instead.

`session_preload_libraries` (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. The parameter value only takes effect at the start of the connection. Subsequent changes have no effect. If a specified library is not found, the connection attempt will fail. Only superusers can change this setting.

The intent of this feature is to allow debugging or performance-measurement libraries to be loaded into specific sessions without an explicit `LOAD` command being given. For example, `auto_explain` could be enabled for all sessions under a given user name by setting this parameter with `ALTER ROLE SET`. Also, this parameter can be changed without restarting the server (but changes only take effect when a new session is started), so it is easier to add new modules this way, even if they should apply to all sessions.

Unlike `shared_preload_libraries`, there is no large performance advantage to loading a library at session start rather than when it is first used. There is some advantage, however, when connection pooling is used.

`shared_preload_libraries` (string)

This variable specifies one or more shared libraries to be preloaded at server start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. This parameter can only be set at server start. If a specified library is not found, the server will fail to start.

Some libraries need to perform certain operations that can only take place at postmaster start, such as allocating shared memory, reserving light-weight locks, or starting background workers. Those libraries must be loaded at server start through this parameter. See the documentation of each library for details.

Other libraries can also be preloaded. By preloading a shared library, the library startup time is avoided when the library is first used. However, the time to start each new server process might increase slightly, even if that process never uses the library. So this parameter is recommended only for libraries that will be used in most sessions. Also, changing this parameter requires a server restart, so this is not the right setting to use for short-term debugging tasks, say. Use `session_preload_libraries` for that instead.

**Note**

On Windows hosts, preloading a library at server start will not reduce the time required to start each new server process; each server process will re-load all preload libraries. However, `shared_preload_libraries` is still useful on Windows hosts for libraries that need to perform operations at postmaster start time.

`jit_provider` (string)

This variable is the name of the JIT provider library to be used (see Section 29.4.2). The default is `llvmjit`. This parameter can only be set at server start.

If set to a non-existent library, JIT will not be available, but no error will be raised. This allows JIT support to be installed separately from the main LightDB package.

## 17.11.4. Other Defaults

`dynamic_library_path` (string)

If a dynamically loadable module needs to be opened and the file name specified in the `CREATE FUNCTION` or `LOAD` command does not have a directory component (i.e., the name does not contain a slash), the system will search this path for the required file.

The value for `dynamic_library_path` must be a list of absolute directory paths separated by colons (or semi-colons on Windows). If a list element starts with the special string `$libdir`, the compiled-in LightDB package library directory is substituted for `$libdir`; this is where the modules provided by the standard LightDB distribution are installed. (Use `lt_config --pkglibdir` to find out the name of this directory.) For example:

```
dynamic_library_path = '/usr/local/lib/lightdb:/home/my_project/lib:$libdir'
```

The default value for this parameter is `'$libdir'`. If the value is set to an empty string, the automatic path search is turned off.

This parameter can be changed at run time by superusers, but a setting done that way will only persist until the end of the client connection, so this method should be reserved for development purposes. The recommended way to set this parameter is in the `lightdb.conf` configuration file.

`gin_fuzzy_search_limit` (integer)

Soft upper limit of the size of the set returned by GIN index scans. For more information see Section 62.5.

## 17.12. Lock Management

`deadlock_timeout` (integer)

This is the amount of time to wait on a lock before checking to see if there is a deadlock condition. The check for deadlock is relatively expensive, so the server doesn't run it every time it waits for a lock. We optimistically assume that deadlocks are not common in production applications and just wait on the lock for a while before checking for a deadlock. Increasing this value reduces the amount of time wasted in needless deadlock checks, but slows down reporting of real deadlock errors. If this value is specified without units, it is taken as milliseconds. The default is one second (1s), which is probably about the smallest value you would want in practice. On a heavily loaded server you might want to raise it. Ideally the setting should exceed your typical transaction time, so as to improve the odds that a lock will be released before the waiter decides to check for deadlock. Only superusers can change this setting.

When `log_lock_waits` is set, this parameter also determines the amount of time to wait before a log message is issued about the lock wait. If you are trying to investigate locking delays you might want to set a shorter than normal `deadlock_timeout`.

`max_locks_per_transaction` (integer)

The shared lock table tracks locks on `max_locks_per_transaction * (max_connections + max_prepared_transactions)` objects (e.g., tables); hence, no more than this many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of rows that can be locked; that value is unlimited. The default, 64, has historically proven sufficient, but you might need to raise

this value if you have queries that touch many different tables in a single transaction, e.g., query of a parent table with many children. This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`max_pred_locks_per_transaction` (integer)

The shared predicate lock table tracks locks on `max_pred_locks_per_transaction * (max_connections + max_prepared_transactions)` objects (e.g., tables); hence, no more than this many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of rows that can be locked; that value is unlimited. The default, 64, has generally been sufficient in testing, but you might need to raise this value if you have clients that touch many different tables in a single serializable transaction. This parameter can only be set at server start.

`max_pred_locks_per_relation` (integer)

This controls how many pages or tuples of a single relation can be predicate-locked before the lock is promoted to covering the whole relation. Values greater than or equal to zero mean an absolute limit, while negative values mean `max_pred_locks_per_transaction` divided by the absolute value of this setting. The default is -2, which keeps the behavior from previous versions of LightDB. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`max_pred_locks_per_page` (integer)

This controls how many rows on a single page can be predicate-locked before the lock is promoted to covering the whole page. The default is 2. This parameter can only be set in the `lightdb.conf` file or on the server command line.

## 17.13. Version and Platform Compatibility

### 17.13.1. Previous LightDB Versions

`array_nulls` (boolean)

This controls whether the array input parser recognizes unquoted NULL as specifying a null array element. By default, this is `on`, allowing array values containing null values to be entered. However, LightDB versions before 8.2 did not support null values in arrays, and therefore would treat NULL as specifying a normal array element with the string value “NULL”. For backward compatibility with applications that require the old behavior, this variable can be turned `off`.

Note that it is possible to create array values containing null values even when this variable is `off`.

`backslash_quote` (enum)

This controls whether a quote mark can be represented by `\'` in a string literal. The preferred, SQL-standard way to represent a quote mark is by doubling it (`' '`) but LightDB has historically also accepted `\'`. However, use of `\'` creates security risks because in some client character set encodings, there are multibyte characters in which the last byte is numerically equivalent to ASCII `\`. If client-side code does escaping incorrectly then a SQL-injection attack is possible. This risk can be prevented by making the server reject queries in which a quote mark appears to be escaped by a backslash. The allowed values of `backslash_quote` are `on` (allow `\'` always), `off` (reject always), and `safe_encoding` (allow only if client encoding does not allow ASCII `\` within a multibyte character). `safe_encoding` is the default setting.

Note that in a standard-conforming string literal, `\` just means `\` anyway. This parameter only affects the handling of non-standard-conforming literals, including escape string syntax (`E' . . . '`).

`escape_string_warning` (boolean)

When on, a warning is issued if a backslash (`\`) appears in an ordinary string literal (`'...'` syntax) and `standard_conforming_strings` is off. The default is on.

Applications that wish to use backslash as escape should be modified to use escape string syntax (`E'...'`), because the default behavior of ordinary strings is now to treat backslash as an ordinary character, per SQL standard. This variable can be enabled to help locate code that needs to be changed.

`lo_compat_privileges` (boolean)

The default is off. Only superusers can change this setting.

Setting this variable does not disable all security checks related to large objects — only those for which the default behavior has changed in LightDB 9.0.

`operator_precedence_warning` (boolean)

When on, the parser will emit a warning for any construct that might have changed meanings since LightDB 9.4 as a result of changes in operator precedence. This is useful for auditing applications to see if precedence changes have broken anything; but it is not meant to be kept turned on in production, since it will warn about some perfectly valid, standard-compliant SQL code. The default is off.

See Section 4.1.6 for more information.

`quote_all_identifiers` (boolean)

When the database generates SQL, force all identifiers to be quoted, even if they are not (currently) keywords. This will affect the output of `EXPLAIN` as well as the results of functions like `pg_get_viewdef`. See also the `--quote-all-identifiers` option of `lt_dump` and `lt_dumpall`.

`standard_conforming_strings` (boolean)

This controls whether ordinary string literals (`'...'`) treat backslashes literally, as specified in the SQL standard. Beginning in LightDB 9.1, the default is on. Applications can check this parameter to determine how string literals will be processed. The presence of this parameter can also be taken as an indication that the escape string syntax (`E'...'`) is supported. Escape string syntax (Section 4.1.2.2) should be used if an application desires backslashes to be treated as escape characters.

`synchronize_seqscans` (boolean)

This allows sequential scans of large tables to synchronize with each other, so that concurrent scans read the same block at about the same time and hence share the I/O workload. When this is enabled, a scan might start in the middle of the table and then “wrap around” the end to cover all rows, so as to synchronize with the activity of scans already in progress. This can result in unpredictable changes in the row ordering returned by queries that have no `ORDER BY` clause. Setting this parameter to off ensures the pre-8.3 behavior in which a sequential scan always starts from the beginning of the table. The default is on.

## 17.13.2. Platform and Client Compatibility

`transform_null_equals` (boolean)

When on and the value of `lightdb_dblevel_syntax_compatible_type` is off, expressions of the form `expr = NULL` (or `NULL = expr`) are treated as `expr IS NULL`, that is, they return true if `expr` evaluates to the null value, and false otherwise. The correct SQL-spec-compliant behavior of `expr = NULL` is to always return null (unknown). This parameter defaults to on.

However, filtered forms in Microsoft Access generate queries that appear to use `expr = NULL` to test for null values, so if you use that interface to access the database you might want to turn this option on. Since expressions of the form `expr = NULL` always return the null value (using the SQL standard interpretation), they are not very useful and do not appear often in normal applications so this option does little harm in practice. But new users are frequently confused about the semantics of expressions involving null values, so this option is off by default.

Note that this option only affects the exact form `= NULL`, not other comparison operators or other expressions that are computationally equivalent to some expression involving the equals operator (such as `IN`). Thus, this option is not a general fix for bad programming.

Refer to Section 9.2 for related information.

## 17.14. Error Handling

`exit_on_error` (boolean)

If on, any error will terminate the current session. By default, this is set to off, so that only FATAL errors will terminate the session.

`restart_after_crash` (boolean)

When set to on, which is the default, LightDB will automatically reinitialize after a backend crash. Leaving this value set to on is normally the best way to maximize the availability of the database. However, in some circumstances, such as when LightDB is being invoked by clusterware, it may be useful to disable the restart so that the clusterware can gain control and take any actions it deems appropriate.

This parameter can only be set in the `lightdb.conf` file or on the server command line.

`data_sync_retry` (boolean)

When set to off, which is the default, LightDB will raise a PANIC-level error on failure to flush modified data files to the file system. This causes the database server to crash. This parameter can only be set at server start.

On some operating systems, the status of data in the kernel's page cache is unknown after a write-back failure. In some cases it might have been entirely forgotten, making it unsafe to retry; the second attempt may be reported as successful, when in fact the data has been lost. In these circumstances, the only way to avoid data loss is to recover from the WAL after any failure is reported, preferably after investigating the root cause of the failure and replacing any faulty hardware.

If set to on, LightDB will instead report an error but continue to run so that the data flushing operation can be retried in a later checkpoint. Only set it to on after investigating the operating system's treatment of buffered data in case of write-back failure.

## 17.15. Preset Options

The following “parameters” are read-only, and are determined when LightDB is compiled or when it is installed. As such, they have been excluded from the sample `lightdb.conf` file. These options report various aspects of LightDB behavior that might be of interest to certain applications, particularly administrative front-ends.

`block_size` (integer)

Reports the size of a disk block. It is determined by the value of `BLCKSZ` when building the server. The default value is 8192 bytes. The meaning of some configuration variables (such as `shared_buffers`) is influenced by `block_size`. See Section 17.4 for information.



`data_checksums` (boolean)

Reports whether data checksums are enabled for this cluster. See `data_checksums` for more information.

`data_directory_mode` (integer)

On Unix systems this parameter reports the permissions of the data directory defined by (`data_directory`) at startup. (On Microsoft Windows this parameter will always display 0700). See `group access` for more information.

`debug_assertions` (boolean)

Reports whether LightDB has been built with assertions enabled. That is the case if the macro `USE_ASSERT_CHECKING` is defined when LightDB is built (accomplished e.g., by the configure option `--enable-cassert`). By default LightDB is built without assertions.

`integer_datetimes` (boolean)

Reports whether LightDB was built with support for 64-bit-integer dates and times. As of LightDB 10, this is always on.

`lc_collate` (string)

Reports the locale in which sorting of textual data is done. See Section 21.1 for more information. This value is determined when a database is created.

`lc_ctype` (string)

Reports the locale that determines character classifications. See Section 21.1 for more information. This value is determined when a database is created. Ordinarily this will be the same as `lc_collate`, but for special applications it might be set differently.

`max_function_args` (integer)

Reports the maximum number of function arguments. It is determined by the value of `FUNC_MAX_ARGS` when building the server. The default value is 100 arguments.

`max_identifier_length` (integer)

Reports the maximum identifier length. It is determined as one less than the value of `NAMEDATALEN` when building the server. The default value of `NAMEDATALEN` is 64; therefore the default `max_identifier_length` is 63 bytes, which can be less than 63 characters when using multibyte encodings.

`max_index_keys` (integer)

Reports the maximum number of index keys. It is determined by the value of `INDEX_MAX_KEYS` when building the server. The default value is 32 keys.

`segment_size` (integer)

Reports the number of blocks (pages) that can be stored within a file segment. It is determined by the value of `RELSEG_SIZE` when building the server. The maximum size of a segment file in bytes is equal to `segment_size` multiplied by `block_size`; by default this is 1GB.

`server_encoding` (string)

Reports the database encoding (character set). It is determined when the database is created. Ordinarily, clients need only be concerned with the value of `client_encoding`.

`server_version` (string)

Reports the version number of the server. It is determined by the value of `PG_VERSION` when building the server.

`server_version_num` (integer)

Reports the version number of the server as an integer. It is determined by the value of `PG_VERSION_NUM` when building the server.

`ssl_library` (string)

Reports the name of the SSL library that this LightDB server was built with (even if SSL is not currently configured or in use on this instance), for example `OpenSSL`, or an empty string if none.

`wal_block_size` (integer)

Reports the size of a WAL disk block. It is determined by the value of `XLOG_BLCKSZ` when building the server. The default value is 8192 bytes.

`wal_segment_size` (integer)

Reports the size of write ahead log segments. The default value is 16MB. See Section 27.4 for more information.

## 17.16. Customized Options

This feature was designed to allow parameters not normally known to LightDB to be added by add-on modules (such as procedural languages). This allows extension modules to be configured in the standard ways.

Custom options have two-part names: an extension name, then a dot, then the parameter name proper, much like qualified names in SQL. An example is `plpgsql.variable_conflict`.

Because custom options may need to be set in processes that have not loaded the relevant extension module, LightDB will accept a setting for any two-part parameter name. Such variables are treated as placeholders and have no function until the module that defines them is loaded. When an extension module is loaded, it will add its variable definitions, convert any placeholder values according to those definitions, and issue warnings for any unrecognized placeholders that begin with its extension name.

## 17.17. Developer Options

The following parameters are intended for work on the LightDB source code, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them on a production database. As such, they have been excluded from the sample `lightdb.conf` file. Note that many of these parameters require special source compilation flags to work at all.

`allow_in_place_tablespace` (boolean)

Allows tablespaces to be created as directories inside `lt_tblspc`, when an empty location string is provided to the `CREATE TABLESPACE` command. This is intended to allow testing replication scenarios where primary and standby servers are running on the same machine. Such directories are likely to confuse backup tools that expect to find only symbolic links in that location. Only superusers can change this setting.

`allow_system_table_mods` (boolean)

Allows modification of the structure of system tables as well as certain other risky actions on system tables. This is otherwise not allowed even for superusers. Ill-advised use of this setting can cause irretrievable data loss or seriously corrupt the database system. Only superusers can change this setting.

`backtrace_functions` (string)

This parameter contains a comma-separated list of C function names. If an error is raised and the name of the internal C function where the error happens matches a value in the list, then a backtrace is written to the server log together with the error message. This can be used to debug specific areas of the source code.

Backtrace support is not available on all platforms, and the quality of the backtraces depends on compilation options.

This parameter can only be set by superusers.

`ignore_system_indexes` (boolean)

Ignore system indexes when reading system tables (but still update the indexes when modifying the tables). This is useful when recovering from damaged system indexes. This parameter cannot be changed after session start.

`post_auth_delay` (integer)

The amount of time to delay when a new server process is started, after it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger. If this value is specified without units, it is taken as seconds. A value of zero (the default) disables the delay. This parameter cannot be changed after session start.

`pre_auth_delay` (integer)

The amount of time to delay just after a new server process is forked, before it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger to trace down misbehavior in authentication. If this value is specified without units, it is taken as seconds. A value of zero (the default) disables the delay. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`trace_notify` (boolean)

Generates a great amount of debugging output for the `LISTEN` and `NOTIFY` commands. `client_min_messages` or `log_min_messages` must be `DEBUG1` or lower to send this output to the client or server logs, respectively.

`trace_recovery_messages` (enum)

Enables logging of recovery-related debugging output that otherwise would not be logged. This parameter allows the user to override the normal setting of `log_min_messages`, but only for specific messages. This is intended for use in debugging Hot Standby. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, and `LOG`. The default, `LOG`, does not affect logging decisions at all. The other values cause recovery-related debug messages of that priority or higher to be logged as though they had `LOG` priority; for common settings of `log_min_messages` this results in unconditionally sending them to the server log. This parameter can only be set in the `lightdb.conf` file or on the server command line.

`trace_sort` (boolean)

If on, emit information about resource usage during sort operations. This parameter is only available if the `TRACE_SORT` macro was defined when LightDB was compiled. (However, `TRACE_SORT` is currently defined by default.)

`trace_locks` (boolean)

If on, emit information about lock usage. Information dumped includes the type of lock operation, the type of lock and the unique identifier of the object being locked or unlocked. Also included

are bit masks for the lock types already granted on this object as well as for the lock types awaited on this object. For each lock type a count of the number of granted locks and waiting locks is also dumped as well as the totals. An example of the log file output is shown here:

```
LOG: LockAcquire: new: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG: GrantLock: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(2) req(1,0,0,0,0,0,0,0)=1 grant(1,0,0,0,0,0,0,0)=1
      wait(0) type(AccessShareLock)
LOG: UnGrantLock: updated: lock(0xb7acd844)
      id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG: CleanUpLock: deleting: lock(0xb7acd844)
      id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0,0)=0
      wait(0) type(INVALID)
```

Details of the structure being dumped may be found in `src/include/storage/lock.h`.

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`trace_lwlocks` (boolean)

If on, emit information about lightweight lock usage. Lightweight locks are intended primarily to provide mutual exclusion of access to shared-memory data structures.

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`trace_userlocks` (boolean)

If on, emit information about user lock usage. Output is the same as for `trace_locks`, only for advisory locks.

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`trace_lock_oidmin` (integer)

If set, do not trace locks for tables below this OID (used to avoid output on system tables).

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`trace_lock_table` (integer)

Unconditionally trace locks on this table (OID).

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`debug_deadlocks` (boolean)

If set, dumps information about all current locks when a deadlock timeout occurs.

This parameter is only available if the `LOCK_DEBUG` macro was defined when LightDB was compiled.

`log_btree_build_stats` (boolean)

If set, logs system resource usage statistics (memory and CPU) on various B-tree operations.

This parameter is only available if the `BTREE_BUILD_STATS` macro was defined when LightDB was compiled.

`wal_consistency_checking` (string)

This parameter is intended to be used to check for bugs in the WAL redo routines. When enabled, full-page images of any buffers modified in conjunction with the WAL record are added to the record. If the record is subsequently replayed, the system will first apply each record and then test whether the buffers modified by the record match the stored images. In certain cases (such as hint bits), minor variations are acceptable, and will be ignored. Any unexpected differences will result in a fatal error, terminating recovery.

The default value of this setting is the empty string, which disables the feature. It can be set to `all` to check all records, or to a comma-separated list of resource managers to check only records originating from those resource managers. Currently, the supported resource managers are `heap`, `heap2`, `btree`, `hash`, `gin`, `gist`, `sequence` and `generic`. Only superusers can change this setting.

`wal_debug` (boolean)

If on, emit WAL-related debugging output. This parameter is only available if the `WAL_DEBUG` macro was defined when LightDB was compiled.

`ignore_checksum_failure` (boolean)

Only has effect if data checksums are enabled.

Detection of a checksum failure during a read normally causes LightDB to report an error, aborting the current transaction. Setting `ignore_checksum_failure` to `on` causes the system to ignore the failure (but still report a warning), and continue processing. This behavior may *cause crashes, propagate or hide corruption, or other serious problems*. However, it may allow you to get past the error and retrieve undamaged tuples that might still be present in the table if the block header is still sane. If the header is corrupt an error will be reported even if this option is enabled. The default setting is `off`, and it can only be changed by a superuser.

`zero_damaged_pages` (boolean)

Detection of a damaged page header normally causes LightDB to report an error, aborting the current transaction. Setting `zero_damaged_pages` to `on` causes the system to instead report a warning, zero out the damaged page in memory, and continue processing. This behavior *will destroy data*, namely all the rows on the damaged page. However, it does allow you to get past the error and retrieve rows from any undamaged pages that might be present in the table. It is useful for recovering data if corruption has occurred due to a hardware or software error. You should generally not set this on until you have given up hope of recovering data from the damaged pages of a table. Zeroed-out pages are not forced to disk so it is recommended to recreate the table or the index before turning this parameter off again. The default setting is `off`, and it can only be changed by a superuser.

`ignore_invalid_pages` (boolean)

If set to `off` (the default), detection of WAL records having references to invalid pages during recovery causes LightDB to raise a PANIC-level error, aborting the recovery. Setting `ignore_invalid_pages` to `on` causes the system to ignore invalid page references in WAL records (but still report a warning), and continue the recovery. This behavior may *cause crashes, data loss, propagate or hide corruption, or other serious problems*. However, it may allow you to get past the PANIC-level error, to finish the recovery, and to cause the server to start up. The parameter can only be set at server start. It only has effect during recovery or in standby mode.

`jit_debugging_support` (boolean)

If LLVM has the required functionality, register generated functions with GDB. This makes debugging easier. The default setting is `off`. This parameter can only be set at server start.

`jit_dump_bitcode` (boolean)

Writes the generated LLVM IR out to the file system, inside `data_directory`. This is only useful for working on the internals of the JIT implementation. The default setting is `off`. This parameter can only be changed by a superuser.

`jit_expressions` (boolean)

Determines whether expressions are JIT compiled, when JIT compilation is activated (see Section 29.2). The default is `on`.

`jit_profiling_support` (boolean)

If LLVM has the required functionality, emit the data needed to allow `perf` to profile functions generated by JIT. This writes out files to `$HOME/.debug/jit/`; the user is responsible for performing cleanup when desired. The default setting is `off`. This parameter can only be set at server start.

`jit_tuple_deforming` (boolean)

Determines whether tuple deforming is JIT compiled, when JIT compilation is activated (see Section 29.2). The default is `on`.

## 17.18. Short Options

For convenience there are also single letter command-line option switches available for some parameters. They are described in Table 17.3. Some of these options exist for historical reasons, and their presence as a single-letter option does not necessarily indicate an endorsement to use the option heavily.

**Table 17.3. Short Option Key**

Short Option	Equivalent
<code>-B x</code>	<code>shared_buffers = x</code>
<code>-d x</code>	<code>log_min_messages = DEBUGx</code>
<code>-e</code>	<code>datestyle = euro</code>
<code>-fb, -fh, -fi, -fm, -fn, -fo, -fs, -ft</code>	<code>enable_bitmapscan = off, enable_hashjoin = off, enable_indexscan = off, enable_mergejoin = off, enable_nestloop = off, enable_indexonlyscan = off, enable_seqscan = off, enable_tidscan = off</code>
<code>-F</code>	<code>fsync = off</code>
<code>-h x</code>	<code>listen_addresses = x</code>
<code>-i</code>	<code>listen_addresses = '*'</code>
<code>-k x</code>	<code>unix_socket_directories = x</code>
<code>-l</code>	<code>ssl = on</code>
<code>-N x</code>	<code>max_connections = x</code>
<code>-O</code>	<code>allow_system_table_mods = on</code>
<code>-p x</code>	<code>port = x</code>

Short Option	Equivalent
-P	ignore_system_indexes = on
-s	log_statement_stats = on
-S x	work_mem = x
-tpa, -tpl, -te	log_parser_stats = on, log_planner_stats = on, log_executor_stats = on
-W x	post_auth_delay = x

## 17.19. Other Options

`lightdb_enable_default_tablespace` (integer)

Enables or disables default tablespace `lt_users` for create database. This is off by default.

`lightdb_external_virtual_ip` (string)

Configure the external virtual IP. If there is an external virtual IP, before the standby automatically switches to primary, it will determine whether the local machine has this IP address. If there is no IP address, it will not be promoted automatically. see `ltcluster`<sup>2</sup>

`lightdb_auto_incre_null_mysql_compatible` (integer)

this guc parameter controls whether or not compatible below mysql behavior. When mysql's table column is `auto_increment` and has not null constraint, it allow explicit insert null value to this column, and will use auto generated value as the value, in oracle and postgresql, it will error with non-violated not null. when this guc set on, and in mysql mode, it will compatible with mysql and success, else failed. the default value is off to comptible with previous version.

`lt_statement_rollback_enable` (integer)

Turn statement level rollback on or off in the transaction block. This is off by default. This function takes effect in Oracle or MySQL mode. Statement level rollback is enabled, and the performance loss is about 5%. It is better not to set this switch in the transaction block, which may cause unexpected errors. When using `lt_dump`, you also need to turn it off.

`lightdb_aborted_rollback` (boolean)

`Lightdb_aborted_rollback` is off by default. Enable `lightdb_aborted_rollback`, report an error and rollback all statements when an error occurs in a transaction. The `lt_statement_rollback_enable` parameter has been opened, you cannot set `Lightdb_aborted_rollback`, it will fail to execute. The opposite is the same.

`lightdb_sql_mode` (String)

`lightdb_sql_mode` specifies some SQL execution rules, separated by commas. The following rules are supported: `no_zero_date`, `uppercase_identifier`.

This setting can be changed within individual sessions. But the rule of `'uppercase_identifier'` is not suggested that. It should be enabled in the `lightdb.conf` as far as possible and don't modify it casually. For more information about the rule `'uppercase_identifier'` could be found in `create_table.sgml`'s section of `'column_name'` and `select.sgml`'s section of `'SELECT List'` with some examples listed in `'Examples'` as a guidance for how to use it.

`lightdb_oracle_sql_mode` (String)

`lightdb_oracle_sql_mode` is a user setting parameter on session. Set `lightdb_oracle_sql_mode` to `'show_identifier_uppercase'` to display column name in uppercase by default when executed

<sup>2</sup> <http://www.light-pg.com/docs/ltcluster/13.8-23.4/index.html>

a select statement. More information about this function could be found in `create_table.sgml`'s section of 'column\_name' and `select.sgml`'s section of 'SELECT List' with some examples listed in 'Examples' as a guidance for how to use it.

`lightdb_cursor_after_commit` (String)

Add GUC parameter `lightdb_cursor_after_commit`, When the parameter value is on, the cursor can continue after the transaction commits. When the parameter value is off, the cursor cannot proceed after the transaction is committed. The default value of this parameter is off.



---

# Chapter 18. Client Authentication

When a client application connects to the database server, it specifies which LightDB database user name it wants to connect as, much the same way one logs into a Unix computer as a particular user. Within the SQL environment the active database user name determines access privileges to database objects — see Chapter 19 for more information. Therefore, it is essential to restrict which database users can connect.

## Note

As explained in Chapter 19, LightDB actually does privilege management in terms of “roles”. In this chapter, we consistently use *database user* to mean “role with the LOGIN privilege”.

*Authentication* is the process by which the database server establishes the identity of the client, and by extension determines whether the client application (or the user who runs the client application) is permitted to connect with the database user name that was requested.

LightDB offers a number of different client authentication methods. The method used to authenticate a particular client connection can be selected on the basis of (client) host address, database, and user.

LightDB database user names are logically separate from user names of the operating system in which the server runs. If all the users of a particular server also have accounts on the server's machine, it makes sense to assign database user names that match their operating system user names. However, a server that accepts remote connections might have many database users who have no local operating system account, and in such cases there need be no connection between database user names and OS user names.

## 18.1. The `lt_hba.conf` File

Client authentication is controlled by a configuration file, which traditionally is named `lt_hba.conf` and is stored in the database cluster's data directory. (HBA stands for host-based authentication.) A default `lt_hba.conf` file is installed when the data directory is initialized by `initdb`. It is possible to place the authentication configuration file elsewhere, however; see the `hba_file` configuration parameter.

The general format of the `lt_hba.conf` file is a set of records, one per line. Blank lines are ignored, as is any text after the `#` comment character. Records cannot be continued across lines. A record is made up of a number of fields which are separated by spaces and/or tabs. Fields can contain white space if the field value is double-quoted. Quoting one of the keywords in a database, user, or address field (e.g., `all` or `replication`) makes the word lose its special meaning, and just match a database, user, or host with that name.

Each record specifies a connection type, a client IP address range (if relevant for the connection type), a database name, a user name, and the authentication method to be used for connections matching these parameters. The first record with a matching connection type, client address, requested database, and user name is used to perform authentication. There is no “fall-through” or “backup”: if one record is chosen and the authentication fails, subsequent records are not considered. If no record matches, access is denied.

A record can have several formats:

```
local          database user auth-method [auth-options]
host          database user address auth-method [auth-
options]
```

---

<code>hostssl</code>	<code>database</code>	<code>user</code>	<code>address</code>	<code>auth-method</code>	<code>[auth-options]</code>
<code>hostnoss1</code>	<code>database</code>	<code>user</code>	<code>address</code>	<code>auth-method</code>	<code>[auth-options]</code>
<code>hostgssenc</code>	<code>database</code>	<code>user</code>	<code>address</code>	<code>auth-method</code>	<code>[auth-options]</code>
<code>hostnogssenc</code>	<code>database</code>	<code>user</code>	<code>address</code>	<code>auth-method</code>	<code>[auth-options]</code>
<code>host</code>	<code>database</code>	<code>user</code>	<code>IP-address</code>	<code>IP-mask</code>	<code>auth-method</code> <code>[auth-options]</code>
<code>hostssl</code>	<code>database</code>	<code>user</code>	<code>IP-address</code>	<code>IP-mask</code>	<code>auth-method</code> <code>[auth-options]</code>
<code>hostnoss1</code>	<code>database</code>	<code>user</code>	<code>IP-address</code>	<code>IP-mask</code>	<code>auth-method</code> <code>[auth-options]</code>
<code>hostgssenc</code>	<code>database</code>	<code>user</code>	<code>IP-address</code>	<code>IP-mask</code>	<code>auth-method</code> <code>[auth-options]</code>
<code>hostnogssenc</code>	<code>database</code>	<code>user</code>	<code>IP-address</code>	<code>IP-mask</code>	<code>auth-method</code> <code>[auth-options]</code>

The meaning of the fields is as follows:

#### local

This record matches connection attempts using Unix-domain sockets. Without a record of this type, Unix-domain socket connections are disallowed.

#### host

This record matches connection attempts made using TCP/IP. `host` records match SSL or non-SSL connection attempts as well as GSSAPI encrypted or non-GSSAPI encrypted connection attempts.

### Note

Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the `listen_addresses` configuration parameter, since the default behavior is to listen for TCP/IP connections only on the local loopback address `localhost`.

#### hostssl

This record matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption.

To make use of this option the server must be built with SSL support. Furthermore, SSL must be enabled by setting the `ssl` configuration parameter (see Section 16.9 for more information). Otherwise, the `hostssl` record is ignored except for logging a warning that it cannot match any connections.

#### hostnoss1

This record type has the opposite behavior of `hostssl`; it only matches connection attempts made over TCP/IP that do not use SSL.

#### hostgssenc

This record matches connection attempts made using TCP/IP, but only when the connection is made with GSSAPI encryption.

To make use of this option the server must be built with GSSAPI support. Otherwise, the `hostgssenc` record is ignored except for logging a warning that it cannot match any connections.

#### `hostnogssenc`

This record type has the opposite behavior of `hostgssenc`; it only matches connection attempts made over TCP/IP that do not use GSSAPI encryption.

#### `database`

Specifies which database name(s) this record matches. The value `all` specifies that it matches all databases. The value `sameuser` specifies that the record matches if the requested database has the same name as the requested user. The value `samerole` specifies that the requested user must be a member of the role with the same name as the requested database. (`samegroup` is an obsolete but still accepted spelling of `samerole`.) Superusers are not considered to be members of a role for the purposes of `samerole` unless they are explicitly members of the role, directly or indirectly, and not just by virtue of being a superuser. The value `replication` specifies that the record matches if a physical replication connection is requested (note that replication connections do not specify any particular database). Otherwise, this is the name of a specific LightDB database. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with `@`.

#### `user`

Specifies which database user name(s) this record matches. The value `all` specifies that it matches all users. Otherwise, this is either the name of a specific database user, or a group name preceded by `+`. (Recall that there is no real distinction between users and groups in LightDB; a `+` mark really means “match any of the roles that are directly or indirectly members of this role”, while a name without a `+` mark matches only that specific role.) For this purpose, a superuser is only considered to be a member of a role if they are explicitly a member of the role, directly or indirectly, and not just by virtue of being a superuser. Multiple user names can be supplied by separating them with commas. A separate file containing user names can be specified by preceding the file name with `@`.

#### `address`

Specifies the client machine address(es) that this record matches. This field can contain either a host name, an IP address range, or one of the special key words mentioned below.

An IP address range is specified using standard numeric notation for the range's starting address, then a slash (`/`) and a CIDR mask length. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this should be zero in the given IP address. There must not be any white space between the IP address, the `/`, and the CIDR mask length.

Typical examples of an IPv4 address range specified this way are `172.20.143.89/32` for a single host, or `172.20.143.0/24` for a small network, or `10.6.0.0/16` for a larger one. An IPv6 address range might look like `::1/128` for a single host (in this case the IPv6 loopback address) or `fe80::7a31:c1ff:0000:0000/96` for a small network. `0.0.0.0/0` represents all IPv4 addresses, and `::0/0` represents all IPv6 addresses. To specify a single host, use a mask length of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.

An entry given in IPv4 format will match only IPv4 connections, and an entry given in IPv6 format will match only IPv6 connections, even if the represented address is in the IPv4-in-IPv6 range. Note that entries in IPv6 format will be rejected if the system's C library does not have support for IPv6 addresses.

You can also write `all` to match any IP address, `samehost` to match any of the server's own IP addresses, or `samenet` to match any address in any subnet that the server is directly connected to.

If a host name is specified (anything that is not an IP address range or a special key word is treated as a host name), that name is compared with the result of a reverse name resolution of the client's IP address (e.g., reverse DNS lookup, if DNS is used). Host name comparisons are case insensitive. If there is a match, then a forward name resolution (e.g., forward DNS lookup) is performed on the host name to check whether any of the addresses it resolves to are equal to the client's IP address. If both directions match, then the entry is considered to match. (The host name that is used in `lt_hba.conf` should be the one that address-to-name resolution of the client's IP address returns, otherwise the line won't be matched. Some host name databases allow associating an IP address with multiple host names, but the operating system will only return one host name when asked to resolve an IP address.)

A host name specification that starts with a dot (.) matches a suffix of the actual host name. So `.example.com` would match `foo.example.com` (but not just `example.com`).

When host names are specified in `lt_hba.conf`, you should make sure that name resolution is reasonably fast. It can be of advantage to set up a local name resolution cache such as `nsd`. Also, you may wish to enable the configuration parameter `log_hostname` to see the client's host name instead of the IP address in the log.

These fields do not apply to `local` records.

### Note

Users sometimes wonder why host names are handled in this seemingly complicated way, with two name resolutions including a reverse lookup of the client's IP address. This complicates use of the feature in case the client's reverse DNS entry is not set up or yields some undesirable host name. It is done primarily for efficiency: this way, a connection attempt requires at most two resolver lookups, one reverse and one forward. If there is a resolver problem with some address, it becomes only that client's problem. A hypothetical alternative implementation that only did forward lookups would have to resolve every host name mentioned in `lt_hba.conf` during every connection attempt. That could be quite slow if many names are listed. And if there is a resolver problem with one of the host names, it becomes everyone's problem.

Also, a reverse lookup is necessary to implement the suffix matching feature, because the actual client host name needs to be known in order to match it against the pattern.

Note that this behavior is consistent with other popular implementations of host name-based access control, such as the Apache HTTP Server and TCP Wrappers.

*IP-address*

*IP-mask*

These two fields can be used as an alternative to the *IP-address/mask-length* notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, `255.0.0.0` represents an IPv4 CIDR mask length of 8, and `255.255.255.255` represents a CIDR mask length of 32.

These fields do not apply to `local` records.

*auth-method*

Specifies the authentication method to use when a connection matches this record. The possible choices are summarized here; details are in Section 18.3. All the options are lower case and treated case sensitively, so even acronyms like `ldap` must be specified as lower case.

`trust`

Allow the connection unconditionally. This method allows anyone that can connect to the LightDB database server to login as any LightDB user they wish, without the need for a password or any other authentication. See Section 18.4 for details.

`reject`

Reject the connection unconditionally. This is useful for “filtering out” certain hosts from a group, for example a `reject` line could block a specific host from connecting, while a later line allows the remaining hosts in a specific network to connect.

`scram-sha-256`

Perform SCRAM-SHA-256 authentication to verify the user's password. See Section 18.5 for details.

`md5`

Perform SCRAM-SHA-256 or MD5 authentication to verify the user's password. See Section 18.5 for details.

`password`

Require the client to supply an unencrypted password for authentication. Since the password is sent in clear text over the network, this should not be used on untrusted networks. See Section 18.5 for details.

`gss`

Use GSSAPI to authenticate the user. This is only available for TCP/IP connections. See Section 18.6 for details. It can be used in conjunction with GSSAPI encryption.

`ident`

Obtain the operating system user name of the client by contacting the ident server on the client and check if it matches the requested database user name. Ident authentication can only be used on TCP/IP connections. When specified for local connections, peer authentication will be used instead. See Section 18.8 for details.

`peer`

Obtain the client's operating system user name from the operating system and check if it matches the requested database user name. This is only available for local connections. See Section 18.9 for details.

`ldap`

Authenticate using an LDAP server. See Section 18.10 for details.

`radius`

Authenticate using a RADIUS server. See Section 18.11 for details.

`cert`

Authenticate using SSL client certificates. See Section 18.12 for details.

`pam`

Authenticate using the Pluggable Authentication Modules (PAM) service provided by the operating system. See Section 18.13 for details.

bsd

Authenticate using the BSD Authentication service provided by the operating system. See Section 18.14 for details.

*auth-options*

After the *auth-method* field, there can be field(s) of the form *name=value* that specify options for the authentication method. Details about which options are available for which authentication methods appear below.

In addition to the method-specific options listed below, there is one method-independent authentication option *clientcert*, which can be specified in any *hostssl* record. This option can be set to *verify-ca* or *verify-full*. Both options require the client to present a valid (trusted) SSL certificate, while *verify-full* additionally enforces that the *cn* (Common Name) in the certificate matches the username or an applicable mapping. This behavior is similar to the *cert* authentication method (see Section 18.12) but enables pairing the verification of client certificates with any authentication method that supports *hostssl* entries.

Files included by @ constructs are read as lists of names, which can be separated by either whitespace or commas. Comments are introduced by #, just as in *lt\_hba.conf*, and nested @ constructs are allowed. Unless the file name following @ is an absolute path, it is taken to be relative to the directory containing the referencing file.

Since the *lt\_hba.conf* records are examined sequentially for each connection attempt, the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example, one might wish to use *trust* authentication for local TCP/IP connections but require a password for remote TCP/IP connections. In this case a record specifying *trust* authentication for connections from 127.0.0.1 would appear before a record specifying password authentication for a wider range of allowed client IP addresses.

The *lt\_hba.conf* file is read on start-up and when the main server process receives a SIGHUP signal. If you edit the file on an active system, you will need to signal the postmaster (using *lt\_ctl reload*, calling the SQL function *pg\_reload\_conf()*, or using *kill -HUP*) to make it re-read the file.

The system view *pg\_hba\_file\_rules* can be helpful for pre-testing changes to the *lt\_hba.conf* file, or for diagnosing problems if loading of the file did not have the desired effects. Rows in the view with non-null *error* fields indicate problems in the corresponding lines of the file.

### Tip

To connect to a particular database, a user must not only pass the *lt\_hba.conf* checks, but must have the *CONNECT* privilege for the database. If you wish to restrict which users can connect to which databases, it's usually easier to control this by granting/revoking *CONNECT* privilege than to put the rules in *lt\_hba.conf* entries.

Some examples of *lt\_hba.conf* entries are shown in Example 18.1. See the next section for details on the different authentication methods.

### Example 18.1. Example *lt\_hba.conf* Entries

```
# Allow any user on the local system to connect to any database
with
# any database user name using Unix-domain sockets (the default for
local
# connections).
```

```

#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
local  all                  all
trust

# The same using local loopback TCP/IP connections.
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all           127.0.0.1/32
trust

# The same as the previous line, but using a separate netmask
# column
#
# TYPE  DATABASE          USER          IP-ADDRESS    IP-MASK
# METHOD
host   all                  all           127.0.0.1
255.255.255.255 trust

# The same over IPv6.
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all           ::1/128
trust

# The same using a host name (would typically cover both IPv4 and
# IPv6).
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all           localhost
trust

# Allow any user from any host with IP address 192.168.93.x to
# connect
# to database "postgres" as the same user name that ident reports
# for
# the connection (typically the operating system user name).
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   postgres            all           192.168.93.0/24
ident

# Allow any user from host 192.168.12.10 to connect to database
# "postgres" if the user's password is correctly supplied.
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   postgres            all           192.168.12.10/32
scram-sha-256

# Allow any user from hosts in the example.com domain to connect to
# any database if the user's password is correctly supplied.
#

```

```
# Require SCRAM authentication for most users, but make an
exception
# for user 'mike', who uses an older client that doesn't support
SCRAM
# authentication.
#
# TYPE  DATABASE      USER      ADDRESS
METHOD
host    all              mike      .example.com      md5
host    all              all       .example.com
scram-sha-256

# In the absence of preceding "host" lines, these three lines will
# reject all connections from 192.168.54.1 (since that entry will
be
# matched first), but allow GSSAPI-encrypted connections from
anywhere else
# on the Internet. The zero mask causes no bits of the host IP
address to
# be considered, so it matches any host. Unencrypted GSSAPI
connections
# (which "fall through" to the third line since "hostgssenc" only
matches
# encrypted GSSAPI connections) are allowed, but only from
192.168.12.10.
#
# TYPE  DATABASE      USER      ADDRESS
METHOD
host    all              all       192.168.54.1/32
reject
hostgssenc all          all       0.0.0.0/0          gss
host    all              all       192.168.12.10/32  gss

# Allow users from 192.168.x.x hosts to connect to any database, if
# they pass the ident check. If, for example, ident says the user
is
# "bryanh" and he requests to connect as LightDB user "guest1", the
# connection is allowed if there is an entry in lt_ident.conf for
map
# "omicron" that says "bryanh" is allowed to connect as "guest1".
#
# TYPE  DATABASE      USER      ADDRESS
METHOD
host    all              all       192.168.0.0/16
ident map=omicron

# If these are the only three lines for local connections, they
will
# allow local users to connect only to their own databases
(databases
# with the same name as their database user name) except for
administrators
# and members of role "support", who can connect to all databases.
The file
# $LTDATA/admins contains a list of names of administrators.
Passwords
# are required in all cases.
#
```



```

# TYPE DATABASE USER ADDRESS
METHOD
local sameuser all md5
local all @admins md5
local all +support md5

# The last two lines above can be combined into a single line:
local all @admins,+support md5

# The database column can also use lists and file names:
local db1,db2,@demodbs all md5

```

## 18.2. User Name Maps

When using an external authentication system such as Ident or GSSAPI, the name of the operating system user that initiated the connection might not be the same as the database user (role) that is to be used. In this case, a user name map can be applied to map the operating system user name to a database user. To use user name mapping, specify `map=map-name` in the options field in `lt_hba.conf`. This option is supported for all authentication methods that receive external user names. Since different mappings might be needed for different connections, the name of the map to be used is specified in the `map-name` parameter in `lt_hba.conf` to indicate which map to use for each individual connection.

User name maps are defined in the ident map file, which by default is named `lt_ident.conf` and is stored in the cluster's data directory. (It is possible to place the map file elsewhere, however; see the `ident_file` configuration parameter.) The ident map file contains lines of the general form:

```
map-name system-username database-username
```

Comments and whitespace are handled in the same way as in `lt_hba.conf`. The `map-name` is an arbitrary name that will be used to refer to this mapping in `lt_hba.conf`. The other two fields specify an operating system user name and a matching database user name. The same `map-name` can be used repeatedly to specify multiple user-mappings within a single map.

There is no restriction regarding how many database users a given operating system user can correspond to, nor vice versa. Thus, entries in a map should be thought of as meaning “this operating system user is allowed to connect as this database user”, rather than implying that they are equivalent. The connection will be allowed if there is any map entry that pairs the user name obtained from the external authentication system with the database user name that the user has requested to connect as.

If the `system-username` field starts with a slash (/), the remainder of the field is treated as a regular expression. (See Section 9.7.3.1 for details of LightDB's regular expression syntax.) The regular expression can include a single capture, or parenthesized subexpression, which can then be referenced in the `database-username` field as `\1` (backslash-one). This allows the mapping of multiple user names in a single line, which is particularly useful for simple syntax substitutions. For example, these entries

```

mymap    /^(.*)@mydomain\.com$      \1
mymap    /^(.*)@otherdomain\.com$   guest

```

will remove the domain part for users with system user names that end with `@mydomain.com`, and allow any user whose system name ends with `@otherdomain.com` to log in as `guest`.

**Tip**

Keep in mind that by default, a regular expression can match just part of a string. It's usually wise to use `^` and `$`, as shown in the above example, to force the match to be to the entire system user name.

The `lt_ident.conf` file is read on start-up and when the main server process receives a `SIGHUP` signal. If you edit the file on an active system, you will need to signal the postmaster (using `lt_ctl reload`, calling the SQL function `pg_reload_conf()`, or using `kill -HUP`) to make it re-read the file.

A `lt_ident.conf` file that could be used in conjunction with the `lt_hba.conf` file in Example 18.1 is shown in Example 18.2. In this example, anyone logged in to a machine on the 192.168 network that does not have the operating system user name `bryanh`, `ann`, or `robert` would not be granted access. Unix user `robert` would only be allowed access when he tries to connect as LightDB user `bob`, not as `robert` or anyone else. `ann` would only be allowed to connect as `ann`. User `bryanh` would be allowed to connect as either `bryanh` or as `guest1`.

**Example 18.2. An Example `lt_ident.conf` File**

```
# MAPNAME          SYSTEM-USERNAME      PG-USERNAME

omicron            bryanh              bryanh
omicron            ann                 ann
# bob has user name robert on these machines
omicron            robert             bob
# bryanh can also connect as guest1
omicron            bryanh             guest1
```

## 18.3. Authentication Methods

LightDB provides various methods for authenticating users:

- Trust authentication, which simply trusts that users are who they say they are.
- Password authentication, which requires that users send a password.
- GSSAPI authentication, which relies on a GSSAPI-compatible security library. Typically this is used to access an authentication server such as a Kerberos or Microsoft Active Directory server.
- Ident authentication, which relies on an “Identification Protocol” (RFC 1413) service on the client's machine. (On local Unix-socket connections, this is treated as peer authentication.)
- Peer authentication, which relies on operating system facilities to identify the process at the other end of a local connection. This is not supported for remote connections.
- LDAP authentication, which relies on an LDAP authentication server.
- RADIUS authentication, which relies on a RADIUS authentication server.
- Certificate authentication, which requires an SSL connection and authenticates users by checking the SSL certificate they send.
- PAM authentication, which relies on a PAM (Pluggable Authentication Modules) library.
- BSD authentication, which relies on the BSD Authentication framework (currently available only on OpenBSD).

Peer authentication is usually recommendable for local connections, though trust authentication might be sufficient in some circumstances. Password authentication is the easiest choice for remote connections. All the other options require some kind of external security infrastructure (usually an authentication server or a certificate authority for issuing SSL certificates), or are platform-specific.

The following sections describe each of these authentication methods in more detail.

## 18.4. Trust Authentication

When `trust` authentication is specified, LightDB assumes that anyone who can connect to the server is authorized to access the database with whatever database user name they specify (even superuser names). Of course, restrictions made in the `database` and `user` columns still apply. This method should only be used when there is adequate operating-system-level protection on connections to the server.

`trust` authentication is appropriate and very convenient for local connections on a single-user workstation. It is usually *not* appropriate by itself on a multiuser machine. However, you might be able to use `trust` even on a multiuser machine, if you restrict access to the server's Unix-domain socket file using file-system permissions. To do this, set the `unix_socket_permissions` (and possibly `unix_socket_group`) configuration parameters as described in Section 17.3. Or you could set the `unix_socket_directories` configuration parameter to place the socket file in a suitably restricted directory.

Setting file-system permissions only helps for Unix-socket connections. Local TCP/IP connections are not restricted by file-system permissions. Therefore, if you want to use file-system permissions for local security, remove the `host . . . 127.0.0.1 . . .` line from `lt_hba.conf`, or change it to a non-`trust` authentication method.

`trust` authentication is only suitable for TCP/IP connections if you trust every user on every machine that is allowed to connect to the server by the `lt_hba.conf` lines that specify `trust`. It is seldom reasonable to use `trust` for any TCP/IP connections other than those from localhost (127.0.0.1).

## 18.5. Password Authentication

There are several password-based authentication methods. These methods operate similarly but differ in how the users' passwords are stored on the server and how the password provided by a client is sent across the connection.

`scram-sha-256`

The method `scram-sha-256` performs SCRAM-SHA-256 authentication, as described in RFC 7677<sup>1</sup>. It is a challenge-response scheme that prevents password sniffing on untrusted connections and supports storing passwords on the server in a cryptographically hashed form that is thought to be secure.

This is the most secure of the currently provided methods, but it is not supported by older client libraries.

`md5`

The method `md5` uses a custom less secure challenge-response mechanism. It prevents password sniffing and avoids storing passwords on the server in plain text but provides no protection if an attacker manages to steal the password hash from the server. Also, the MD5 hash algorithm is nowadays no longer considered secure against determined attacks.

The `md5` method cannot be used with the `db_user_namespace` feature.

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<sup>1</sup> <https://tools.ietf.org/html/rfc7677>

To ease transition from the `md5` method to the newer SCRAM method, if `md5` is specified as a method in `lt_hba.conf` but the user's password on the server is encrypted for SCRAM (see below), then SCRAM-based authentication will automatically be chosen instead.

### `password`

The method `password` sends the password in clear-text and is therefore vulnerable to password “sniffing” attacks. It should always be avoided if possible. If the connection is protected by SSL encryption then `password` can be used safely, though. (Though SSL certificate authentication might be a better choice if one is depending on using SSL).

LightDB database passwords are separate from operating system user passwords. The password for each database user is stored in the `pg_authid` system catalog. Passwords can be managed with the SQL commands `CREATE ROLE` and `ALTER ROLE`, e.g., **`CREATE ROLE foo WITH LOGIN PASSWORD 'secret'`**, or the `ltsql` command `\password`. If no password has been set up for a user, the stored password is null and password authentication will always fail for that user.

The availability of the different password-based authentication methods depends on how a user's password on the server is encrypted (or hashed, more accurately). This is controlled by the configuration parameter `password_encryption` at the time the password is set. If a password was encrypted using the `scram-sha-256` setting, then it can be used for the authentication methods `scram-sha-256` and `password` (but password transmission will be in plain text in the latter case). The authentication method specification `md5` will automatically switch to using the `scram-sha-256` method in this case, as explained above, so it will also work. If a password was encrypted using the `md5` setting, then it can be used only for the `md5` and `password` authentication method specifications (again, with the password transmitted in plain text in the latter case). To check the currently stored password hashes, see the system catalog `pg_authid`.

To upgrade an existing installation from `md5` to `scram-sha-256`, after having ensured that all client libraries in use are new enough to support SCRAM, set `password_encryption = 'scram-sha-256'` in `lightdb.conf`, make all users set new passwords, and change the authentication method specifications in `lt_hba.conf` to `scram-sha-256`.

## 18.6. GSSAPI Authentication

GSSAPI is an industry-standard protocol for secure authentication defined in RFC 2743<sup>2</sup>. LightDB supports GSSAPI for authentication, communications encryption, or both. GSSAPI provides automatic authentication (single sign-on) for systems that support it. The authentication itself is secure. If GSSAPI encryption or SSL encryption is used, the data sent along the database connection will be encrypted; otherwise, it will not.

When GSSAPI uses Kerberos, it uses a standard service principal (authentication identity) name in the format `servicename/hostname@realm`. The principal name used by a particular installation is not encoded in the LightDB server in any way; rather it is specified in the `keytab` file that the server reads to determine its identity. If multiple principals are listed in the `keytab` file, the server will accept any one of them. The server's realm name is the preferred realm specified in the Kerberos configuration file(s) accessible to the server.

When connecting, the client must know the principal name of the server it intends to connect to. The `servicename` part of the principal is ordinarily `postgres`, but another value can be selected via `libpq`'s `krbsrvname` connection parameter. The `hostname` part is the fully qualified host name that `libpq` is told to connect to. The realm name is the preferred realm specified in the Kerberos configuration file(s) accessible to the client.

The client will also have a principal name for its own identity (and it must have a valid ticket for this principal). To use GSSAPI for authentication, the client principal must be associated with a LightDB database user name. The `lt_ident.conf` configuration file can be used to map principals to user

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<sup>2</sup> <https://tools.ietf.org/html/rfc2743>

names; for example, `ltusername@realm` could be mapped to just `ltusername`. Alternatively, you can use the full `username@realm` principal as the role name in LightDB without any mapping.

LightDB also supports mapping client principals to user names by just stripping the realm from the principal. This method is supported for backwards compatibility and is strongly discouraged as it is then impossible to distinguish different users with the same user name but coming from different realms. To enable this, set `include_realm` to 0. For simple single-realm installations, doing that combined with setting the `krb_realm` parameter (which checks that the principal's realm matches exactly what is in the `krb_realm` parameter) is still secure; but this is a less capable approach compared to specifying an explicit mapping in `lt_ident.conf`.

The location of the server's keytab file is specified by the `krb_server_keyfile` configuration parameter. For security reasons, it is recommended to use a separate keytab just for the LightDB server rather than allowing the server to read the system keytab file. Make sure that your server keytab file is readable (and preferably only readable, not writable) by the LightDB server account. (See also Section 16.1.)

The keytab file is generated using the Kerberos software; see the Kerberos documentation for details. The following example shows doing this using the `kadmin` tool of MIT-compatible Kerberos 5 implementations:

```
kadmin% addprinc -randkey postgres/server.my.domain.org
kadmin% ktadd -k krb5.keytab postgres/server.my.domain.org
```

The following authentication options are supported for the GSSAPI authentication method:

`include_realm`

If set to 0, the realm name from the authenticated user principal is stripped off before being passed through the user name mapping (Section 18.2). This is discouraged and is primarily available for backwards compatibility, as it is not secure in multi-realm environments unless `krb_realm` is also used. It is recommended to leave `include_realm` set to the default (1) and to provide an explicit mapping in `lt_ident.conf` to convert principal names to LightDB user names.

`map`

Allows mapping from client principals to database user names. See Section 18.2 for details. For a GSSAPI/Kerberos principal, such as `username@EXAMPLE.COM` (or, less commonly, `username/hostbased@EXAMPLE.COM`), the user name used for mapping is `username@EXAMPLE.COM` (or `username/hostbased@EXAMPLE.COM`, respectively), unless `include_realm` has been set to 0, in which case `username` (or `username/hostbased`) is what is seen as the system user name when mapping.

`krb_realm`

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

In addition to these settings, which can be different for different `lt_hba.conf` entries, there is the server-wide `krb_caseins_users` configuration parameter. If that is set to true, client principals are matched to user map entries case-insensitively. `krb_realm`, if set, is also matched case-insensitively.

## 18.7. SSPI Authentication

SSPI is a Windows technology for secure authentication with single sign-on. LightDB will use SSPI in `negotiate` mode, which will use Kerberos when possible and automatically fall back to NTLM in other cases. SSPI authentication only works when both server and client are running Windows, or, on non-Windows platforms, when GSSAPI is available.

When using Kerberos authentication, SSPI works the same way GSSAPI does; see Section 18.6 for details.

The following configuration options are supported for SSPI:

`include_realm`

If set to 0, the realm name from the authenticated user principal is stripped off before being passed through the user name mapping (Section 18.2). This is discouraged and is primarily available for backwards compatibility, as it is not secure in multi-realm environments unless `krb_realm` is also used. It is recommended to leave `include_realm` set to the default (1) and to provide an explicit mapping in `lt_ident.conf` to convert principal names to LightDB user names.

`compat_realm`

If set to 1, the domain's SAM-compatible name (also known as the NetBIOS name) is used for the `include_realm` option. This is the default. If set to 0, the true realm name from the Kerberos user principal name is used.

Do not disable this option unless your server runs under a domain account (this includes virtual service accounts on a domain member system) and all clients authenticating through SSPI are also using domain accounts, or authentication will fail.

`upn_username`

If this option is enabled along with `compat_realm`, the user name from the Kerberos UPN is used for authentication. If it is disabled (the default), the SAM-compatible user name is used. By default, these two names are identical for new user accounts.

Note that `libpq` uses the SAM-compatible name if no explicit user name is specified. If you use `libpq` or a driver based on it, you should leave this option disabled or explicitly specify user name in the connection string.

`map`

Allows for mapping between system and database user names. See Section 18.2 for details. For a SSPI/Kerberos principal, such as `username@EXAMPLE.COM` (or, less commonly, `username/hostbased@EXAMPLE.COM`), the user name used for mapping is `username@EXAMPLE.COM` (or `username/hostbased@EXAMPLE.COM`, respectively), unless `include_realm` has been set to 0, in which case `username` (or `username/hostbased`) is what is seen as the system user name when mapping.

`krb_realm`

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

## 18.8. Ident Authentication

The ident authentication method works by obtaining the client's operating system user name from an ident server and using it as the allowed database user name (with an optional user name mapping). This is only supported on TCP/IP connections.

### Note

When `ident` is specified for a local (non-TCP/IP) connection, peer authentication (see Section 18.9) will be used instead.

The following configuration options are supported for `ident`:

`map`

Allows for mapping between system and database user names. See Section 18.2 for details.

The “Identification Protocol” is described in RFC 1413. Virtually every Unix-like operating system ships with an `ident` server that listens on TCP port 113 by default. The basic functionality of an `ident` server is to answer questions like “What user initiated the connection that goes out of your port *X* and connects to my port *Y*?”. Since LightDB knows both *X* and *Y* when a physical connection is established, it can interrogate the `ident` server on the host of the connecting client and can theoretically determine the operating system user for any given connection.

The drawback of this procedure is that it depends on the integrity of the client: if the client machine is untrusted or compromised, an attacker could run just about any program on port 113 and return any user name they choose. This authentication method is therefore only appropriate for closed networks where each client machine is under tight control and where the database and system administrators operate in close contact. In other words, you must trust the machine running the `ident` server. Heed the warning:

The Identification Protocol is not intended as an authorization or access control protocol.

—RFC 1413

Some `ident` servers have a nonstandard option that causes the returned user name to be encrypted, using a key that only the originating machine's administrator knows. This option *must not* be used when using the `ident` server with LightDB, since LightDB does not have any way to decrypt the returned string to determine the actual user name.

## 18.9. Peer Authentication

The peer authentication method works by obtaining the client's operating system user name from the kernel and using it as the allowed database user name (with optional user name mapping). This method is only supported on local connections.

The following configuration options are supported for `peer`:

`map`

Allows for mapping between system and database user names. See Section 18.2 for details.

Peer authentication is only available on operating systems providing the `getpeereid()` function, the `SO_PEERCRECRED` socket parameter, or similar mechanisms. Currently that includes Linux, most flavors of BSD including macOS, and Solaris.

## 18.10. LDAP Authentication

This authentication method operates similarly to `password` except that it uses LDAP as the password verification method. LDAP is used only to validate the user name/password pairs. Therefore the user must already exist in the database before LDAP can be used for authentication.

LDAP authentication can operate in two modes. In the first mode, which we will call the simple bind mode, the server will bind to the distinguished name constructed as *prefix* *username* *suffix*. Typically, the *prefix* parameter is used to specify `cn=`, or `DOMAIN\` in an Active Directory environment. *suffix* is used to specify the remaining part of the DN in a non-Active Directory environment.

In the second mode, which we will call the search+bind mode, the server first binds to the LDAP directory with a fixed user name and password, specified with `ldapbinddn` and

*ldapbindpasswd*, and performs a search for the user trying to log in to the database. If no user and password is configured, an anonymous bind will be attempted to the directory. The search will be performed over the subtree at *ldapbasedn*, and will try to do an exact match of the attribute specified in *ldapsearchattribute*. Once the user has been found in this search, the server disconnects and re-binds to the directory as this user, using the password specified by the client, to verify that the login is correct. This mode is the same as that used by LDAP authentication schemes in other software, such as Apache `mod_authnz_ldap` and `pam_ldap`. This method allows for significantly more flexibility in where the user objects are located in the directory, but will cause two separate connections to the LDAP server to be made.

The following configuration options are used in both modes:

`ldapservers`

Names or IP addresses of LDAP servers to connect to. Multiple servers may be specified, separated by spaces.

`ldapport`

Port number on LDAP server to connect to. If no port is specified, the LDAP library's default port setting will be used.

`ldapscheme`

Set to `ldaps` to use LDAPS. This is a non-standard way of using LDAP over SSL, supported by some LDAP server implementations. See also the `ldaptls` option for an alternative.

`ldaptls`

Set to 1 to make the connection between LightDB and the LDAP server use TLS encryption. This uses the `StartTLS` operation per RFC 4513. See also the `ldapscheme` option for an alternative.

Note that using `ldapscheme` or `ldaptls` only encrypts the traffic between the LightDB server and the LDAP server. The connection between the LightDB server and the LightDB client will still be unencrypted unless SSL is used there as well.

The following options are used in simple bind mode only:

`ldapprefix`

String to prepend to the user name when forming the DN to bind as, when doing simple bind authentication.

`ldapsuffix`

String to append to the user name when forming the DN to bind as, when doing simple bind authentication.

The following options are used in search+bind mode only:

`ldapbasedn`

Root DN to begin the search for the user in, when doing search+bind authentication.

`ldapbinddn`

DN of user to bind to the directory with to perform the search when doing search+bind authentication.

`ldapbindpasswd`

Password for user to bind to the directory with to perform the search when doing search+bind authentication.



**ldapsearchattribute**

Attribute to match against the user name in the search when doing search+bind authentication. If no attribute is specified, the `uid` attribute will be used.

**ldapsearchfilter**

The search filter to use when doing search+bind authentication. Occurrences of `$username` will be replaced with the user name. This allows for more flexible search filters than `ldapsearchattribute`.

**ldapurl**

An RFC 4516 LDAP URL. This is an alternative way to write some of the other LDAP options in a more compact and standard form. The format is

```
ldap[s]://host[:port]/basedn[?[attribute][?[scope][?[filter]]]
```

*scope* must be one of `base`, `one`, `sub`, typically the last. (The default is `base`, which is normally not useful in this application.) *attribute* can nominate a single attribute, in which case it is used as a value for `ldapsearchattribute`. If *attribute* is empty then *filter* can be used as a value for `ldapsearchfilter`.

The URL scheme `ldaps` chooses the LDAPS method for making LDAP connections over SSL, equivalent to using `ldapscheme=ldaps`. To use encrypted LDAP connections using the StartTLS operation, use the normal URL scheme `ldap` and specify the `ldaptls` option in addition to `ldapurl`.

For non-anonymous binds, `ldapbinddn` and `ldapbindpasswd` must be specified as separate options.

LDAP URLs are currently only supported with OpenLDAP, not on Windows.

It is an error to mix configuration options for simple bind with options for search+bind.

When using search+bind mode, the search can be performed using a single attribute specified with `ldapsearchattribute`, or using a custom search filter specified with `ldapsearchfilter`. Specifying `ldapsearchattribute=foo` is equivalent to specifying `ldapsearchfilter="(foo=$username)"`. If neither option is specified the default is `ldapsearchattribute=uid`.

If LightDB was compiled with OpenLDAP as the LDAP client library, the `ldapserver` setting may be omitted. In that case, a list of host names and ports is looked up via RFC 2782 DNS SRV records. The name `_ldap._tcp.DOMAIN` is looked up, where `DOMAIN` is extracted from `ldapbasedn`.

Here is an example for a simple-bind LDAP configuration:

```
host ... ldap ldapserver=ldap.example.net ldapprefix="cn="
      ldapsuffix=", dc=example, dc=net"
```

When a connection to the database server as database user `someuser` is requested, LightDB will attempt to bind to the LDAP server using the DN `cn=someuser, dc=example, dc=net` and the password provided by the client. If that connection succeeds, the database access is granted.

Here is an example for a search+bind configuration:

```
host ... ldap ldapserver=ldap.example.net ldapbasedn="dc=example,
      dc=net" ldapsearchattribute=uid
```

When a connection to the database server as database user `someuser` is requested, LightDB will attempt to bind anonymously (since `ldapbinddn` was not specified) to the LDAP server, perform a search for `(uid=someuser)` under the specified base DN. If an entry is found, it will then attempt to bind using that found information and the password supplied by the client. If that second connection succeeds, the database access is granted.

Here is the same search+bind configuration written as a URL:

```
host ... ldap ldapurl="ldap://ldap.example.net/dc=example,dc=net?uid?sub"
```

Some other software that supports authentication against LDAP uses the same URL format, so it will be easier to share the configuration.

Here is an example for a search+bind configuration that uses `ldapsearchfilter` instead of `ldapsearchattribute` to allow authentication by user ID or email address:

```
host ... ldap ldapserver=ldap.example.net ldapbasedn="dc=example,dc=net" ldapsearchfilter="(|(uid=$username)(mail=$username))"
```

Here is an example for a search+bind configuration that uses DNS SRV discovery to find the host name(s) and port(s) for the LDAP service for the domain name `example.net`:

```
host ... ldap ldapbasedn="dc=example,dc=net"
```

### Tip

Since LDAP often uses commas and spaces to separate the different parts of a DN, it is often necessary to use double-quoted parameter values when configuring LDAP options, as shown in the examples.

## 18.11. RADIUS Authentication

This authentication method operates similarly to `password` except that it uses RADIUS as the password verification method. RADIUS is used only to validate the user name/password pairs. Therefore the user must already exist in the database before RADIUS can be used for authentication.

When using RADIUS authentication, an Access Request message will be sent to the configured RADIUS server. This request will be of type `Authenticate Only`, and include parameters for `user name`, `password (encrypted)` and `NAS Identifier`. The request will be encrypted using a secret shared with the server. The RADIUS server will respond to this request with either `Access Accept` or `Access Reject`. There is no support for RADIUS accounting.

Multiple RADIUS servers can be specified, in which case they will be tried sequentially. If a negative response is received from a server, the authentication will fail. If no response is received, the next server in the list will be tried. To specify multiple servers, separate the server names with commas and surround the list with double quotes. If multiple servers are specified, the other RADIUS options can also be given as comma-separated lists, to provide individual values for each server. They can also be specified as a single value, in which case that value will apply to all servers.

The following configuration options are supported for RADIUS:

```
radiusservers
```

The DNS names or IP addresses of the RADIUS servers to connect to. This parameter is required.

### radiussecrets

The shared secrets used when talking securely to the RADIUS servers. This must have exactly the same value on the LightDB and RADIUS servers. It is recommended that this be a string of at least 16 characters. This parameter is required.

#### Note

The encryption vector used will only be cryptographically strong if LightDB is built with support for OpenSSL. In other cases, the transmission to the RADIUS server should only be considered obfuscated, not secured, and external security measures should be applied if necessary.

### radiusports

The port numbers to connect to on the RADIUS servers. If no port is specified, the default RADIUS port (1812) will be used.

### radiusidentifiers

The strings to be used as `NAS Identifier` in the RADIUS requests. This parameter can be used, for example, to identify which database cluster the user is attempting to connect to, which can be useful for policy matching on the RADIUS server. If no identifier is specified, the default `postgresql` will be used.

If it is necessary to have a comma or whitespace in a RADIUS parameter value, that can be done by putting double quotes around the value, but it is tedious because two layers of double-quoting are now required. An example of putting whitespace into RADIUS secret strings is:

```
host ... radius radiusservers="server1,server2"
radiussecrets="" "secret one" , "secret two" ""
```

## 18.12. Certificate Authentication

This authentication method uses SSL client certificates to perform authentication. It is therefore only available for SSL connections. When using this authentication method, the server will require that the client provide a valid, trusted certificate. No password prompt will be sent to the client. The `cn` (Common Name) attribute of the certificate will be compared to the requested database user name, and if they match the login will be allowed. User name mapping can be used to allow `cn` to be different from the database user name.

The following configuration options are supported for SSL certificate authentication:

### map

Allows for mapping between system and database user names. See Section 18.2 for details.

It is redundant to use the `clientcert` option with `cert` authentication because `cert` authentication is effectively `trust` authentication with `clientcert=verify-full`.

## 18.13. PAM Authentication

This authentication method operates similarly to `password` except that it uses PAM (Pluggable Authentication Modules) as the authentication mechanism. The default PAM service name is `postgresql`. PAM is used only to validate user name/password pairs and optionally the connected

remote host name or IP address. Therefore the user must already exist in the database before PAM can be used for authentication. For more information about PAM, please read the [Linux-PAM Page](#)<sup>3</sup>.

The following configuration options are supported for PAM:

`pamservice`

PAM service name.

`pam_use_hostname`

Determines whether the remote IP address or the host name is provided to PAM modules through the `PAM_RHOST` item. By default, the IP address is used. Set this option to 1 to use the resolved host name instead. Host name resolution can lead to login delays. (Most PAM configurations don't use this information, so it is only necessary to consider this setting if a PAM configuration was specifically created to make use of it.)

### Note

If PAM is set up to read `/etc/shadow`, authentication will fail because the LightDB server is started by a non-root user. However, this is not an issue when PAM is configured to use LDAP or other authentication methods.

## 18.14. BSD Authentication

This authentication method operates similarly to `password` except that it uses BSD Authentication to verify the password. BSD Authentication is used only to validate user name/password pairs. Therefore the user's role must already exist in the database before BSD Authentication can be used for authentication. The BSD Authentication framework is currently only available on OpenBSD.

BSD Authentication in LightDB uses the `auth-postgresql` login type and authenticates with the `postgresql` login class if that's defined in `login.conf`. By default that login class does not exist, and LightDB will use the default login class.

### Note

To use BSD Authentication, the LightDB user account (that is, the operating system user running the server) must first be added to the `auth` group. The `auth` group exists by default on OpenBSD systems.

## 18.15. Authentication Problems

Authentication failures and related problems generally manifest themselves through error messages like the following:

```
FATAL: no lt_hba.conf entry for host "123.123.123.123", user
"andym", database "testdb"
```

This is what you are most likely to get if you succeed in contacting the server, but it does not want to talk to you. As the message suggests, the server refused the connection request because it found no matching entry in its `lt_hba.conf` configuration file.

---

<sup>3</sup> <https://www.kernel.org/pub/linux/libs/pam/>

```
FATAL: password authentication failed for user "andym"
```

Messages like this indicate that you contacted the server, and it is willing to talk to you, but not until you pass the authorization method specified in the `lt_hba.conf` file. Check the password you are providing, or check your Kerberos or ident software if the complaint mentions one of those authentication types.

```
FATAL: user "andym" does not exist
```

The indicated database user name was not found.

```
FATAL: database "testdb" does not exist
```

The database you are trying to connect to does not exist. Note that if you do not specify a database name, it defaults to the database user name, which might or might not be the right thing.

**Tip**

The server log might contain more information about an authentication failure than is reported to the client. If you are confused about the reason for a failure, check the server log.

---

# Chapter 19. Database Roles

LightDB manages database access permissions using the concept of *roles*. A role can be thought of as either a database user, or a group of database users, depending on how the role is set up. Roles can own database objects (for example, tables and functions) and can assign privileges on those objects to other roles to control who has access to which objects. Furthermore, it is possible to grant *membership* in a role to another role, thus allowing the member role to use privileges assigned to another role.

The concept of roles subsumes the concepts of “users” and “groups”. In LightDB versions before 8.1, users and groups were distinct kinds of entities, but now there are only roles. Any role can act as a user, a group, or both.

This chapter describes how to create and manage roles. More information about the effects of role privileges on various database objects can be found in Section 5.7.

## 19.1. Database Roles

Database roles are conceptually completely separate from operating system users. In practice it might be convenient to maintain a correspondence, but this is not required. Database roles are global across a database cluster installation (and not per individual database). To create a role use the CREATE ROLE SQL command:

```
CREATE ROLE name ;
```

*name* follows the rules for SQL identifiers: either unadorned without special characters, or double-quoted. (In practice, you will usually want to add additional options, such as LOGIN, to the command. More details appear below.) To remove an existing role, use the analogous DROP ROLE command:

```
DROP ROLE name ;
```

For convenience, the programs `createuser` and `dropuser` are provided as wrappers around these SQL commands that can be called from the shell command line:

```
createuser name  
dropuser name
```

To determine the set of existing roles, examine the `pg_roles` system catalog, for example

```
SELECT rolname FROM pg_roles ;
```

The `ltsql` program's `\du` meta-command is also useful for listing the existing roles.

In order to bootstrap the database system, a freshly initialized system always contains one predefined role. This role is always a “superuser”, and by default (unless altered when running `initdb`) it will have the same name as the operating system user that initialized the database cluster. Customarily, this role will be named `postgres`. In order to create more roles you first have to connect as this initial role.

Every connection to the database server is made using the name of some particular role, and this role determines the initial access privileges for commands issued in that connection. The role name to use for a particular database connection is indicated by the client that is initiating the connection request in an application-specific fashion. For example, the `ltsql` program uses the `-U` command line option to indicate the role to connect as. Many applications assume the name of the current operating system

user by default (including `createuser` and `ltsql`). Therefore it is often convenient to maintain a naming correspondence between roles and operating system users.

The set of database roles a given client connection can connect as is determined by the client authentication setup, as explained in Chapter 18. (Thus, a client is not limited to connect as the role matching its operating system user, just as a person's login name need not match his or her real name.) Since the role identity determines the set of privileges available to a connected client, it is important to carefully configure privileges when setting up a multiuser environment.

## 19.2. Role Attributes

A database role can have a number of attributes that define its privileges and interact with the client authentication system.

### login privilege

Only roles that have the `LOGIN` attribute can be used as the initial role name for a database connection. A role with the `LOGIN` attribute can be considered the same as a “database user”. To create a role with login privilege, use either:

```
CREATE ROLE name LOGIN;  
CREATE USER name ;
```

(`CREATE USER` is equivalent to `CREATE ROLE` except that `CREATE USER` includes `LOGIN` by default, while `CREATE ROLE` does not.)

### superuser status

A database superuser bypasses all permission checks, except the right to log in. This is a dangerous privilege and should not be used carelessly; it is best to do most of your work as a role that is not a superuser. To create a new database superuser, use `CREATE ROLE name SUPERUSER`. You must do this as a role that is already a superuser.

### database creation

A role must be explicitly given permission to create databases (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEDB`.

### role creation

A role must be explicitly given permission to create more roles (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEROLE`. A role with `CREATEROLE` privilege can alter and drop other roles, too, as well as grant or revoke membership in them. However, to create, alter, drop, or change membership of a superuser role, superuser status is required; `CREATEROLE` is insufficient for that.

### initiating replication

A role must explicitly be given permission to initiate streaming replication (except for superusers, since those bypass all permission checks). A role used for streaming replication must have `LOGIN` permission as well. To create such a role, use `CREATE ROLE name REPLICATION LOGIN`.

### password

A password is only significant if the client authentication method requires the user to supply a password when connecting to the database. The `password` and `md5` authentication methods make use of passwords. Database passwords are separate from operating system passwords. Specify a password upon role creation with `CREATE ROLE name PASSWORD 'string'`.

A role's attributes can be modified after creation with `ALTER ROLE`. See the reference pages for the `CREATE ROLE` and `ALTER ROLE` commands for details.

### Tip

It is good practice to create a role that has the `CREATEDB` and `CREATEROLE` privileges, but is not a superuser, and then use this role for all routine management of databases and roles. This approach avoids the dangers of operating as a superuser for tasks that do not really require it.

A role can also have role-specific defaults for many of the run-time configuration settings described in Chapter 17. For example, if for some reason you want to disable index scans (hint: not a good idea) anytime you connect, you can use:

```
ALTER ROLE myname SET enable_indexscan TO off;
```

This will save the setting (but not set it immediately). In subsequent connections by this role it will appear as though `SET enable_indexscan TO off` had been executed just before the session started. You can still alter this setting during the session; it will only be the default. To remove a role-specific default setting, use `ALTER ROLE rolename RESET varname`. Note that role-specific defaults attached to roles without `LOGIN` privilege are fairly useless, since they will never be invoked.

## 19.3. Role Membership

It is frequently convenient to group users together to ease management of privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In LightDB this is done by creating a role that represents the group, and then granting *membership* in the group role to individual user roles.

To set up a group role, first create the role:

```
CREATE ROLE name;
```

Typically a role being used as a group would not have the `LOGIN` attribute, though you can set it if you wish.

Once the group role exists, you can add and remove members using the `GRANT` and `REVOKE` commands:

```
GRANT group_role TO role1, ... ;
REVOKE group_role FROM role1, ... ;
```

You can grant membership to other group roles, too (since there isn't really any distinction between group roles and non-group roles). The database will not let you set up circular membership loops. Also, it is not permitted to grant membership in a role to `PUBLIC`.

The members of a group role can use the privileges of the role in two ways. First, every member of a group can explicitly do `SET ROLE` to temporarily “become” the group role. In this state, the database session has access to the privileges of the group role rather than the original login role, and any database objects created are considered owned by the group role not the login role. Second, member roles that have the `INHERIT` attribute automatically have use of the privileges of roles of which they are members, including any privileges inherited by those roles. As an example, suppose we have done:

```
CREATE ROLE joe LOGIN INHERIT;
CREATE ROLE admin NOINHERIT;
```



```
CREATE ROLE wheel NOINHERIT;  
GRANT admin TO joe;  
GRANT wheel TO admin;
```

Immediately after connecting as role `joe`, a database session will have use of privileges granted directly to `joe` plus any privileges granted to `admin`, because `joe` “inherits” `admin`'s privileges. However, privileges granted to `wheel` are not available, because even though `joe` is indirectly a member of `wheel`, the membership is via `admin` which has the `NOINHERIT` attribute. After:

```
SET ROLE admin;
```

the session would have use of only those privileges granted to `admin`, and not those granted to `joe`. After:

```
SET ROLE wheel;
```

the session would have use of only those privileges granted to `wheel`, and not those granted to either `joe` or `admin`. The original privilege state can be restored with any of:

```
SET ROLE joe;  
SET ROLE NONE;  
RESET ROLE;
```

### Note

The `SET ROLE` command always allows selecting any role that the original login role is directly or indirectly a member of. Thus, in the above example, it is not necessary to become `admin` before becoming `wheel`.

### Note

In the SQL standard, there is a clear distinction between users and roles, and users do not automatically inherit privileges while roles do. This behavior can be obtained in LightDB by giving roles being used as SQL roles the `INHERIT` attribute, while giving roles being used as SQL users the `NOINHERIT` attribute. However, LightDB defaults to giving all roles the `INHERIT` attribute, for backward compatibility with pre-8.1 releases in which users always had use of permissions granted to groups they were members of.

The role attributes `LOGIN`, `SUPERUSER`, `CREATEDB`, and `CREATEROLE` can be thought of as special privileges, but they are never inherited as ordinary privileges on database objects are. You must actually `SET ROLE` to a specific role having one of these attributes in order to make use of the attribute. Continuing the above example, we might choose to grant `CREATEDB` and `CREATEROLE` to the `admin` role. Then a session connecting as role `joe` would not have these privileges immediately, only after doing `SET ROLE admin`.

To destroy a group role, use `DROP ROLE`:

```
DROP ROLE name;
```

Any memberships in the group role are automatically revoked (but the member roles are not otherwise affected).

## 19.4. Dropping Roles

Because roles can own database objects and can hold privileges to access other objects, dropping a role is often not just a matter of a quick `DROP ROLE`. Any objects owned by the role must first be dropped or reassigned to other owners; and any permissions granted to the role must be revoked.

Ownership of objects can be transferred one at a time using `ALTER` commands, for example:

```
ALTER TABLE bobs_table OWNER TO alice;
```

Alternatively, the `REASSIGN OWNED` command can be used to reassign ownership of all objects owned by the role-to-be-dropped to a single other role. Because `REASSIGN OWNED` cannot access objects in other databases, it is necessary to run it in each database that contains objects owned by the role. (Note that the first such `REASSIGN OWNED` will change the ownership of any shared-across-databases objects, that is databases or tablespaces, that are owned by the role-to-be-dropped.)

Once any valuable objects have been transferred to new owners, any remaining objects owned by the role-to-be-dropped can be dropped with the `DROP OWNED` command. Again, this command cannot access objects in other databases, so it is necessary to run it in each database that contains objects owned by the role. Also, `DROP OWNED` will not drop entire databases or tablespaces, so it is necessary to do that manually if the role owns any databases or tablespaces that have not been transferred to new owners.

`DROP OWNED` also takes care of removing any privileges granted to the target role for objects that do not belong to it. Because `REASSIGN OWNED` does not touch such objects, it's typically necessary to run both `REASSIGN OWNED` and `DROP OWNED` (in that order!) to fully remove the dependencies of a role to be dropped.

In short then, the most general recipe for removing a role that has been used to own objects is:

```
REASSIGN OWNED BY doomed_role TO successor_role;
DROP OWNED BY doomed_role;
-- repeat the above commands in each database of the cluster
DROP ROLE doomed_role;
```

When not all owned objects are to be transferred to the same successor owner, it's best to handle the exceptions manually and then perform the above steps to mop up.

If `DROP ROLE` is attempted while dependent objects still remain, it will issue messages identifying which objects need to be reassigned or dropped.

## 19.5. Default Roles

LightDB provides a set of default roles which provide access to certain, commonly needed, privileged capabilities and information. Administrators can `GRANT` these roles to users and/or other roles in their environment, providing those users with access to the specified capabilities and information.

The default roles are described in Table 19.1. Note that the specific permissions for each of the default roles may change in the future as additional capabilities are added. Administrators should monitor the release notes for changes.

**Table 19.1. Default Roles**

Role	Allowed Access
<code>pg_read_all_settings</code>	Read all configuration variables, even those normally visible only to superusers.

Role	Allowed Access
<code>pg_read_all_stats</code>	Read all <code>pg_stat_*</code> views and use various statistics related extensions, even those normally visible only to superusers.
<code>pg_stat_scan_tables</code>	Execute monitoring functions that may take <code>ACCESS SHARE</code> locks on tables, potentially for a long time.
<code>pg_monitor</code>	Read/execute various monitoring views and functions. This role is a member of <code>pg_read_all_settings</code> , <code>pg_read_all_stats</code> and <code>pg_stat_scan_tables</code> .
<code>pg_signal_backend</code>	Signal another backend to cancel a query or terminate its session.
<code>pg_read_server_files</code>	Allow reading files from any location the database can access on the server with <code>COPY</code> and other file-access functions.
<code>pg_write_server_files</code>	Allow writing to files in any location the database can access on the server with <code>COPY</code> and other file-access functions.
<code>pg_execute_server_program</code>	Allow executing programs on the database server as the user the database runs as with <code>COPY</code> and other functions which allow executing a server-side program.

The `pg_monitor`, `pg_read_all_settings`, `pg_read_all_stats` and `pg_stat_scan_tables` roles are intended to allow administrators to easily configure a role for the purpose of monitoring the database server. They grant a set of common privileges allowing the role to read various useful configuration settings, statistics and other system information normally restricted to superusers.

The `pg_signal_backend` role is intended to allow administrators to enable trusted, but non-superuser, roles to send signals to other backends. Currently this role enables sending of signals for canceling a query on another backend or terminating its session. A user granted this role cannot however send signals to a backend owned by a superuser. See Section 9.27.2.

The `pg_read_server_files`, `pg_write_server_files` and `pg_execute_server_program` roles are intended to allow administrators to have trusted, but non-superuser, roles which are able to access files and run programs on the database server as the user the database runs as. As these roles are able to access any file on the server file system, they bypass all database-level permission checks when accessing files directly and they could be used to gain superuser-level access, therefore great care should be taken when granting these roles to users.

Care should be taken when granting these roles to ensure they are only used where needed and with the understanding that these roles grant access to privileged information.

Administrators can grant access to these roles to users using the `GRANT` command, for example:

```
GRANT pg_signal_backend TO admin_user;
```

## 19.6. Function Security

Functions, triggers and row-level security policies allow users to insert code into the backend server that other users might execute unintentionally. Hence, these mechanisms permit users to “Trojan horse” others with relative ease. The strongest protection is tight control over who can define objects. Where that is infeasible, write queries referring only to objects having trusted owners. Remove from `search_path` the public schema and any other schemas that permit untrusted users to create objects.

Functions run inside the backend server process with the operating system permissions of the database server daemon. If the programming language used for the function allows unchecked memory accesses, it is possible to change the server's internal data structures. Hence, among many other things, such functions can circumvent any system access controls. Function languages that allow such access

are considered “untrusted”, and LightDB allows only superusers to create functions written in those languages.

---

# Chapter 20. Managing Databases

Every instance of a running LightDB server manages one or more databases. Databases are therefore the topmost hierarchical level for organizing SQL objects (“database objects”). This chapter describes the properties of databases, and how to create, manage, and destroy them.

## 20.1. Overview

A small number of objects, like role, database, and tablespace names, are defined at the cluster level and stored in the `pg_global` tablespace. Inside the cluster are multiple databases, which are isolated from each other but can access cluster-level objects. Inside each database are multiple schemas, which contain objects like tables and functions. So the full hierarchy is: cluster, database, schema, table (or some other kind of object, such as a function).

When connecting to the database server, a client must specify the database name in its connection request. It is not possible to access more than one database per connection. However, clients can open multiple connections to the same database, or different databases. Database-level security has two components: access control (see Section 18.1), managed at the connection level, and authorization control (see Section 5.7), managed via the grant system. Foreign data wrappers (see `postgres_fdw`) allow for objects within one database to act as proxies for objects in other database or clusters. The older `dblink` module (see `dblink`) provides a similar capability. By default, all users can connect to all databases using all connection methods.

If one LightDB server cluster is planned to contain unrelated projects or users that should be, for the most part, unaware of each other, it is recommended to put them into separate databases and adjust authorizations and access controls accordingly. If the projects or users are interrelated, and thus should be able to use each other's resources, they should be put in the same database but probably into separate schemas; this provides a modular structure with namespace isolation and authorization control. More information about managing schemas is in Section 5.9.

While multiple databases can be created within a single cluster, it is advised to consider carefully whether the benefits outweigh the risks and limitations. In particular, the impact that having a shared WAL (see Chapter 27) has on backup and recovery options. While individual databases in the cluster are isolated when considered from the user's perspective, they are closely bound from the database administrator's point-of-view.

Databases are created with the `CREATE DATABASE` command (see Section 20.2) and destroyed with the `DROP DATABASE` command (see Section 20.5). To determine the set of existing databases, examine the `pg_database` system catalog, for example

```
SELECT datname FROM pg_database;
```

The `ltsql` program's `\l` meta-command and `-l` command-line option are also useful for listing the existing databases.

### Note

The SQL standard calls databases “catalogs”, but there is no difference in practice.

## 20.2. Creating a Database

In order to create a database, the LightDB server must be up and running (see Section 16.3).

Databases are created with the SQL command `CREATE DATABASE`:

```
CREATE DATABASE name ;
```

where *name* follows the usual rules for SQL identifiers. The current role automatically becomes the owner of the new database. It is the privilege of the owner of a database to remove it later (which also removes all the objects in it, even if they have a different owner).

The creation of databases is a restricted operation. See Section 19.2 for how to grant permission.

Since you need to be connected to the database server in order to execute the `CREATE DATABASE` command, the question remains how the *first* database at any given site can be created. The first database is always created by the `initdb` command when the data storage area is initialized. (See Section 16.2.) This database is called `postgres`. So to create the first “ordinary” database you can connect to `postgres`.

A second database, `template1`, is also created during database cluster initialization. Whenever a new database is created within the cluster, `template1` is essentially cloned. This means that any changes you make in `template1` are propagated to all subsequently created databases. Because of this, avoid creating objects in `template1` unless you want them propagated to every newly created database. More details appear in Section 20.3.

As a convenience, there is a program you can execute from the shell to create new databases, `createdb`.

```
createdb dbname
```

`createdb` does no magic. It connects to the `postgres` database and issues the `CREATE DATABASE` command, exactly as described above. The `createdb` reference page contains the invocation details. Note that `createdb` without any arguments will create a database with the current user name.

### Note

Chapter 18 contains information about how to restrict who can connect to a given database.

Sometimes you want to create a database for someone else, and have them become the owner of the new database, so they can configure and manage it themselves. To achieve that, use one of the following commands:

```
CREATE DATABASE dbname OWNER rolename ;
```

from the SQL environment, or:

```
createdb -O rolename dbname
```

from the shell. Only the superuser is allowed to create a database for someone else (that is, for a role you are not a member of).

## 20.3. Template Databases

`CREATE DATABASE` actually works by copying an existing database. By default, it copies the standard system database named `template1`. Thus that database is the “template” from which new databases are made. If you add objects to `template1`, these objects will be copied into subsequently created user databases. This behavior allows site-local modifications to the standard set of objects in

databases. For example, if you install the extension `admcheck` in `template1`, it will automatically be available in user databases without any extra action being taken when those databases are created.

There is a second standard system database named `template0`. This database contains the same data as the initial contents of `template1`, that is, only the standard objects predefined by your version of LightDB. `template0` should never be changed after the database cluster has been initialized. By instructing `CREATE DATABASE` to copy `template0` instead of `template1`, you can create a “pristine” user database (one where no user-defined objects exist and where the system objects have not been altered) that contains none of the site-local additions in `template1`. This is particularly handy when restoring a `lt_dump` dump: the dump script should be restored in a pristine database to ensure that one recreates the correct contents of the dumped database, without conflicting with objects that might have been added to `template1` later on.

Another common reason for copying `template0` instead of `template1` is that new encoding and locale settings can be specified when copying `template0`, whereas a copy of `template1` must use the same settings it does. This is because `template1` might contain encoding-specific or locale-specific data, while `template0` is known not to.

To create a database by copying `template0`, use:

```
CREATE DATABASE dbname TEMPLATE template0;
```

from the SQL environment, or:

```
createdb -T template0 dbname
```

from the shell.

It is possible to create additional template databases, and indeed one can copy any database in a cluster by specifying its name as the template for `CREATE DATABASE`. It is important to understand, however, that this is not (yet) intended as a general-purpose “COPY DATABASE” facility. The principal limitation is that no other sessions can be connected to the source database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; during the copy operation, new connections to the source database are prevented.

Two useful flags exist in `pg_database` for each database: the columns `datistemplate` and `dataallowconn`. `datistemplate` can be set to indicate that a database is intended as a template for `CREATE DATABASE`. If this flag is set, the database can be cloned by any user with `CREATEDB` privileges; if it is not set, only superusers and the owner of the database can clone it. If `dataallowconn` is false, then no new connections to that database will be allowed (but existing sessions are not terminated simply by setting the flag false). The `template0` database is normally marked `dataallowconn = false` to prevent its modification. Both `template0` and `template1` should always be marked with `datistemplate = true`.

### Note

`template1` and `template0` do not have any special status beyond the fact that the name `template1` is the default source database name for `CREATE DATABASE`. For example, one could drop `template1` and recreate it from `template0` without any ill effects. This course of action might be advisable if one has carelessly added a bunch of junk in `template1`. (To delete `template1`, it must have `pg_database.datistemplate = false`.)

The `postgres` database is also created when a database cluster is initialized. This database is meant as a default database for users and applications to connect to. It is simply a copy of `template1` and can be dropped and recreated if necessary.

## 20.4. Database Configuration

Recall from Chapter 17 that the LightDB server provides a large number of run-time configuration variables. You can set database-specific default values for many of these settings.

For example, if for some reason you want to disable the GEQO optimizer for a given database, you'd ordinarily have to either disable it for all databases or make sure that every connecting client is careful to issue `SET geqo TO off`. To make this setting the default within a particular database, you can execute the command:

```
ALTER DATABASE mydb SET geqo TO off;
```

This will save the setting (but not set it immediately). In subsequent connections to this database it will appear as though `SET geqo TO off` had been executed just before the session started. Note that users can still alter this setting during their sessions; it will only be the default. To undo any such setting, use `ALTER DATABASE dbname RESET varname`.

## 20.5. Destroying a Database

Databases are destroyed with the command `DROP DATABASE`:

```
DROP DATABASE name;
```

Only the owner of the database, or a superuser, can drop a database. Dropping a database removes all objects that were contained within the database. The destruction of a database cannot be undone.

You cannot execute the `DROP DATABASE` command while connected to the victim database. You can, however, be connected to any other database, including the `template1` database. `template1` would be the only option for dropping the last user database of a given cluster.

For convenience, there is also a shell program to drop databases, `dropdb`:

```
dropdb dbname
```

(Unlike `createdb`, it is not the default action to drop the database with the current user name.)

## 20.6. Tablespaces

Tablespaces in LightDB allow database administrators to define locations in the file system where the files representing database objects can be stored. Once created, a tablespace can be referred to by name when creating database objects.

By using tablespaces, an administrator can control the disk layout of a LightDB installation. This is useful in at least two ways. First, if the partition or volume on which the cluster was initialized runs out of space and cannot be extended, a tablespace can be created on a different partition and used until the system can be reconfigured.

Second, tablespaces allow an administrator to use knowledge of the usage pattern of database objects to optimize performance. For example, an index which is very heavily used can be placed on a very fast, highly available disk, such as an expensive solid state device. At the same time a table storing archived data which is rarely used or not performance critical could be stored on a less expensive, slower disk system.



**Warning**

Even though located outside the main LightDB data directory, tablespaces are an integral part of the database cluster and *cannot* be treated as an autonomous collection of data files. They are dependent on metadata contained in the main data directory, and therefore cannot be attached to a different database cluster or backed up individually. Similarly, if you lose a tablespace (file deletion, disk failure, etc), the database cluster might become unreadable or unable to start. Placing a tablespace on a temporary file system like a RAM disk risks the reliability of the entire cluster.

To define a tablespace, use the CREATE TABLESPACE command, for example::

```
CREATE TABLESPACE fastspace LOCATION '/ssdl/postgresql/data';
```

The location must be an existing, empty directory that is owned by the LightDB operating system user. All objects subsequently created within the tablespace will be stored in files underneath this directory. The location must not be on removable or transient storage, as the cluster might fail to function if the tablespace is missing or lost.

**Note**

There is usually not much point in making more than one tablespace per logical file system, since you cannot control the location of individual files within a logical file system. However, LightDB does not enforce any such limitation, and indeed it is not directly aware of the file system boundaries on your system. It just stores files in the directories you tell it to use.

Creation of the tablespace itself must be done as a database superuser, but after that you can allow ordinary database users to use it. To do that, grant them the CREATE privilege on it.

Tables, indexes, and entire databases can be assigned to particular tablespaces. To do so, a user with the CREATE privilege on a given tablespace must pass the tablespace name as a parameter to the relevant command. For example, the following creates a table in the tablespace `space1`:

```
CREATE TABLE foo(i int) TABLESPACE space1;
```

Alternatively, use the `default_tablespace` parameter:

```
SET default_tablespace = space1;  
CREATE TABLE foo(i int);
```

When `default_tablespace` is set to anything but an empty string, it supplies an implicit TABLESPACE clause for CREATE TABLE and CREATE INDEX commands that do not have an explicit one.

There is also a `temp_tablespaces` parameter, which determines the placement of temporary tables and indexes, as well as temporary files that are used for purposes such as sorting large data sets. This can be a list of tablespace names, rather than only one, so that the load associated with temporary objects can be spread over multiple tablespaces. A random member of the list is picked each time a temporary object is to be created.

The tablespace associated with a database is used to store the system catalogs of that database. Furthermore, it is the default tablespace used for tables, indexes, and temporary files created

within the database, if no `TABLESPACE` clause is given and no other selection is specified by `default_tablespace` or `temp_tablespaces` (as appropriate). If a database is created without specifying a tablespace for it, it uses the same tablespace as the template database it is copied from.

Two tablespaces are automatically created when the database cluster is initialized. The `pg_global` tablespace is used for shared system catalogs. The `pg_default` tablespace is the default tablespace of the `template1` and `template0` databases (and, therefore, will be the default tablespace for other databases as well, unless overridden by a `TABLESPACE` clause in `CREATE DATABASE`).

Once created, a tablespace can be used from any database, provided the requesting user has sufficient privilege. This means that a tablespace cannot be dropped until all objects in all databases using the tablespace have been removed.

To remove an empty tablespace, use the `DROP TABLESPACE` command.

To determine the set of existing tablespaces, examine the `pg_tablespace` system catalog, for example

```
SELECT spcname FROM pg_tablespace;
```

The `ltsql` program's `\db` meta-command is also useful for listing the existing tablespaces.

LightDB makes use of symbolic links to simplify the implementation of tablespaces. This means that tablespaces can be used *only* on systems that support symbolic links.

The directory `$LTDATA/lt_tblspc` contains symbolic links that point to each of the non-built-in tablespaces defined in the cluster. Although not recommended, it is possible to adjust the tablespace layout by hand by redefining these links. Under no circumstances perform this operation while the server is running. Note that in LightDB 9.1 and earlier you will also need to update the `pg_tablespace` catalog with the new locations. (If you do not, `lt_dump` will continue to output the old tablespace locations.)

---

# Chapter 21. Localization

This chapter describes the available localization features from the point of view of the administrator. LightDB supports two localization facilities:

- Using the locale features of the operating system to provide locale-specific collation order, number formatting, translated messages, and other aspects. This is covered in Section 21.1 and Section 21.2.
- Providing a number of different character sets to support storing text in all kinds of languages, and providing character set translation between client and server. This is covered in Section 21.3.

## 21.1. Locale Support

*Locale* support refers to an application respecting cultural preferences regarding alphabets, sorting, number formatting, etc. LightDB uses the standard ISO C and POSIX locale facilities provided by the server operating system. For additional information refer to the documentation of your system.

### 21.1.1. Overview

Locale support is automatically initialized when a database cluster is created using `initdb`. `initdb` will initialize the database cluster with the locale setting of its execution environment by default, so if your system is already set to use the locale that you want in your database cluster then there is nothing else you need to do. If you want to use a different locale (or you are not sure which locale your system is set to), you can instruct `initdb` exactly which locale to use by specifying the `--locale` option. For example:

```
initdb --locale=sv_SE
```

This example for Unix systems sets the locale to Swedish (`sv`) as spoken in Sweden (`SE`). Other possibilities might include `en_US` (U.S. English) and `fr_CA` (French Canadian). If more than one character set can be used for a locale then the specifications can take the form `language_territory.codeset`. For example, `fr_BE.UTF-8` represents the French language (`fr`) as spoken in Belgium (`BE`), with a UTF-8 character set encoding.

What locales are available on your system under what names depends on what was provided by the operating system vendor and what was installed. On most Unix systems, the command `locale -a` will provide a list of available locales.

Occasionally it is useful to mix rules from several locales, e.g., use English collation rules but Spanish messages. To support that, a set of locale subcategories exist that control only certain aspects of the localization rules:

LC_COLLATE	String sort order
LC_CTYPE	Character classification (What is a letter? Its upper-case equivalent?)
LC_MESSAGES	Language of messages
LC_MONETARY	Formatting of currency amounts
LC_NUMERIC	Formatting of numbers
LC_TIME	Formatting of dates and times

The category names translate into names of `initdb` options to override the locale choice for a specific category. For instance, to set the locale to French Canadian, but use U.S. rules for formatting currency, use `initdb --locale=fr_CA --lc-monetary=en_US`.

If you want the system to behave as if it had no locale support, use the special locale name `C`, or equivalently `POSIX`.

Some locale categories must have their values fixed when the database is created. You can use different settings for different databases, but once a database is created, you cannot change them for that database anymore. `LC_COLLATE` and `LC_CTYPE` are these categories. They affect the sort order of indexes, so they must be kept fixed, or indexes on text columns would become corrupt. (But you can alleviate this restriction using collations, as discussed in Section 21.2.) The default values for these categories are determined when `initdb` is run, and those values are used when new databases are created, unless specified otherwise in the `CREATE DATABASE` command.

The other locale categories can be changed whenever desired by setting the server configuration parameters that have the same name as the locale categories (see Section 17.11.2 for details). The values that are chosen by `initdb` are actually only written into the configuration file `lightdb.conf` to serve as defaults when the server is started. If you remove these assignments from `lightdb.conf` then the server will inherit the settings from its execution environment.

Note that the locale behavior of the server is determined by the environment variables seen by the server, not by the environment of any client. Therefore, be careful to configure the correct locale settings before starting the server. A consequence of this is that if client and server are set up in different locales, messages might appear in different languages depending on where they originated.

### Note

When we speak of inheriting the locale from the execution environment, this means the following on most operating systems: For a given locale category, say the collation, the following environment variables are consulted in this order until one is found to be set: `LC_ALL`, `LC_COLLATE` (or the variable corresponding to the respective category), `LANG`. If none of these environment variables are set then the locale defaults to `C`.

Some message localization libraries also look at the environment variable `LANGUAGE` which overrides all other locale settings for the purpose of setting the language of messages. If in doubt, please refer to the documentation of your operating system, in particular the documentation about `gettext`.

To enable messages to be translated to the user's preferred language, NLS must have been selected at build time (`configure --enable-nls`). All other locale support is built in automatically.

## 21.1.2. Behavior

The locale settings influence the following SQL features:

- Sort order in queries using `ORDER BY` or the standard comparison operators on textual data
- The `upper`, `lower`, and `initcap` functions
- Pattern matching operators (`LIKE`, `SIMILAR TO`, and POSIX-style regular expressions); locales affect both case insensitive matching and the classification of characters by character-class regular expressions
- The `to_char` family of functions
- The ability to use indexes with `LIKE` clauses

The drawback of using locales other than `C` or `POSIX` in LightDB is its performance impact. It slows character handling and prevents ordinary indexes from being used by `LIKE`. For this reason use locales only if you actually need them.

As a workaround to allow LightDB to use indexes with `LIKE` clauses under a non-`C` locale, several custom operator classes exist. These allow the creation of an index that performs a strict character-by-character comparison, ignoring locale comparison rules. Refer to Section 11.10 for more information. Another approach is to create indexes using the `C` collation, as discussed in Section 21.2.

### 21.1.3. Problems

If locale support doesn't work according to the explanation above, check that the locale support in your operating system is correctly configured. To check what locales are installed on your system, you can use the command `locale -a` if your operating system provides it.

Check that LightDB is actually using the locale that you think it is. The `LC_COLLATE` and `LC_CTYPE` settings are determined when a database is created, and cannot be changed except by creating a new database. Other locale settings including `LC_MESSAGES` and `LC_MONETARY` are initially determined by the environment the server is started in, but can be changed on-the-fly. You can check the active locale settings using the `SHOW` command.

The directory `src/test/locale` in the source distribution contains a test suite for LightDB's locale support.

Client applications that handle server-side errors by parsing the text of the error message will obviously have problems when the server's messages are in a different language. Authors of such applications are advised to make use of the error code scheme instead.

Maintaining catalogs of message translations requires the on-going efforts of many volunteers that want to see LightDB speak their preferred language well. If messages in your language are currently not available or not fully translated, your assistance would be appreciated. If you want to help, refer to Chapter 51 or write to the developers' mailing list.

## 21.2. Collation Support

The collation feature allows specifying the sort order and character classification behavior of data per-column, or even per-operation. This alleviates the restriction that the `LC_COLLATE` and `LC_CTYPE` settings of a database cannot be changed after its creation.

### 21.2.1. Concepts

Conceptually, every expression of a collatable data type has a collation. (The built-in collatable data types are `text`, `varchar`, and `char`. User-defined base types can also be marked collatable, and of course a domain over a collatable data type is collatable.) If the expression is a column reference, the collation of the expression is the defined collation of the column. If the expression is a constant, the collation is the default collation of the data type of the constant. The collation of a more complex expression is derived from the collations of its inputs, as described below.

The collation of an expression can be the “default” collation, which means the locale settings defined for the database. It is also possible for an expression's collation to be indeterminate. In such cases, ordering operations and other operations that need to know the collation will fail.

When the database system has to perform an ordering or a character classification, it uses the collation of the input expression. This happens, for example, with `ORDER BY` clauses and function or operator calls such as `<`. The collation to apply for an `ORDER BY` clause is simply the collation of the sort key. The collation to apply for a function or operator call is derived from the arguments, as described below. In addition to comparison operators, collations are taken into account by functions that convert between lower and upper case letters, such as `lower`, `upper`, and `initcap`; by pattern matching operators; and by `to_char` and related functions.

For a function or operator call, the collation that is derived by examining the argument collations is used at run time for performing the specified operation. If the result of the function or operator call is of a collatable data type, the collation is also used at parse time as the defined collation of the function or operator expression, in case there is a surrounding expression that requires knowledge of its collation.

The *collation derivation* of an expression can be implicit or explicit. This distinction affects how collations are combined when multiple different collations appear in an expression. An explicit collation derivation occurs when a `COLLATE` clause is used; all other collation derivations are implicit.

When multiple collations need to be combined, for example in a function call, the following rules are used:

1. If any input expression has an explicit collation derivation, then all explicitly derived collations among the input expressions must be the same, otherwise an error is raised. If any explicitly derived collation is present, that is the result of the collation combination.
2. Otherwise, all input expressions must have the same implicit collation derivation or the default collation. If any non-default collation is present, that is the result of the collation combination. Otherwise, the result is the default collation.
3. If there are conflicting non-default implicit collations among the input expressions, then the combination is deemed to have indeterminate collation. This is not an error condition unless the particular function being invoked requires knowledge of the collation it should apply. If it does, an error will be raised at run-time.

For example, consider this table definition:

```
CREATE TABLE test1 (
  a text COLLATE "de_DE",
  b text COLLATE "es_ES",
  ...
);
```

Then in

```
SELECT a < 'foo' FROM test1;
```

the < comparison is performed according to de\_DE rules, because the expression combines an implicitly derived collation with the default collation. But in

```
SELECT a < ('foo' COLLATE "fr_FR") FROM test1;
```

the comparison is performed using fr\_FR rules, because the explicit collation derivation overrides the implicit one. Furthermore, given

```
SELECT a < b FROM test1;
```

the parser cannot determine which collation to apply, since the a and b columns have conflicting implicit collations. Since the < operator does need to know which collation to use, this will result in an error. The error can be resolved by attaching an explicit collation specifier to either input expression, thus:

```
SELECT a < b COLLATE "de_DE" FROM test1;
```

or equivalently

```
SELECT a COLLATE "de_DE" < b FROM test1;
```

On the other hand, the structurally similar case

```
SELECT a || b FROM test1;
```

does not result in an error, because the || operator does not care about collations: its result is the same regardless of the collation.

The collation assigned to a function or operator's combined input expressions is also considered to apply to the function or operator's result, if the function or operator delivers a result of a collatable data type. So, in

```
SELECT * FROM test1 ORDER BY a || 'foo';
```

the ordering will be done according to de\_DE rules. But this query:

```
SELECT * FROM test1 ORDER BY a || b;
```

results in an error, because even though the || operator doesn't need to know a collation, the ORDER BY clause does. As before, the conflict can be resolved with an explicit collation specifier:

```
SELECT * FROM test1 ORDER BY a || b COLLATE "fr_FR";
```

## 21.2.2. Managing Collations

A collation is an SQL schema object that maps an SQL name to locales provided by libraries installed in the operating system. A collation definition has a *provider* that specifies which library supplies the locale data. One standard provider name is `libc`, which uses the locales provided by the operating system C library. These are the locales that most tools provided by the operating system use. Another provider is `icu`, which uses the external ICU library. ICU locales can only be used if support for ICU was configured when LightDB was built.

A collation object provided by `libc` maps to a combination of `LC_COLLATE` and `LC_CTYPE` settings, as accepted by the `setlocale()` system library call. (As the name would suggest, the main purpose of a collation is to set `LC_COLLATE`, which controls the sort order. But it is rarely necessary in practice to have an `LC_CTYPE` setting that is different from `LC_COLLATE`, so it is more convenient to collect these under one concept than to create another infrastructure for setting `LC_CTYPE` per expression.) Also, a `libc` collation is tied to a character set encoding (see Section 21.3). The same collation name may exist for different encodings.

A collation object provided by `icu` maps to a named collator provided by the ICU library. ICU does not support separate “collate” and “ctype” settings, so they are always the same. Also, ICU collations are independent of the encoding, so there is always only one ICU collation of a given name in a database.

### 21.2.2.1. Standard Collations

On all platforms, the collations named `default`, `C`, and `POSIX` are available. Additional collations may be available depending on operating system support. The `default` collation selects the `LC_COLLATE` and `LC_CTYPE` values specified at database creation time. The `C` and `POSIX` collations both specify “traditional C” behavior, in which only the ASCII letters “A” through “Z” are treated as letters, and sorting is done strictly by character code byte values.

Additionally, the SQL standard collation name `ucs_basic` is available for encoding UTF8. It is equivalent to `C` and sorts by Unicode code point.

### 21.2.2.2. Predefined Collations

If the operating system provides support for using multiple locales within a single program (`newlocale` and related functions), or if support for ICU is configured, then when a database cluster is initialized, `initdb` populates the system catalog `pg_collation` with collations based on all the locales it finds in the operating system at the time.

To inspect the currently available locales, use the query `SELECT * FROM pg_collation`, or the command `\dos+ in ltsql`.

### 21.2.2.2.1. libc Collations

For example, the operating system might provide a locale named `de_DE.utf8`. `initdb` would then create a collation named `de_DE.utf8` for encoding UTF8 that has both `LC_COLLATE` and `LC_CTYPE` set to `de_DE.utf8`. It will also create a collation with the `.utf8` tag stripped off the name. So you could also use the collation under the name `de_DE`, which is less cumbersome to write and makes the name less encoding-dependent. Note that, nevertheless, the initial set of collation names is platform-dependent.

The default set of collations provided by `libc` map directly to the locales installed in the operating system, which can be listed using the command `locale -a`. In case a `libc` collation is needed that has different values for `LC_COLLATE` and `LC_CTYPE`, or if new locales are installed in the operating system after the database system was initialized, then a new collation may be created using the `CREATE COLLATION` command. New operating system locales can also be imported en masse using the `pg_import_system_collations()` function.

Within any particular database, only collations that use that database's encoding are of interest. Other entries in `pg_collation` are ignored. Thus, a stripped collation name such as `de_DE` can be considered unique within a given database even though it would not be unique globally. Use of the stripped collation names is recommended, since it will make one fewer thing you need to change if you decide to change to another database encoding. Note however that the `default`, `C`, and `POSIX` collations can be used regardless of the database encoding.

LightDB considers distinct collation objects to be incompatible even when they have identical properties. Thus for example,

```
SELECT a COLLATE "C" < b COLLATE "POSIX" FROM test1;
```

will draw an error even though the `C` and `POSIX` collations have identical behaviors. Mixing stripped and non-stripped collation names is therefore not recommended.

### 21.2.2.2.2. ICU Collations

With ICU, it is not sensible to enumerate all possible locale names. ICU uses a particular naming system for locales, but there are many more ways to name a locale than there are actually distinct locales. `initdb` uses the ICU APIs to extract a set of distinct locales to populate the initial set of collations. Collations provided by ICU are created in the SQL environment with names in BCP 47 language tag format, with a “private use” extension `-x-icu` appended, to distinguish them from `libc` locales.

Here are some example collations that might be created:

```
de-x-icu
```

German collation, default variant

```
de-AT-x-icu
```

German collation for Austria, default variant

(There are also, say, `de-DE-x-icu` or `de-CH-x-icu`, but as of this writing, they are equivalent to `de-x-icu`.)

```
und-x-icu (for “undefined”)
```

ICU “root” collation. Use this to get a reasonable language-agnostic sort order.

Some (less frequently used) encodings are not supported by ICU. When the database encoding is one of these, ICU collation entries in `pg_collation` are ignored. Attempting to use one will draw an error along the lines of “collation “de-x-icu” for encoding “WIN874” does not exist”.



### 21.2.2.3. Creating New Collation Objects

If the standard and predefined collations are not sufficient, users can create their own collation objects using the SQL command `CREATE COLLATION`.

The standard and predefined collations are in the schema `pg_catalog`, like all predefined objects. User-defined collations should be created in user schemas. This also ensures that they are saved by `lt_dump`.

#### 21.2.2.3.1. libc Collations

New libc collations can be created like this:

```
CREATE COLLATION german (provider = libc, locale = 'de_DE');
```

The exact values that are acceptable for the `locale` clause in this command depend on the operating system. On Unix-like systems, the command `locale -a` will show a list.

Since the predefined libc collations already include all collations defined in the operating system when the database instance is initialized, it is not often necessary to manually create new ones. Reasons might be if a different naming system is desired (in which case see also Section 21.2.2.3.3) or if the operating system has been upgraded to provide new locale definitions (in which case see also `pg_import_system_collations()`).

#### 21.2.2.3.2. ICU Collations

ICU allows collations to be customized beyond the basic language+country set that is preloaded by `initdb`. Users are encouraged to define their own collation objects that make use of these facilities to suit the sorting behavior to their requirements. See <https://unicode-org.github.io/icu/userguide/locale/> and <https://unicode-org.github.io/icu/userguide/collation/api.html> for information on ICU locale naming. The set of acceptable names and attributes depends on the particular ICU version.

Here are some examples:

```
CREATE COLLATION "de-u-co-phonebk-x-icu" (provider = icu, locale =
'de-u-co-phonebk');
CREATE COLLATION "de-u-co-phonebk-x-icu" (provider = icu, locale =
'de@collation=phonebook');
```

German collation with phone book collation type

The first example selects the ICU locale using a “language tag” per BCP 47. The second example uses the traditional ICU-specific locale syntax. The first style is preferred going forward, but it is not supported by older ICU versions.

Note that you can name the collation objects in the SQL environment anything you want. In this example, we follow the naming style that the predefined collations use, which in turn also follow BCP 47, but that is not required for user-defined collations.

```
CREATE COLLATION "und-u-co-emoji-x-icu" (provider = icu, locale =
'und-u-co-emoji');
CREATE COLLATION "und-u-co-emoji-x-icu" (provider = icu, locale =
'@collation=emoji');
```

Root collation with Emoji collation type, per Unicode Technical Standard #51

Observe how in the traditional ICU locale naming system, the root locale is selected by an empty string.

```
CREATE COLLATION latinlast (provider = icu, locale = 'en-u-kr-grek-
latn');
CREATE COLLATION latinlast (provider = icu, locale =
'en@colReorder=grek-latn');
```

Sort Greek letters before Latin ones. (The default is Latin before Greek.)

```
CREATE COLLATION upperfirst (provider = icu, locale = 'en-u-kf-
upper');
CREATE COLLATION upperfirst (provider = icu, locale =
'en@colCaseFirst=upper');
```

Sort upper-case letters before lower-case letters. (The default is lower-case letters first.)

```
CREATE COLLATION special (provider = icu, locale = 'en-u-kf-upper-
kr-grek-latn');
CREATE COLLATION special (provider = icu, locale =
'en@colCaseFirst=upper;colReorder=grek-latn');
```

Combines both of the above options.

```
CREATE COLLATION numeric (provider = icu, locale = 'en-u-kn-true');
CREATE COLLATION numeric (provider = icu, locale =
'en@colNumeric=yes');
```

Numeric ordering, sorts sequences of digits by their numeric value, for example: A-21 < A-123 (also known as natural sort).

See Unicode Technical Standard #35<sup>1</sup> and BCP 47<sup>2</sup> for details. The list of possible collation types (collation) can be found in the CLDR repository<sup>3</sup>.

Note that while this system allows creating collations that “ignore case” or “ignore accents” or similar (using the *ks* key), in order for such collations to act in a truly case- or accent-insensitive manner, they also need to be declared as not *deterministic* in `CREATE COLLATION`; see Section 21.2.2.4. Otherwise, any strings that compare equal according to the collation but are not byte-wise equal will be sorted according to their byte values.

### Note

By design, ICU will accept almost any string as a locale name and match it to the closest locale it can provide, using the fallback procedure described in its documentation. Thus, there will be no direct feedback if a collation specification is composed using features that the given ICU installation does not actually support. It is therefore recommended to create application-level test cases to check that the collation definitions satisfy one's requirements.

### 21.2.2.3.3. Copying Collations

The command `CREATE COLLATION` can also be used to create a new collation from an existing collation, which can be useful to be able to use operating-system-independent collation names in applications, create compatibility names, or use an ICU-provided collation under a more readable name. For example:

```
CREATE COLLATION german FROM "de_DE";
CREATE COLLATION french FROM "fr-x-icu";
```

<sup>1</sup> <https://www.unicode.org/reports/tr35/tr35-collation.html>

<sup>2</sup> <https://tools.ietf.org/html/bcp47>

<sup>3</sup> <https://github.com/unicode-org/cldr/blob/master/common/bcp47/collation.xml>

### 21.2.2.4. Nondeterministic Collations

A collation is either *deterministic* or *nondeterministic*. A deterministic collation uses deterministic comparisons, which means that it considers strings to be equal only if they consist of the same byte sequence. Nondeterministic comparison may determine strings to be equal even if they consist of different bytes. Typical situations include case-insensitive comparison, accent-insensitive comparison, as well as comparison of strings in different Unicode normal forms. It is up to the collation provider to actually implement such insensitive comparisons; the deterministic flag only determines whether ties are to be broken using bitwise comparison. See also Unicode Technical Standard 10<sup>4</sup> for more information on the terminology.

To create a nondeterministic collation, specify the property `deterministic = false` to `CREATE COLLATION`, for example:

```
CREATE COLLATION ndcoll (provider = icu, locale = 'und',
  deterministic = false);
```

This example would use the standard Unicode collation in a nondeterministic way. In particular, this would allow strings in different normal forms to be compared correctly. More interesting examples make use of the ICU customization facilities explained above. For example:

```
CREATE COLLATION case_insensitive (provider = icu, locale = 'und-u-
ks-level2', deterministic = false);
CREATE COLLATION ignore_accents (provider = icu, locale = 'und-u-
ks-level1-kc-true', deterministic = false);
```

All standard and predefined collations are deterministic, all user-defined collations are deterministic by default. While nondeterministic collations give a more “correct” behavior, especially when considering the full power of Unicode and its many special cases, they also have some drawbacks. Foremost, their use leads to a performance penalty. Note, in particular, that B-tree cannot use deduplication with indexes that use a nondeterministic collation. Also, certain operations are not possible with nondeterministic collations, such as pattern matching operations. Therefore, they should be used only in cases where they are specifically wanted.

#### Tip

To deal with text in different Unicode normalization forms, it is also an option to use the functions/expressions `normalize` and `is_normalized` to preprocess or check the strings, instead of using nondeterministic collations. There are different trade-offs for each approach.

## 21.3. Character Set Support

The character set support in LightDB allows you to store text in a variety of character sets (also called encodings), including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your LightDB database cluster using `initdb`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

An important restriction, however, is that each database's character set must be compatible with the database's `LC_CTYPE` (character classification) and `LC_COLLATE` (string sort order) locale settings.

<sup>4</sup> <https://www.unicode.org/reports/tr10>

For C or POSIX locale, any character set is allowed, but for other libc-provided locales there is only one character set that will work correctly. (On Windows, however, UTF-8 encoding can be used with any locale.) If you have ICU support configured, ICU-provided locales can be used with most but not all server-side encodings.

## 21.3.1. Supported Character Sets

Table 21.1 shows the character sets available for use in LightDB.

**Table 21.1. LightDB Character Sets**

Name	Description	Language	Server?	ICU?	Bytes/ Char	Aliases
BIG5	Big Five	Traditional Chinese	No	No	1–2	WIN950, Windows950
EUC_CN	Extended UNIX Code-CN	Simplified Chinese	Yes	Yes	1–3	
EUC_JP	Extended UNIX Code-JP	Japanese	Yes	Yes	1–3	
EUC_JIS_2004	Extended UNIX Code-JP, JIS X 0213	Japanese	Yes	No	1–3	
EUC_KR	Extended UNIX Code-KR	Korean	Yes	Yes	1–3	
EUC_TW	Extended UNIX Code-TW	Traditional Chinese, Taiwanese	Yes	Yes	1–3	
GB18030	National Standard	Chinese	Yes	No	1–4	
GBK	Extended National Standard	Simplified Chinese	Yes	No	1–2	WIN936, Windows936
ISO_8859_5	ISO 8859-5, ECMA 113	Latin/Cyrillic	Yes	Yes	1	
ISO_8859_6	ISO 8859-6, ECMA 114	Latin/Arabic	Yes	Yes	1	
ISO_8859_7	ISO 8859-7, ECMA 118	Latin/Greek	Yes	Yes	1	
ISO_8859_8	ISO 8859-8, ECMA 121	Latin/Hebrew	Yes	Yes	1	
JOHAB	JOHAB	Korean (Hangul)	No	No	1–3	
KOI8R	KOI8-R	Cyrillic (Russian)	Yes	Yes	1	KOI8
KOI8U	KOI8-U	Cyrillic (Ukrainian)	Yes	Yes	1	
LATIN1	ISO 8859-1, ECMA 94	Western European	Yes	Yes	1	ISO88591

Name	Description	Language	Server?	ICU?	Bytes/ Char	Aliases
LATIN2	ISO 8859-2, ECMA 94	Central European	Yes	Yes	1	ISO88592
LATIN3	ISO 8859-3, ECMA 94	South European	Yes	Yes	1	ISO88593
LATIN4	ISO 8859-4, ECMA 94	North European	Yes	Yes	1	ISO88594
LATIN5	ISO 8859-9, ECMA 128	Turkish	Yes	Yes	1	ISO88599
LATIN6	ISO 8859-10, ECMA 144	Nordic	Yes	Yes	1	ISO885910
LATIN7	ISO 8859-13	Baltic	Yes	Yes	1	ISO885913
LATIN8	ISO 8859-14	Celtic	Yes	Yes	1	ISO885914
LATIN9	ISO 8859-15	LATIN1 with Euro and accents	Yes	Yes	1	ISO885915
LATIN10	ISO 8859-16, ASRO SR 14111	Romanian	Yes	No	1	ISO885916
MULE_INTERNAL	Mule internal code	Multilingual Emacs	Yes	No	1-4	
SJIS	Shift JIS	Japanese	No	No	1-2	Mskanji, ShiftJIS, WIN932, Windows932
SHIFT_JIS_2004	Shift JIS, JIS X 0213	Japanese	No	No	1-2	
SQL_ASCII	unspecified (see text)	<i>any</i>	Yes	No	1	
UHC	Unified Hangul Code	Korean	No	No	1-2	WIN949, Windows949
UTF8	Unicode, 8-bit	<i>all</i>	Yes	Yes	1-4	Unicode
WIN866	Windows CP866	Cyrillic	Yes	Yes	1	ALT
WIN874	Windows CP874	Thai	Yes	No	1	
WIN1250	Windows CP1250	Central European	Yes	Yes	1	
WIN1251	Windows CP1251	Cyrillic	Yes	Yes	1	WIN
WIN1252	Windows CP1252	Western European	Yes	Yes	1	
WIN1253	Windows CP1253	Greek	Yes	Yes	1	
WIN1254	Windows CP1254	Turkish	Yes	Yes	1	
WIN1255	Windows CP1255	Hebrew	Yes	Yes	1	

Name	Description	Language	Server?	ICU?	Bytes/Char	Aliases
WIN1256	Windows CP1256	Arabic	Yes	Yes	1	
WIN1257	Windows CP1257	Baltic	Yes	Yes	1	
WIN1258	Windows CP1258	Vietnamese	Yes	Yes	1	ABC, TCVN, TCVN5712, VSCII

Not all client APIs support all the listed character sets. For example, the LightDB JDBC driver does not support MULE\_INTERNAL, LATIN6, LATIN8, and LATIN10.

The `SQL_ASCII` setting behaves considerably differently from the other settings. When the server character set is `SQL_ASCII`, the server interprets byte values 0–127 according to the ASCII standard, while byte values 128–255 are taken as uninterpreted characters. No encoding conversion will be done when the setting is `SQL_ASCII`. Thus, this setting is not so much a declaration that a specific encoding is in use, as a declaration of ignorance about the encoding. In most cases, if you are working with any non-ASCII data, it is unwise to use the `SQL_ASCII` setting because LightDB will be unable to help you by converting or validating non-ASCII characters.

The GB18030 standard supported by LightDB is version 2022. If the GBK/GB18030 encoding contains special values such as 0x40-0x7E, you cannot use these Chinese characters to name database, schema, relation, and column.

## 21.3.2. Setting the Character Set

`initdb` defines the default character set (encoding) for a LightDB cluster. For example,

```
initdb -E EUC_JP
```

sets the default character set to `EUC_JP` (Extended Unix Code for Japanese). You can use `--encoding` instead of `-E` if you prefer longer option strings. If no `-E` or `--encoding` option is given, `initdb` attempts to determine the appropriate encoding to use based on the specified or default locale.

You can specify a non-default encoding at database creation time, provided that the encoding is compatible with the selected locale:

```
createdb -E EUC_KR -T template0 --lc-collate=ko_KR.euckr --lc-ctype=ko_KR.euckr korean
```

This will create a database named `korean` that uses the character set `EUC_KR`, and locale `ko_KR`. Another way to accomplish this is to use this SQL command:

```
CREATE DATABASE korean WITH ENCODING 'EUC_KR'
LC_COLLATE='ko_KR.euckr' LC_CTYPE='ko_KR.euckr'
TEMPLATE=template0;
```

Notice that the above commands specify copying the `template0` database. When copying any other database, the encoding and locale settings cannot be changed from those of the source database, because that might result in corrupt data. For more information see Section 20.3.

The encoding for a database is stored in the system catalog `pg_database`. You can see it by using the `ltsql -l` option or the `\l` command.

```
$ ltsql -l
```

List of databases				
Name	Owner	Encoding	Collation	Ctype
Access Privileges				
clocaledb	hlinnaka	SQL_ASCII	C	C
englishdb	hlinnaka	UTF8	en_GB.UTF8	en_GB.UTF8
japanese	hlinnaka	UTF8	ja_JP.UTF8	ja_JP.UTF8
korean	hlinnaka	EUC_KR	ko_KR.euckr	ko_KR.euckr
postgres	hlinnaka	UTF8	fi_FI.UTF8	fi_FI.UTF8
template0	hlinnaka	UTF8	fi_FI.UTF8	fi_FI.UTF8
{=c/hlinnaka,hlinnaka=CTc/hlinnaka}				
template1	hlinnaka	UTF8	fi_FI.UTF8	fi_FI.UTF8
{=c/hlinnaka,hlinnaka=CTc/hlinnaka}				

(7 rows)

### Important

On most modern operating systems, LightDB can determine which character set is implied by the LC\_CTYPE setting, and it will enforce that only the matching database encoding is used. On older systems it is your responsibility to ensure that you use the encoding expected by the locale you have selected. A mistake in this area is likely to lead to strange behavior of locale-dependent operations such as sorting.

LightDB will allow superusers to create databases with SQL\_ASCII encoding even when LC\_CTYPE is not C or POSIX. As noted above, SQL\_ASCII does not enforce that the data stored in the database has any particular encoding, and so this choice poses risks of locale-dependent misbehavior. Using this combination of settings is deprecated and may someday be forbidden altogether.

## 21.3.3. Automatic Character Set Conversion Between Server and Client

LightDB supports automatic character set conversion between server and client for many combinations of character sets (Section 21.3.4 shows which ones).

To enable automatic character set conversion, you have to tell LightDB the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in `ltsql`. `\encoding` allows you to change client encoding on the fly. For example, to change the encoding to `SJIS`, type:

```
\encoding SJIS
```

- `libpq` (Section 32.10) has functions to control the client encoding.
- Using `SET client_encoding TO`. Setting the client encoding can be done with this SQL command:

```
SET CLIENT_ENCODING TO 'value';
```

Also you can use the standard SQL syntax `SET NAMES` for this purpose:

```
SET NAMES 'value';
```

To query the current client encoding:

```
SHOW client_encoding;
```

To return to the default encoding:

```
RESET client_encoding;
```

- Using `LTCLIENTENCODING`. If the environment variable `LTCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)
- Using the configuration variable `client_encoding`. If the `client_encoding` variable is set, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible — suppose you chose `EUC_JP` for the server and `LATIN1` for the client, and some Japanese characters are returned that do not have a representation in `LATIN1` — an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is disabled, regardless of the server's character set. (However, if the server's character set is not `SQL_ASCII`, the server will still check that incoming data is valid for that encoding; so the net effect is as though the client character set were the same as the server's.) Just as for the server, use of `SQL_ASCII` is unwise unless you are working with all-ASCII data.

## 21.3.4. Available Character Set Conversions

LightDB allows conversion between any two character sets for which a conversion function is listed in the `pg_conversion` system catalog. LightDB comes with some predefined conversions, as summarized in Table 21.2 and shown in more detail in Table 21.3. You can create a new conversion using the SQL command `CREATE CONVERSION`. (To be used for automatic client/server conversions, a conversion must be marked as “default” for its character set pair.)

**Table 21.2. Built-in Client/Server Character Set Conversions**

Server Character Set	Available Client Character Sets
BIG5	<i>not supported as a server encoding</i>
EUC_CN	<i>EUC_CN</i> , MULE_INTERNAL, UTF8
EUC_JP	<i>EUC_JP</i> , MULE_INTERNAL, SJIS, UTF8
EUC_JIS_2004	<i>EUC_JIS_2004</i> , SHIFT_JIS_2004, UTF8
EUC_KR	<i>EUC_KR</i> , MULE_INTERNAL, UTF8
EUC_TW	<i>EUC_TW</i> , BIG5, MULE_INTERNAL, UTF8
GB18030	<i>GB18030</i> , UTF8,
GBK	<i>GBK</i> , UTF8
ISO_8859_5	<i>ISO_8859_5</i> , KOI8R, MULE_INTERNAL, UTF8, WIN866, WIN1251
ISO_8859_6	<i>ISO_8859_6</i> , UTF8
ISO_8859_7	<i>ISO_8859_7</i> , UTF8
ISO_8859_8	<i>ISO_8859_8</i> , UTF8
JOHAB	<i>not supported as a server encoding</i>
KOI8R	<i>KOI8R</i> , ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251



Server Character Set	Available Client Character Sets
KOI8U	<i>KOI8U</i> , UTF8
LATIN1	<i>LATIN1</i> , MULE_INTERNAL, UTF8
LATIN2	<i>LATIN2</i> , MULE_INTERNAL, UTF8, WIN1250
LATIN3	<i>LATIN3</i> , MULE_INTERNAL, UTF8
LATIN4	<i>LATIN4</i> , MULE_INTERNAL, UTF8
LATIN5	<i>LATIN5</i> , UTF8
LATIN6	<i>LATIN6</i> , UTF8
LATIN7	<i>LATIN7</i> , UTF8
LATIN8	<i>LATIN8</i> , UTF8
LATIN9	<i>LATIN9</i> , UTF8
LATIN10	<i>LATIN10</i> , UTF8
MULE_INTERNAL	<i>MULE_INTERNAL</i> , BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8R, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251
SJIS	<i>not supported as a server encoding</i>
SHIFT_JIS_2004	<i>not supported as a server encoding</i>
SQL_ASCII	<i>any (no conversion will be performed)</i>
UHC	<i>not supported as a server encoding</i>
UTF8	<i>all supported encodings</i>
WIN866	<i>WIN866</i> , ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN1251
WIN874	<i>WIN874</i> , UTF8
WIN1250	<i>WIN1250</i> , LATIN2, MULE_INTERNAL, UTF8
WIN1251	<i>WIN1251</i> , ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN866
WIN1252	<i>WIN1252</i> , UTF8
WIN1253	<i>WIN1253</i> , UTF8
WIN1254	<i>WIN1254</i> , UTF8
WIN1255	<i>WIN1255</i> , UTF8
WIN1256	<i>WIN1256</i> , UTF8
WIN1257	<i>WIN1257</i> , UTF8
WIN1258	<i>WIN1258</i> , UTF8

**Table 21.3. All Built-in Character Set Conversions**

Conversion Name <sup>a</sup>	Source Encoding	Destination Encoding
big5_to_euc_tw	BIG5	EUC_TW
big5_to_mic	BIG5	MULE_INTERNAL
big5_to_utf8	BIG5	UTF8
euc_cn_to_mic	EUC_CN	MULE_INTERNAL
euc_cn_to_utf8	EUC_CN	UTF8
euc_jp_to_mic	EUC_JP	MULE_INTERNAL
euc_jp_to_sjis	EUC_JP	SJIS
euc_jp_to_utf8	EUC_JP	UTF8
euc_kr_to_mic	EUC_KR	MULE_INTERNAL

Localization

<b>Conversion Name <sup>a</sup></b>	<b>Source Encoding</b>	<b>Destination Encoding</b>
euc_kr_to_utf8	EUC_KR	UTF8
euc_tw_to_big5	EUC_TW	BIG5
euc_tw_to_mic	EUC_TW	MULE_INTERNAL
euc_tw_to_utf8	EUC_TW	UTF8
gb18030_to_utf8	GB18030	UTF8
gbk_to_utf8	GBK	UTF8
iso_8859_10_to_utf8	LATIN6	UTF8
iso_8859_13_to_utf8	LATIN7	UTF8
iso_8859_14_to_utf8	LATIN8	UTF8
iso_8859_15_to_utf8	LATIN9	UTF8
iso_8859_16_to_utf8	LATIN10	UTF8
iso_8859_1_to_mic	LATIN1	MULE_INTERNAL
iso_8859_1_to_utf8	LATIN1	UTF8
iso_8859_2_to_mic	LATIN2	MULE_INTERNAL
iso_8859_2_to_utf8	LATIN2	UTF8
iso_8859_2_to_windows_1250	LATIN2	WIN1250
iso_8859_3_to_mic	LATIN3	MULE_INTERNAL
iso_8859_3_to_utf8	LATIN3	UTF8
iso_8859_4_to_mic	LATIN4	MULE_INTERNAL
iso_8859_4_to_utf8	LATIN4	UTF8
iso_8859_5_to_koi8_r	ISO_8859_5	KOI8R
iso_8859_5_to_mic	ISO_8859_5	MULE_INTERNAL
iso_8859_5_to_utf8	ISO_8859_5	UTF8
iso_8859_5_to_windows_1251	ISO_8859_5	WIN1251
iso_8859_5_to_windows_866	ISO_8859_5	WIN866
iso_8859_6_to_utf8	ISO_8859_6	UTF8
iso_8859_7_to_utf8	ISO_8859_7	UTF8
iso_8859_8_to_utf8	ISO_8859_8	UTF8
iso_8859_9_to_utf8	LATIN5	UTF8
johab_to_utf8	JOHAB	UTF8
koi8_r_to_iso_8859_5	KOI8R	ISO_8859_5
koi8_r_to_mic	KOI8R	MULE_INTERNAL
koi8_r_to_utf8	KOI8R	UTF8
koi8_r_to_windows_1251	KOI8R	WIN1251
koi8_r_to_windows_866	KOI8R	WIN866
koi8_u_to_utf8	KOI8U	UTF8
mic_to_big5	MULE_INTERNAL	BIG5
mic_to_euc_cn	MULE_INTERNAL	EUC_CN
mic_to_euc_jp	MULE_INTERNAL	EUC_JP
mic_to_euc_kr	MULE_INTERNAL	EUC_KR
mic_to_euc_tw	MULE_INTERNAL	EUC_TW

Localization

Conversion Name <sup>a</sup>	Source Encoding	Destination Encoding
mic_to_iso_8859_1	MULE_INTERNAL	LATIN1
mic_to_iso_8859_2	MULE_INTERNAL	LATIN2
mic_to_iso_8859_3	MULE_INTERNAL	LATIN3
mic_to_iso_8859_4	MULE_INTERNAL	LATIN4
mic_to_iso_8859_5	MULE_INTERNAL	ISO_8859_5
mic_to_koi8_r	MULE_INTERNAL	KOI8R
mic_to_sjis	MULE_INTERNAL	SJIS
mic_to_windows_1250	MULE_INTERNAL	WIN1250
mic_to_windows_1251	MULE_INTERNAL	WIN1251
mic_to_windows_866	MULE_INTERNAL	WIN866
sjis_to_euc_jp	SJIS	EUC_JP
sjis_to_mic	SJIS	MULE_INTERNAL
sjis_to_utf8	SJIS	UTF8
windows_1258_to_utf8	WIN1258	UTF8
uhc_to_utf8	UHC	UTF8
utf8_to_big5	UTF8	BIG5
utf8_to_euc_cn	UTF8	EUC_CN
utf8_to_euc_jp	UTF8	EUC_JP
utf8_to_euc_kr	UTF8	EUC_KR
utf8_to_euc_tw	UTF8	EUC_TW
utf8_to_gbl8030	UTF8	GB18030
utf8_to_gbk	UTF8	GBK
utf8_to_iso_8859_1	UTF8	LATIN1
utf8_to_iso_8859_10	UTF8	LATIN6
utf8_to_iso_8859_13	UTF8	LATIN7
utf8_to_iso_8859_14	UTF8	LATIN8
utf8_to_iso_8859_15	UTF8	LATIN9
utf8_to_iso_8859_16	UTF8	LATIN10
utf8_to_iso_8859_2	UTF8	LATIN2
utf8_to_iso_8859_3	UTF8	LATIN3
utf8_to_iso_8859_4	UTF8	LATIN4
utf8_to_iso_8859_5	UTF8	ISO_8859_5
utf8_to_iso_8859_6	UTF8	ISO_8859_6
utf8_to_iso_8859_7	UTF8	ISO_8859_7
utf8_to_iso_8859_8	UTF8	ISO_8859_8
utf8_to_iso_8859_9	UTF8	LATIN5
utf8_to_johab	UTF8	JOHAB
utf8_to_koi8_r	UTF8	KOI8R
utf8_to_koi8_u	UTF8	KOI8U
utf8_to_sjis	UTF8	SJIS
utf8_to_windows_1258	UTF8	WIN1258

Conversion Name <sup>a</sup>	Source Encoding	Destination Encoding
utf8_to_uhc	UTF8	UHC
utf8_to_windows_1250	UTF8	WIN1250
utf8_to_windows_1251	UTF8	WIN1251
utf8_to_windows_1252	UTF8	WIN1252
utf8_to_windows_1253	UTF8	WIN1253
utf8_to_windows_1254	UTF8	WIN1254
utf8_to_windows_1255	UTF8	WIN1255
utf8_to_windows_1256	UTF8	WIN1256
utf8_to_windows_1257	UTF8	WIN1257
utf8_to_windows_866	UTF8	WIN866
utf8_to_windows_874	UTF8	WIN874
windows_1250_to_iso_8859_2	WIN1250	LATIN2
windows_1250_to_mic	WIN1250	MULE_INTERNAL
windows_1250_to_utf8	WIN1250	UTF8
windows_1251_to_iso_8859_5	WIN1251	ISO_8859_5
windows_1251_to_koi8_r	WIN1251	KOI8R
windows_1251_to_mic	WIN1251	MULE_INTERNAL
windows_1251_to_utf8	WIN1251	UTF8
windows_1251_to_windows_866	WIN1251	WIN866
windows_1252_to_utf8	WIN1252	UTF8
windows_1256_to_utf8	WIN1256	UTF8
windows_866_to_iso_8859_5	WIN866	ISO_8859_5
windows_866_to_koi8_r	WIN866	KOI8R
windows_866_to_mic	WIN866	MULE_INTERNAL
windows_866_to_utf8	WIN866	UTF8
windows_866_to_windows_1251	WIN866	WIN
windows_874_to_utf8	WIN874	UTF8
euc_jis_2004_to_utf8	EUC_JIS_2004	UTF8
utf8_to_euc_jis_2004	UTF8	EUC_JIS_2004
shift_jis_2004_to_utf8	SHIFT_JIS_2004	UTF8
utf8_to_shift_jis_2004	UTF8	SHIFT_JIS_2004
euc_jis_2004_to_shift_jis_2004	EUC_JIS_2004	SHIFT_JIS_2004
shift_jis_2004_to_euc_jis_2004	SHIFT_JIS_2004	EUC_JIS_2004

<sup>a</sup> The conversion names follow a standard naming scheme: The official name of the source encoding with all non-alphanumeric characters replaced by underscores, followed by `_to_`, followed by the similarly processed destination encoding name. Therefore, these names sometimes deviate from the customary encoding names shown in Table 21.1.

## 21.3.5. Further Reading

These are good sources to start learning about various kinds of encoding systems.

*CJKV Information Processing: Chinese, Japanese, Korean & Vietnamese Computing*

Contains detailed explanations of EUC\_JP, EUC\_CN, EUC\_KR, EUC\_TW.

<https://www.unicode.org/>

The web site of the Unicode Consortium.

RFC 3629

UTF-8 (8-bit UCS/Unicode Transformation Format) is defined here.

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# Chapter 22. Routine Database Maintenance Tasks

LightDB, like any database software, requires that certain tasks be performed regularly to achieve optimum performance. The tasks discussed here are *required*, but they are repetitive in nature and can easily be automated using standard tools such as cron scripts or Windows' Task Scheduler. It is the database administrator's responsibility to set up appropriate scripts, and to check that they execute successfully.

One obvious maintenance task is the creation of backup copies of the data on a regular schedule. Without a recent backup, you have no chance of recovery after a catastrophe (disk failure, fire, mistakenly dropping a critical table, etc.). The backup and recovery mechanisms available in LightDB are discussed at length in Chapter 23.

The other main category of maintenance task is periodic “vacuuming” of the database. This activity is discussed in Section 22.1. Closely related to this is updating the statistics that will be used by the query planner, as discussed in Section 22.1.3.

Another task that might need periodic attention is log file management. This is discussed in Section 22.3.

`check_postgres`<sup>1</sup> is available for monitoring database health and reporting unusual conditions. `check_postgres` integrates with Nagios and MRTG, but can be run standalone too.

LightDB is low-maintenance compared to some other database management systems. Nonetheless, appropriate attention to these tasks will go far towards ensuring a pleasant and productive experience with the system.

## 22.1. Routine Vacuuming

LightDB databases require periodic maintenance known as *vacuuming*. For many installations, it is sufficient to let vacuuming be performed by the *autovacuum daemon*, which is described in Section 22.1.6. You might need to adjust the autovacuuming parameters described there to obtain best results for your situation. Some database administrators will want to supplement or replace the daemon's activities with manually-managed VACUUM commands, which typically are executed according to a schedule by cron or Task Scheduler scripts. To set up manually-managed vacuuming properly, it is essential to understand the issues discussed in the next few subsections. Administrators who rely on autovacuuming may still wish to skim this material to help them understand and adjust autovacuuming.

### 22.1.1. Vacuuming Basics

LightDB's VACUUM command has to process each table on a regular basis for several reasons:

1. To recover or reuse disk space occupied by updated or deleted rows.
2. To update data statistics used by the LightDB query planner.
3. To update the visibility map, which speeds up index-only scans.
4. To protect against loss of very old data due to *transaction ID wraparound* or *multixact ID wraparound*.

---

<sup>1</sup> [https://bucardo.org/check\\_postgres/](https://bucardo.org/check_postgres/)

Each of these reasons dictates performing `VACUUM` operations of varying frequency and scope, as explained in the following subsections.

There are two variants of `VACUUM`: standard `VACUUM` and `VACUUM FULL`. `VACUUM FULL` can reclaim more disk space but runs much more slowly. Also, the standard form of `VACUUM` can run in parallel with production database operations. (Commands such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE` will continue to function normally, though you will not be able to modify the definition of a table with commands such as `ALTER TABLE` while it is being vacuumed.) `VACUUM FULL` requires an `ACCESS EXCLUSIVE` lock on the table it is working on, and therefore cannot be done in parallel with other use of the table. Generally, therefore, administrators should strive to use standard `VACUUM` and avoid `VACUUM FULL`.

`VACUUM` creates a substantial amount of I/O traffic, which can cause poor performance for other active sessions. There are configuration parameters that can be adjusted to reduce the performance impact of background vacuuming — see Section 17.4.4.

## 22.1.2. Recovering Disk Space

In LightDB, an `UPDATE` or `DELETE` of a row does not immediately remove the old version of the row. This approach is necessary to gain the benefits of multiversion concurrency control (MVCC, see Chapter 13): the row version must not be deleted while it is still potentially visible to other transactions. But eventually, an outdated or deleted row version is no longer of interest to any transaction. The space it occupies must then be reclaimed for reuse by new rows, to avoid unbounded growth of disk space requirements. This is done by running `VACUUM`.

The standard form of `VACUUM` removes dead row versions in tables and indexes and marks the space available for future reuse. However, it will not return the space to the operating system, except in the special case where one or more pages at the end of a table become entirely free and an exclusive table lock can be easily obtained. In contrast, `VACUUM FULL` actively compacts tables by writing a complete new version of the table file with no dead space. This minimizes the size of the table, but can take a long time. It also requires extra disk space for the new copy of the table, until the operation completes.

The usual goal of routine vacuuming is to do standard `VACUUM`s often enough to avoid needing `VACUUM FULL`. The autovacuum daemon attempts to work this way, and in fact will never issue `VACUUM FULL`. In this approach, the idea is not to keep tables at their minimum size, but to maintain steady-state usage of disk space: each table occupies space equivalent to its minimum size plus however much space gets used up between vacuum runs. Although `VACUUM FULL` can be used to shrink a table back to its minimum size and return the disk space to the operating system, there is not much point in this if the table will just grow again in the future. Thus, moderately-frequent standard `VACUUM` runs are a better approach than infrequent `VACUUM FULL` runs for maintaining heavily-updated tables.

Some administrators prefer to schedule vacuuming themselves, for example doing all the work at night when load is low. The difficulty with doing vacuuming according to a fixed schedule is that if a table has an unexpected spike in update activity, it may get bloated to the point that `VACUUM FULL` is really necessary to reclaim space. Using the autovacuum daemon alleviates this problem, since the daemon schedules vacuuming dynamically in response to update activity. It is unwise to disable the daemon completely unless you have an extremely predictable workload. One possible compromise is to set the daemon's parameters so that it will only react to unusually heavy update activity, thus keeping things from getting out of hand, while scheduled `VACUUM`s are expected to do the bulk of the work when the load is typical.

For those not using autovacuum, a typical approach is to schedule a database-wide `VACUUM` once a day during a low-usage period, supplemented by more frequent vacuuming of heavily-updated tables as necessary. (Some installations with extremely high update rates vacuum their busiest tables as often as once every few minutes.) If you have multiple databases in a cluster, don't forget to `VACUUM` each one; the program `vacuumdb` might be helpful.

### Tip

Plain `VACUUM` may not be satisfactory when a table contains large numbers of dead row versions as a result of massive update or delete activity. If you have such a table and you need to reclaim the excess disk space it occupies, you will need to use `VACUUM FULL`, or alternatively `CLUSTER` or one of the table-rewriting variants of `ALTER TABLE`. These commands rewrite an entire new copy of the table and build new indexes for it. All these options require an `ACCESS EXCLUSIVE` lock. Note that they also temporarily use extra disk space approximately equal to the size of the table, since the old copies of the table and indexes can't be released until the new ones are complete.

### Tip

If you have a table whose entire contents are deleted on a periodic basis, consider doing it with `TRUNCATE` rather than using `DELETE` followed by `VACUUM`. `TRUNCATE` removes the entire content of the table immediately, without requiring a subsequent `VACUUM` or `VACUUM FULL` to reclaim the now-unused disk space. The disadvantage is that strict MVCC semantics are violated.

## 22.1.3. Updating Planner Statistics

The LightDB query planner relies on statistical information about the contents of tables in order to generate good plans for queries. These statistics are gathered by the `ANALYZE` command, which can be invoked by itself or as an optional step in `VACUUM`. It is important to have reasonably accurate statistics, otherwise poor choices of plans might degrade database performance.

The autovacuum daemon, if enabled, will automatically issue `ANALYZE` commands whenever the content of a table has changed sufficiently. However, administrators might prefer to rely on manually-scheduled `ANALYZE` operations, particularly if it is known that update activity on a table will not affect the statistics of “interesting” columns. The daemon schedules `ANALYZE` strictly as a function of the number of rows inserted or updated; it has no knowledge of whether that will lead to meaningful statistical changes.

Tuples changed in partitions and inheritance children do not trigger `analyze` on the parent table. If the parent table is empty or rarely changed, it may never be processed by autovacuum, and the statistics for the inheritance tree as a whole won't be collected. It is necessary to run `ANALYZE` on the parent table manually in order to keep the statistics up to date.

As with vacuuming for space recovery, frequent updates of statistics are more useful for heavily-updated tables than for seldom-updated ones. But even for a heavily-updated table, there might be no need for statistics updates if the statistical distribution of the data is not changing much. A simple rule of thumb is to think about how much the minimum and maximum values of the columns in the table change. For example, a `timestamp` column that contains the time of row update will have a constantly-increasing maximum value as rows are added and updated; such a column will probably need more frequent statistics updates than, say, a column containing URLs for pages accessed on a website. The URL column might receive changes just as often, but the statistical distribution of its values probably changes relatively slowly.

It is possible to run `ANALYZE` on specific tables and even just specific columns of a table, so the flexibility exists to update some statistics more frequently than others if your application requires it. In practice, however, it is usually best to just analyze the entire database, because it is a fast operation. `ANALYZE` uses a statistically random sampling of the rows of a table rather than reading every single row.



### Tip

Although per-column tweaking of `ANALYZE` frequency might not be very productive, you might find it worthwhile to do per-column adjustment of the level of detail of the statistics collected by `ANALYZE`. Columns that are heavily used in `WHERE` clauses and have highly irregular data distributions might require a finer-grain data histogram than other columns. See `ALTER TABLE SET STATISTICS`, or change the database-wide default using the `default_statistics_target` configuration parameter.

Also, by default there is limited information available about the selectivity of functions. However, if you create an expression index that uses a function call, useful statistics will be gathered about the function, which can greatly improve query plans that use the expression index.

### Tip

The autovacuum daemon does not issue `ANALYZE` commands for foreign tables, since it has no means of determining how often that might be useful. If your queries require statistics on foreign tables for proper planning, it's a good idea to run manually-managed `ANALYZE` commands on those tables on a suitable schedule.

### Tip

The autovacuum daemon does not issue `ANALYZE` commands for partitioned tables. Inheritance parents will only be analyzed if the parent itself is changed - changes to child tables do not trigger `autoanalyze` on the parent table. If your queries require statistics on parent tables for proper planning, it is necessary to periodically run a manual `ANALYZE` on those tables to keep the statistics up to date.

## 22.1.4. Updating the Visibility Map

Vacuum maintains a visibility map for each table to keep track of which pages contain only tuples that are known to be visible to all active transactions (and all future transactions, until the page is again modified). This has two purposes. First, vacuum itself can skip such pages on the next run, since there is nothing to clean up.

Second, it allows LightDB to answer some queries using only the index, without reference to the underlying table. Since LightDB indexes don't contain tuple visibility information, a normal index scan fetches the heap tuple for each matching index entry, to check whether it should be seen by the current transaction. An *index-only scan*, on the other hand, checks the visibility map first. If it's known that all tuples on the page are visible, the heap fetch can be skipped. This is most useful on large data sets where the visibility map can prevent disk accesses. The visibility map is vastly smaller than the heap, so it can easily be cached even when the heap is very large.

## 22.1.5. Preventing Transaction ID Wraparound Failures

LightDB's MVCC transaction semantics depend on being able to compare transaction ID (XID) numbers: a row version with an insertion XID greater than the current transaction's XID is “in the future” and should not be visible to the current transaction. But since transaction IDs have limited size (32 bits) a cluster that runs for a long time (more than 4 billion transactions) would suffer *transaction ID wraparound*: the XID counter wraps around to zero, and all of a sudden transactions that were in

the past appear to be in the future — which means their output become invisible. In short, catastrophic data loss. (Actually the data is still there, but that's cold comfort if you cannot get at it.) To avoid this, it is necessary to vacuum every table in every database at least once every two billion transactions.

The reason that periodic vacuuming solves the problem is that `VACUUM` will mark rows as *frozen*, indicating that they were inserted by a transaction that committed sufficiently far in the past that the effects of the inserting transaction are certain to be visible to all current and future transactions. Normal XIDs are compared using modulo-2<sup>32</sup> arithmetic. This means that for every normal XID, there are two billion XIDs that are “older” and two billion that are “newer”; another way to say it is that the normal XID space is circular with no endpoint. Therefore, once a row version has been created with a particular normal XID, the row version will appear to be “in the past” for the next two billion transactions, no matter which normal XID we are talking about. If the row version still exists after more than two billion transactions, it will suddenly appear to be in the future. To prevent this, LightDB reserves a special XID, `FrozenTransactionId`, which does not follow the normal XID comparison rules and is always considered older than every normal XID. Frozen row versions are treated as if the inserting XID were `FrozenTransactionId`, so that they will appear to be “in the past” to all normal transactions regardless of wraparound issues, and so such row versions will be valid until deleted, no matter how long that is.

`vacuum_freeze_min_age` controls how old an XID value has to be before rows bearing that XID will be frozen. Increasing this setting may avoid unnecessary work if the rows that would otherwise be frozen will soon be modified again, but decreasing this setting increases the number of transactions that can elapse before the table must be vacuumed again.

`VACUUM` uses the visibility map to determine which pages of a table must be scanned. Normally, it will skip pages that don't have any dead row versions even if those pages might still have row versions with old XID values. Therefore, normal `VACUUMs` won't always freeze every old row version in the table. Periodically, `VACUUM` will perform an *aggressive vacuum*, skipping only those pages which contain neither dead rows nor any unfrozen XID or MXID values. `vacuum_freeze_table_age` controls when `VACUUM` does that: all-visible but not all-frozen pages are scanned if the number of transactions that have passed since the last such scan is greater than `vacuum_freeze_table_age` minus `vacuum_freeze_min_age`. Setting `vacuum_freeze_table_age` to 0 forces `VACUUM` to use this more aggressive strategy for all scans.

The maximum time that a table can go unvacuumed is two billion transactions minus the `vacuum_freeze_min_age` value at the time of the last aggressive vacuum. If it were to go unvacuumed for longer than that, data loss could result. To ensure that this does not happen, autovacuum is invoked on any table that might contain unfrozen rows with XIDs older than the age specified by the configuration parameter `autovacuum_freeze_max_age`. (This will happen even if autovacuum is disabled.)

This implies that if a table is not otherwise vacuumed, autovacuum will be invoked on it approximately once every `autovacuum_freeze_max_age` minus `vacuum_freeze_min_age` transactions. For tables that are regularly vacuumed for space reclamation purposes, this is of little importance. However, for static tables (including tables that receive inserts, but no updates or deletes), there is no need to vacuum for space reclamation, so it can be useful to try to maximize the interval between forced autovacuaums on very large static tables. Obviously one can do this either by increasing `autovacuum_freeze_max_age` or decreasing `vacuum_freeze_min_age`.

The effective maximum for `vacuum_freeze_table_age` is `0.95 * autovacuum_freeze_max_age`; a setting higher than that will be capped to the maximum. A value higher than `autovacuum_freeze_max_age` wouldn't make sense because an anti-wraparound autovacuum would be triggered at that point anyway, and the 0.95 multiplier leaves some breathing room to run a manual `VACUUM` before that happens. As a rule of thumb, `vacuum_freeze_table_age` should be set to a value somewhat below `autovacuum_freeze_max_age`, leaving enough gap so that a regularly scheduled `VACUUM` or an autovacuum triggered by normal delete and update activity is run in that window. Setting it too close could lead to anti-wraparound autovacuaums, even though the table was recently vacuumed to reclaim space, whereas lower values lead to more frequent aggressive vacuuming.

The sole disadvantage of increasing `autovacuum_freeze_max_age` (and `vacuum_freeze_table_age` along with it) is that the `lt_xact` and `lt_commit_ts` subdirectories of the database cluster will take more space, because it must store the commit status and (if `track_commit_timestamp` is enabled) timestamp of all transactions back to the `autovacuum_freeze_max_age` horizon. The commit status uses two bits per transaction, so if `autovacuum_freeze_max_age` is set to its maximum allowed value of two billion, `lt_xact` can be expected to grow to about half a gigabyte and `lt_commit_ts` to about 20GB. If this is trivial compared to your total database size, setting `autovacuum_freeze_max_age` to its maximum allowed value is recommended. Otherwise, set it depending on what you are willing to allow for `lt_xact` and `lt_commit_ts` storage. (The default, 200 million transactions, translates to about 50MB of `lt_xact` storage and about 2GB of `lt_commit_ts` storage.)

One disadvantage of decreasing `vacuum_freeze_min_age` is that it might cause `VACUUM` to do useless work: freezing a row version is a waste of time if the row is modified soon thereafter (causing it to acquire a new `XID`). So the setting should be large enough that rows are not frozen until they are unlikely to change any more.

To track the age of the oldest unfrozen `XIDs` in a database, `VACUUM` stores `XID` statistics in the system tables `pg_class` and `pg_database`. In particular, the `relfrozenxid` column of a table's `pg_class` row contains the freeze cutoff `XID` that was used by the last aggressive `VACUUM` for that table. All rows inserted by transactions with `XIDs` older than this cutoff `XID` are guaranteed to have been frozen. Similarly, the `datfrozenxid` column of a database's `pg_database` row is a lower bound on the unfrozen `XIDs` appearing in that database — it is just the minimum of the per-table `relfrozenxid` values within the database. A convenient way to examine this information is to execute queries such as:

```
SELECT c.oid::regclass as table_name,
       greatest(age(c.relfrozenxid),age(t.relfrozenxid)) as age
FROM pg_class c
LEFT JOIN pg_class t ON c.reltoastrelid = t.oid
WHERE c.relkind IN ('r', 'm');

SELECT datname, age(datfrozenxid) FROM pg_database;
```

The `age` column measures the number of transactions from the cutoff `XID` to the current transaction's `XID`.

`VACUUM` normally only scans pages that have been modified since the last vacuum, but `relfrozenxid` can only be advanced when every page of the table that might contain unfrozen `XIDs` is scanned. This happens when `relfrozenxid` is more than `vacuum_freeze_table_age` transactions old, when `VACUUM`'s `FREEZE` option is used, or when all pages that are not already all-frozen happen to require vacuuming to remove dead row versions. When `VACUUM` scans every page in the table that is not already all-frozen, it should set `age(relfrozenxid)` to a value just a little more than the `vacuum_freeze_min_age` setting that was used (more by the number of transactions started since the `VACUUM` started). If no `relfrozenxid`-advancing `VACUUM` is issued on the table until `autovacuum_freeze_max_age` is reached, an `autovacuum` will soon be forced for the table.

If for some reason `autovacuum` fails to clear old `XIDs` from a table, the system will begin to emit warning messages like this when the database's oldest `XIDs` reach eleven million transactions from the wraparound point:

```
WARNING: database "mydb" must be vacuumed within 10985967
transactions
HINT: To avoid a database shutdown, execute a database-wide VACUUM
in that database.
```

(A manual `VACUUM` should fix the problem, as suggested by the hint; but note that the `VACUUM` must be performed by a superuser, else it will fail to process system catalogs and thus not be able to advance the database's `datfrozenxid`.) If these warnings are ignored, the system will shut down and refuse to start any new transactions once there are fewer than 1 million transactions left until wraparound:

```
ERROR: database is not accepting commands to avoid wraparound data
       loss in database "mydb"
HINT:  Stop the postmaster and vacuum that database in single-user
       mode.
```

The 1-million-transaction safety margin exists to let the administrator recover without data loss, by manually executing the required `VACUUM` commands. However, since the system will not execute commands once it has gone into the safety shutdown mode, the only way to do this is to stop the server and start the server in single-user mode to execute `VACUUM`. The shutdown mode is not enforced in single-user mode. See the `lightdb` reference page for details about using single-user mode.

### 22.1.5.1. Multixacts and Wraparound

*Multixact IDs* are used to support row locking by multiple transactions. Since there is only limited space in a tuple header to store lock information, that information is encoded as a “multiple transaction ID”, or multixact ID for short, whenever there is more than one transaction concurrently locking a row. Information about which transaction IDs are included in any particular multixact ID is stored separately in the `lt_multixact` subdirectory, and only the multixact ID appears in the `xmax` field in the tuple header. Like transaction IDs, multixact IDs are implemented as a 32-bit counter and corresponding storage, all of which requires careful aging management, storage cleanup, and wraparound handling. There is a separate storage area which holds the list of members in each multixact, which also uses a 32-bit counter and which must also be managed.

Whenever `VACUUM` scans any part of a table, it will replace any multixact ID it encounters which is older than `vacuum_multixact_freeze_min_age` by a different value, which can be the zero value, a single transaction ID, or a newer multixact ID. For each table, `pg_class.relmixmapid` stores the oldest possible multixact ID still appearing in any tuple of that table. If this value is older than `vacuum_multixact_freeze_table_age`, an aggressive vacuum is forced. As discussed in the previous section, an aggressive vacuum means that only those pages which are known to be all-frozen will be skipped. `mxid_age()` can be used on `pg_class.relmixmapid` to find its age.

Aggressive `VACUUM` scans, regardless of what causes them, enable advancing the value for that table. Eventually, as all tables in all databases are scanned and their oldest multixact values are advanced, on-disk storage for older multixacts can be removed.

As a safety device, an aggressive vacuum scan will occur for any table whose multixact-age is greater than `autovacuum_multixact_freeze_max_age`. Aggressive vacuum scans will also occur progressively for all tables, starting with those that have the oldest multixact-age, if the amount of used member storage space exceeds the amount 50% of the addressable storage space. Both of these kinds of aggressive scans will occur even if `autovacuum` is nominally disabled.

### 22.1.6. The Autovacuum Daemon

LightDB has an optional but highly recommended feature called *autovacuum*, whose purpose is to automate the execution of `VACUUM` and `ANALYZE` commands. When enabled, `autovacuum` checks for tables that have had a large number of inserted, updated or deleted tuples. These checks use the statistics collection facility; therefore, `autovacuum` cannot be used unless `track_counts` is set to `true`. In the default configuration, `autovacuuming` is enabled and the related configuration parameters are appropriately set.

The “autovacuum daemon” actually consists of multiple processes. There is a persistent daemon process, called the *autovacuum launcher*, which is in charge of starting *autovacuum worker* processes for all databases. The launcher will distribute the work across time, attempting to start one worker

within each database every `autovacuum_naptime` seconds. (Therefore, if the installation has  $N$  databases, a new worker will be launched every `autovacuum_naptime/N` seconds.) A maximum of `autovacuum_max_workers` worker processes are allowed to run at the same time. If there are more than `autovacuum_max_workers` databases to be processed, the next database will be processed as soon as the first worker finishes. Each worker process will check each table within its database and execute `VACUUM` and/or `ANALYZE` as needed. `log_autovacuum_min_duration` can be set to monitor autovacuum workers' activity.

If several large tables all become eligible for vacuuming in a short amount of time, all autovacuum workers might become occupied with vacuuming those tables for a long period. This would result in other tables and databases not being vacuumed until a worker becomes available. There is no limit on how many workers might be in a single database, but workers do try to avoid repeating work that has already been done by other workers. Note that the number of running workers does not count towards `max_connections` or `superuser_reserved_connections` limits.

Tables whose `relfrozenxid` value is more than `autovacuum_freeze_max_age` transactions old are always vacuumed (this also applies to those tables whose freeze max age has been modified via storage parameters; see below). Otherwise, if the number of tuples obsoleted since the last `VACUUM` exceeds the “vacuum threshold”, the table is vacuumed. The vacuum threshold is defined as:

```
vacuum threshold = vacuum base threshold + vacuum scale factor *  
number of tuples
```

where the vacuum base threshold is `autovacuum_vacuum_threshold`, the vacuum scale factor is `autovacuum_vacuum_scale_factor`, and the number of tuples is `pg_class.rel tuples`.

The table is also vacuumed if the number of tuples inserted since the last vacuum has exceeded the defined insert threshold, which is defined as:

```
vacuum insert threshold = vacuum base insert threshold + vacuum  
insert scale factor * number of tuples
```

where the vacuum insert base threshold is `autovacuum_vacuum_insert_threshold`, and vacuum insert scale factor is `autovacuum_vacuum_insert_scale_factor`. Such vacuums may allow portions of the table to be marked as *all visible* and also allow tuples to be frozen, which can reduce the work required in subsequent vacuums. For tables which receive `INSERT` operations but no or almost no `UPDATE/DELETE` operations, it may be beneficial to lower the table's `autovacuum_freeze_min_age` as this may allow tuples to be frozen by earlier vacuums. The number of obsolete tuples and the number of inserted tuples are obtained from the statistics collector; it is a semi-accurate count updated by each `UPDATE`, `DELETE` and `INSERT` operation. (It is only semi-accurate because some information might be lost under heavy load.) If the `relfrozenxid` value of the table is more than `vacuum_freeze_table_age` transactions old, an aggressive vacuum is performed to freeze old tuples and advance `relfrozenxid`; otherwise, only pages that have been modified since the last vacuum are scanned.

For analyze, a similar condition is used: the threshold, defined as:

```
analyze threshold = analyze base threshold + analyze scale factor *  
number of tuples
```

is compared to the total number of tuples inserted, updated, or deleted since the last `ANALYZE`.

Partitioned tables are not processed by autovacuum. Statistics should be collected by running a manual `ANALYZE` when it is first populated, and again whenever the distribution of data in its partitions changes significantly.

Temporary tables cannot be accessed by autovacuum. Therefore, appropriate vacuum and analyze operations should be performed via session SQL commands.

The default thresholds and scale factors are taken from `lightdb.conf`, but it is possible to override them (and many other autovacuum control parameters) on a per-table basis; see [Storage Parameters](#) for more information. If a setting has been changed via a table's storage parameters, that value is used when processing that table; otherwise the global settings are used. See [Section 17.10](#) for more details on the global settings.

When multiple workers are running, the autovacuum cost delay parameters (see [Section 17.4.4](#)) are “balanced” among all the running workers, so that the total I/O impact on the system is the same regardless of the number of workers actually running. However, any workers processing tables whose per-table `autovacuum_vacuum_cost_delay` or `autovacuum_vacuum_cost_limit` storage parameters have been set are not considered in the balancing algorithm.

Autovacuum workers generally don't block other commands. If a process attempts to acquire a lock that conflicts with the `SHARE UPDATE EXCLUSIVE` lock held by autovacuum, lock acquisition will interrupt the autovacuum. For conflicting lock modes, see [Table 13.2](#). However, if the autovacuum is running to prevent transaction ID wraparound (i.e., the autovacuum query name in the `pg_stat_activity` view ends with `(to prevent wraparound)`), the autovacuum is not automatically interrupted.

### Warning

Regularly running commands that acquire locks conflicting with a `SHARE UPDATE EXCLUSIVE` lock (e.g., `ANALYZE`) can effectively prevent autovacuum from ever completing.

## 22.2. Routine Reindexing

In some situations it is worthwhile to rebuild indexes periodically with the `REINDEX` command or a series of individual rebuilding steps.

B-tree index pages that have become completely empty are reclaimed for re-use. However, there is still a possibility of inefficient use of space: if all but a few index keys on a page have been deleted, the page remains allocated. Therefore, a usage pattern in which most, but not all, keys in each range are eventually deleted will see poor use of space. For such usage patterns, periodic reindexing is recommended.

The potential for bloat in non-B-tree indexes has not been well researched. It is a good idea to periodically monitor the index's physical size when using any non-B-tree index type.

Also, for B-tree indexes, a freshly-constructed index is slightly faster to access than one that has been updated many times because logically adjacent pages are usually also physically adjacent in a newly built index. (This consideration does not apply to non-B-tree indexes.) It might be worthwhile to reindex periodically just to improve access speed.

`REINDEX` can be used safely and easily in all cases. This command requires an `ACCESS EXCLUSIVE` lock by default, hence it is often preferable to execute it with its `CONCURRENTLY` option, which requires only a `SHARE UPDATE EXCLUSIVE` lock.

## 22.3. Log File Maintenance

It is a good idea to save the database server's log output somewhere, rather than just discarding it via `/dev/null`. The log output is invaluable when diagnosing problems. However, the log output tends to be voluminous (especially at higher debug levels) so you won't want to save it indefinitely. You need to *rotate* the log files so that new log files are started and old ones removed after a reasonable period of time.

If you simply direct the `stderr` of `lightdb` into a file, you will have log output, but the only way to truncate the log file is to stop and restart the server. This might be acceptable if you are using LightDB in a development environment, but few production servers would find this behavior acceptable.

A better approach is to send the server's `stderr` output to some type of log rotation program. There is a built-in log rotation facility, which you can use by setting the configuration parameter `logging_collector` to `true` in `lightdb.conf`. The control parameters for this program are described in Section 17.8.1. You can also use this approach to capture the log data in machine readable CSV (comma-separated values) format.

Alternatively, you might prefer to use an external log rotation program if you have one that you are already using with other server software. For example, the `rotatelogs` tool included in the Apache distribution can be used with LightDB. One way to do this is to pipe the server's `stderr` output to the desired program. If you start the server with `lt_ctl`, then `stderr` is already redirected to `stdout`, so you just need a pipe command, for example:

```
lt_ctl start | rotatelogs /var/log/pgsql_log 86400
```

You can combine these approaches by setting up `logrotate` to collect log files produced by LightDB built-in logging collector. In this case, the logging collector defines the names and location of the log files, while `logrotate` periodically archives these files. When initiating log rotation, `logrotate` must ensure that the application sends further output to the new file. This is commonly done with a `postrotate` script that sends a `SIGHUP` signal to the application, which then reopens the log file. In LightDB, you can run `lt_ctl` with the `logrotate` option instead. When the server receives this command, the server either switches to a new log file or reopens the existing file, depending on the logging configuration (see Section 17.8.1).

### Note

When using static log file names, the server might fail to reopen the log file if the max open file limit is reached or a file table overflow occurs. In this case, log messages are sent to the old log file until a successful log rotation. If `logrotate` is configured to compress the log file and delete it, the server may lose the messages logged in this time frame. To avoid this issue, you can configure the logging collector to dynamically assign log file names and use a `prerotate` script to ignore open log files.

Another production-grade approach to managing log output is to send it to `syslog` and let `syslog` deal with file rotation. To do this, set the configuration parameter `log_destination` to `syslog` (to log to `syslog` only) in `lightdb.conf`. Then you can send a `SIGHUP` signal to the `syslog` daemon whenever you want to force it to start writing a new log file. If you want to automate log rotation, the `logrotate` program can be configured to work with log files from `syslog`.

On many systems, however, `syslog` is not very reliable, particularly with large log messages; it might truncate or drop messages just when you need them the most. Also, on Linux, `syslog` will flush each message to disk, yielding poor performance. (You can use a “-” at the start of the file name in the `syslog` configuration file to disable syncing.)

Note that all the solutions described above take care of starting new log files at configurable intervals, but they do not handle deletion of old, no-longer-useful log files. You will probably want to set up a batch job to periodically delete old log files. Another possibility is to configure the rotation program so that old log files are overwritten cyclically.

`pgBadger`<sup>2</sup> is an external project that does sophisticated log file analysis. `check_postgres`<sup>3</sup> provides Nagios alerts when important messages appear in the log files, as well as detection of many other extraordinary conditions.

---

<sup>2</sup> <https://pgbadger.darold.net/>

<sup>3</sup> [https://bucardo.org/check\\_postgres/](https://bucardo.org/check_postgres/)

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# Chapter 23. Backup and Restore

As with everything that contains valuable data, LightDB databases should be backed up regularly. While the procedure is essentially simple, it is important to have a clear understanding of the underlying techniques and assumptions.

There are three fundamentally different approaches to backing up LightDB data:

- SQL dump
- File system level backup
- Continuous archiving

Each has its own strengths and weaknesses; each is discussed in turn in the following sections.

## 23.1. SQL Dump

The idea behind this dump method is to generate a file with SQL commands that, when fed back to the server, will recreate the database in the same state as it was at the time of the dump. LightDB provides the utility program `lt_dump` for this purpose. The basic usage of this command is:

```
lt_dump dbname > dumpfile
```

As you see, `lt_dump` writes its result to the standard output. We will see below how this can be useful. While the above command creates a text file, `lt_dump` can create files in other formats that allow for parallelism and more fine-grained control of object restoration.

`lt_dump` is a regular LightDB client application (albeit a particularly clever one). This means that you can perform this backup procedure from any remote host that has access to the database. But remember that `lt_dump` does not operate with special permissions. In particular, it must have read access to all tables that you want to back up, so in order to back up the entire database you almost always have to run it as a database superuser. (If you do not have sufficient privileges to back up the entire database, you can still back up portions of the database to which you do have access using options such as `-n schema` or `-t table`.)

To specify which database server `lt_dump` should contact, use the command line options `-h host` and `-p port`. The default host is the local host or whatever your `LTHOST` environment variable specifies. Similarly, the default port is indicated by the `LTPORT` environment variable or, failing that, by the compiled-in default. (Conveniently, the server will normally have the same compiled-in default.)

Like any other LightDB client application, `lt_dump` will by default connect with the database user name that is equal to the current operating system user name. To override this, either specify the `-U` option or set the environment variable `LTUSER`. Remember that `lt_dump` connections are subject to the normal client authentication mechanisms (which are described in Chapter 18).

An important advantage of `lt_dump` over the other backup methods described later is that `lt_dump`'s output can generally be re-loaded into newer versions of LightDB, whereas file-level backups and continuous archiving are both extremely server-version-specific. `lt_dump` is also the only method that will work when transferring a database to a different machine architecture, such as going from a 32-bit to a 64-bit server.

Dumps created by `lt_dump` are internally consistent, meaning, the dump represents a snapshot of the database at the time `lt_dump` began running. `lt_dump` does not block other operations on the database while it is working. (Exceptions are those operations that need to operate with an exclusive lock, such as most forms of `ALTER TABLE`.)



## 23.1.1. Restoring the Dump

Text files created by `lt_dump` are intended to be read in by the `ltsql` program. The general command form to restore a dump is

```
ltsql dbname < dumpfile
```

where *dumpfile* is the file output by the `lt_dump` command. The database *dbname* will not be created by this command, so you must create it yourself from `template0` before executing `ltsql` (e.g., with `createdb -T template0 dbname`). `ltsql` supports options similar to `lt_dump` for specifying the database server to connect to and the user name to use. See the `ltsql` reference page for more information. Non-text file dumps are restored using the `lt_restore` utility.

Before restoring an SQL dump, all the users who own objects or were granted permissions on objects in the dumped database must already exist. If they do not, the restore will fail to recreate the objects with the original ownership and/or permissions. (Sometimes this is what you want, but usually it is not.)

By default, the `ltsql` script will continue to execute after an SQL error is encountered. You might wish to run `ltsql` with the `ON_ERROR_STOP` variable set to alter that behavior and have `ltsql` exit with an exit status of 3 if an SQL error occurs:

```
ltsql --set ON_ERROR_STOP=on dbname < dumpfile
```

Either way, you will only have a partially restored database. Alternatively, you can specify that the whole dump should be restored as a single transaction, so the restore is either fully completed or fully rolled back. This mode can be specified by passing the `-1` or `--single-transaction` command-line options to `ltsql`. When using this mode, be aware that even a minor error can rollback a restore that has already run for many hours. However, that might still be preferable to manually cleaning up a complex database after a partially restored dump.

The ability of `lt_dump` and `ltsql` to write to or read from pipes makes it possible to dump a database directly from one server to another, for example:

```
lt_dump -h host1 dbname | ltsql -h host2 dbname
```

### Important

The dumps produced by `lt_dump` are relative to `template0`. This means that any languages, procedures, etc. added via `template1` will also be dumped by `lt_dump`. As a result, when restoring, if you are using a customized `template1`, you must create the empty database from `template0`, as in the example above.

After restoring a backup, it is wise to run `ANALYZE` on each database so the query optimizer has useful statistics; see Section 22.1.3 and Section 22.1.6 for more information. For more advice on how to load large amounts of data into LightDB efficiently, refer to Section 14.4.

## 23.1.2. Using `lt_dumpall`

`lt_dump` dumps only a single database at a time, and it does not dump information about roles or tablespaces (because those are cluster-wide rather than per-database). To support convenient dumping of the entire contents of a database cluster, the `lt_dumpall` program is provided. `lt_dumpall` backs up each database in a given cluster, and also preserves cluster-wide data such as role and tablespace definitions. The basic usage of this command is:

```
lt_dumpall > dumpfile
```

The resulting dump can be restored with `ltsql`:

```
ltsql -f dumpfile postgres
```

(Actually, you can specify any existing database name to start from, but if you are loading into an empty cluster then `postgres` should usually be used.) It is always necessary to have database superuser access when restoring a `lt_dumpall` dump, as that is required to restore the role and tablespace information. If you use tablespaces, make sure that the tablespace paths in the dump are appropriate for the new installation.

`lt_dumpall` works by emitting commands to re-create roles, tablespaces, and empty databases, then invoking `lt_dump` for each database. This means that while each database will be internally consistent, the snapshots of different databases are not synchronized.

Cluster-wide data can be dumped alone using the `lt_dumpall --globals-only` option. This is necessary to fully backup the cluster if running the `lt_dump` command on individual databases.

### 23.1.3. Handling Large Databases

Some operating systems have maximum file size limits that cause problems when creating large `lt_dump` output files. Fortunately, `lt_dump` can write to the standard output, so you can use standard Unix tools to work around this potential problem. There are several possible methods:

**Use compressed dumps.** You can use your favorite compression program, for example `gzip`:

```
lt_dump dbname | gzip > filename.gz
```

Reload with:

```
gunzip -c filename.gz | ltsql dbname
```

or:

```
cat filename.gz | gunzip | ltsql dbname
```

**Use `split`.** The `split` command allows you to split the output into smaller files that are acceptable in size to the underlying file system. For example, to make 2 gigabyte chunks:

```
lt_dump dbname | split -b 2G - filename
```

Reload with:

```
cat filename* | ltsql dbname
```

If using GNU `split`, it is possible to use it and `gzip` together:

```
lt_dump dbname | split -b 2G --filter='gzip > $FILE.gz'
```

It can be restored using `zcat`.

**Use `lt_dump`'s custom dump format.** If LightDB was built on a system with the `zlib` compression library installed, the custom dump format will compress data as it writes it to the output file. This will produce dump file sizes similar to using `gzip`, but it has the added advantage that tables can be restored selectively. The following command dumps a database using the custom dump format:

```
lt_dump -Fc dbname > filename
```

A custom-format dump is not a script for `ltsql`, but instead must be restored with `lt_restore`, for example:

```
lt_restore -d dbname filename
```

See the `lt_dump` and `lt_restore` reference pages for details.

For very large databases, you might need to combine `split` with one of the other two approaches.

**Use `lt_dump`'s parallel dump feature.** To speed up the dump of a large database, you can use `lt_dump`'s parallel mode. This will dump multiple tables at the same time. You can control the degree of parallelism with the `-j` parameter. Parallel dumps are only supported for the "directory" archive format.

```
lt_dump -j num -F d -f out.dir dbname
```

You can use `lt_restore -j` to restore a dump in parallel. This will work for any archive of either the "custom" or the "directory" archive mode, whether or not it has been created with `lt_dump -j`.

## 23.2. File System Level Backup

An alternative backup strategy is to directly copy the files that LightDB uses to store the data in the database; Section 16.2 explains where these files are located. You can use whatever method you prefer for doing file system backups; for example:

```
tar -cf backup.tar /usr/local/lightdb-x/data
```

There are two restrictions, however, which make this method impractical, or at least inferior to the `lt_dump` method:

1. The database server *must* be shut down in order to get a usable backup. Half-way measures such as disallowing all connections will *not* work (in part because `tar` and similar tools do not take an atomic snapshot of the state of the file system, but also because of internal buffering within the server). Information about stopping the server can be found in Section 16.5. Needless to say, you also need to shut down the server before restoring the data.
2. If you have dug into the details of the file system layout of the database, you might be tempted to try to back up or restore only certain individual tables or databases from their respective files or directories. This will *not* work because the information contained in these files is not usable without the commit log files, `lt_xact/*`, which contain the commit status of all transactions. A table file is only usable with this information. Of course it is also impossible to restore only a table and the associated `lt_xact` data because that would render all other tables in the database cluster useless. So file system backups only work for complete backup and restoration of an entire database cluster.

An alternative file-system backup approach is to make a "consistent snapshot" of the data directory, if the file system supports that functionality (and you are willing to trust that it is implemented correctly).

The typical procedure is to make a “frozen snapshot” of the volume containing the database, then copy the whole data directory (not just parts, see above) from the snapshot to a backup device, then release the frozen snapshot. This will work even while the database server is running. However, a backup created in this way saves the database files in a state as if the database server was not properly shut down; therefore, when you start the database server on the backed-up data, it will think the previous server instance crashed and will replay the WAL log. This is not a problem; just be aware of it (and be sure to include the WAL files in your backup). You can perform a `CHECKPOINT` before taking the snapshot to reduce recovery time.

If your database is spread across multiple file systems, there might not be any way to obtain exactly-simultaneous frozen snapshots of all the volumes. For example, if your data files and WAL log are on different disks, or if tablespaces are on different file systems, it might not be possible to use snapshot backup because the snapshots *must* be simultaneous. Read your file system documentation very carefully before trusting the consistent-snapshot technique in such situations.

If simultaneous snapshots are not possible, one option is to shut down the database server long enough to establish all the frozen snapshots. Another option is to perform a continuous archiving base backup (Section 23.3.2) because such backups are immune to file system changes during the backup. This requires enabling continuous archiving just during the backup process; restore is done using continuous archive recovery (Section 23.3.4).

Another option is to use `rsync` to perform a file system backup. This is done by first running `rsync` while the database server is running, then shutting down the database server long enough to do an `rsync --checksum`. (`--checksum` is necessary because `rsync` only has file modification-time granularity of one second.) The second `rsync` will be quicker than the first, because it has relatively little data to transfer, and the end result will be consistent because the server was down. This method allows a file system backup to be performed with minimal downtime.

Note that a file system backup will typically be larger than an SQL dump. (`lt_dump` does not need to dump the contents of indexes for example, just the commands to recreate them.) However, taking a file system backup might be faster.

## 23.3. Continuous Archiving and Point-in-Time Recovery (PITR)

At all times, LightDB maintains a *write ahead log* (WAL) in the `lt_wal/` subdirectory of the cluster's data directory. The log records every change made to the database's data files. This log exists primarily for crash-safety purposes: if the system crashes, the database can be restored to consistency by “replaying” the log entries made since the last checkpoint. However, the existence of the log makes it possible to use a third strategy for backing up databases: we can combine a file-system-level backup with backup of the WAL files. If recovery is needed, we restore the file system backup and then replay from the backed-up WAL files to bring the system to a current state. This approach is more complex to administer than either of the previous approaches, but it has some significant benefits:

- We do not need a perfectly consistent file system backup as the starting point. Any internal inconsistency in the backup will be corrected by log replay (this is not significantly different from what happens during crash recovery). So we do not need a file system snapshot capability, just tar or a similar archiving tool.
- Since we can combine an indefinitely long sequence of WAL files for replay, continuous backup can be achieved simply by continuing to archive the WAL files. This is particularly valuable for large databases, where it might not be convenient to take a full backup frequently.
- It is not necessary to replay the WAL entries all the way to the end. We could stop the replay at any point and have a consistent snapshot of the database as it was at that time. Thus, this technique supports *point-in-time recovery*: it is possible to restore the database to its state at any time since your base backup was taken.

- If we continuously feed the series of WAL files to another machine that has been loaded with the same base backup file, we have a *warm standby* system: at any point we can bring up the second machine and it will have a nearly-current copy of the database.

### Note

`lt_dump` and `lt_dumpall` do not produce file-system-level backups and cannot be used as part of a continuous-archiving solution. Such dumps are *logical* and do not contain enough information to be used by WAL replay.

As with the plain file-system-backup technique, this method can only support restoration of an entire database cluster, not a subset. Also, it requires a lot of archival storage: the base backup might be bulky, and a busy system will generate many megabytes of WAL traffic that have to be archived. Still, it is the preferred backup technique in many situations where high reliability is needed.

To recover successfully using continuous archiving (also called “online backup” by many database vendors), you need a continuous sequence of archived WAL files that extends back at least as far as the start time of your backup. So to get started, you should set up and test your procedure for archiving WAL files *before* you take your first base backup. Accordingly, we first discuss the mechanics of archiving WAL files.

## 23.3.1. Setting Up WAL Archiving

In an abstract sense, a running LightDB system produces an indefinitely long sequence of WAL records. The system physically divides this sequence into WAL *segment files*, which are normally 16MB apiece (although the segment size can be altered during `initdb`). The segment files are given numeric names that reflect their position in the abstract WAL sequence. When not using WAL archiving, the system normally creates just a few segment files and then “recycles” them by renaming no-longer-needed segment files to higher segment numbers. It's assumed that segment files whose contents precede the last checkpoint are no longer of interest and can be recycled.

When archiving WAL data, we need to capture the contents of each segment file once it is filled, and save that data somewhere before the segment file is recycled for reuse. Depending on the application and the available hardware, there could be many different ways of “saving the data somewhere”: we could copy the segment files to an NFS-mounted directory on another machine, write them onto a tape drive (ensuring that you have a way of identifying the original name of each file), or batch them together and burn them onto CDs, or something else entirely. To provide the database administrator with flexibility, LightDB tries not to make any assumptions about how the archiving will be done. Instead, LightDB lets the administrator specify a shell command to be executed to copy a completed segment file to wherever it needs to go. The command could be as simple as a `cp`, or it could invoke a complex shell script — it's all up to you.

To enable WAL archiving, set the `wal_level` configuration parameter to `replica` or higher, `archive_mode` to `on`, and specify the shell command to use in the `archive_command` configuration parameter. In practice these settings will always be placed in the `lightdb.conf` file. In `archive_command`, `%p` is replaced by the path name of the file to archive, while `%f` is replaced by only the file name. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Use `%%` if you need to embed an actual `%` character in the command. The simplest useful command is something like:

```
archive_command = 'test ! -f /mnt/server/archivedir/%f && cp %p /
mnt/server/archivedir/%f' # Unix
```

which will copy archivable WAL segments to the directory `/mnt/server/archivedir`. (This is an example, not a recommendation, and might not work on all platforms.) After the `%p` and `%f` parameters have been replaced, the actual command executed might look like this:

```
test ! -f /mnt/server/archivedir/00000001000000A9000000065
  && cp lt_wal/00000001000000A9000000065 /mnt/server/
archivedir/00000001000000A9000000065
```

A similar command will be generated for each new file to be archived.

The archive command will be executed under the ownership of the same user that the LightDB server is running as. Since the series of WAL files being archived contains effectively everything in your database, you will want to be sure that the archived data is protected from prying eyes; for example, archive into a directory that does not have group or world read access.

It is important that the archive command return zero exit status if and only if it succeeds. Upon getting a zero result, LightDB will assume that the file has been successfully archived, and will remove or recycle it. However, a nonzero status tells LightDB that the file was not archived; it will try again periodically until it succeeds.

The archive command should generally be designed to refuse to overwrite any pre-existing archive file. This is an important safety feature to preserve the integrity of your archive in case of administrator error (such as sending the output of two different servers to the same archive directory).

It is advisable to test your proposed archive command to ensure that it indeed does not overwrite an existing file, *and that it returns nonzero status in this case*. The example command above for Unix ensures this by including a separate `test` step. On some Unix platforms, `cp` has switches such as `-i` that can be used to do the same thing less verbosely, but you should not rely on these without verifying that the right exit status is returned. (In particular, GNU `cp` will return status zero when `-i` is used and the target file already exists, which is *not* the desired behavior.)

While designing your archiving setup, consider what will happen if the archive command fails repeatedly because some aspect requires operator intervention or the archive runs out of space. For example, this could occur if you write to tape without an autochanger; when the tape fills, nothing further can be archived until the tape is swapped. You should ensure that any error condition or request to a human operator is reported appropriately so that the situation can be resolved reasonably quickly. The `lt_wal/` directory will continue to fill with WAL segment files until the situation is resolved. (If the file system containing `lt_wal/` fills up, LightDB will do a PANIC shutdown. No committed transactions will be lost, but the database will remain offline until you free some space.)

The speed of the archiving command is unimportant as long as it can keep up with the average rate at which your server generates WAL data. Normal operation continues even if the archiving process falls a little behind. If archiving falls significantly behind, this will increase the amount of data that would be lost in the event of a disaster. It will also mean that the `lt_wal/` directory will contain large numbers of not-yet-archived segment files, which could eventually exceed available disk space. You are advised to monitor the archiving process to ensure that it is working as you intend.

In writing your archive command, you should assume that the file names to be archived can be up to 64 characters long and can contain any combination of ASCII letters, digits, and dots. It is not necessary to preserve the original relative path (`%P`) but it is necessary to preserve the file name (`%F`).

Note that although WAL archiving will allow you to restore any modifications made to the data in your LightDB database, it will not restore changes made to configuration files (that is, `lightdb.conf`, `lt_hba.conf` and `lt_ident.conf`), since those are edited manually rather than through SQL operations. You might wish to keep the configuration files in a location that will be backed up by your regular file system backup procedures. See Section 17.2 for how to relocate the configuration files.

The archive command is only invoked on completed WAL segments. Hence, if your server generates only little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To put a limit on how old unarchived data can be, you can set `archive_timeout` to force the server to switch to a new WAL segment file at least that often. Note that archived files that are archived early due to a forced

switch are still the same length as completely full files. It is therefore unwise to set a very short `archive_timeout` — it will bloat your archive storage. `archive_timeout` settings of a minute or so are usually reasonable.

Also, you can force a segment switch manually with `pg_switch_wal` if you want to ensure that a just-finished transaction is archived as soon as possible. Other utility functions related to WAL management are listed in Table 9.86.

When `wal_level` is `minimal` some SQL commands are optimized to avoid WAL logging, as described in Section 14.4.7. If archiving or streaming replication were turned on during execution of one of these statements, WAL would not contain enough information for archive recovery. (Crash recovery is unaffected.) For this reason, `wal_level` can only be changed at server start. However, `archive_command` can be changed with a configuration file reload. If you wish to temporarily stop archiving, one way to do it is to set `archive_command` to the empty string ( `' '` ). This will cause WAL files to accumulate in `lt_wal/` until a working `archive_command` is re-established.

## 23.3.2. Making a Base Backup

The easiest way to perform a base backup is to use the `lt_basebackup` tool. It can create a base backup either as regular files or as a tar archive. If more flexibility than `lt_basebackup` can provide is required, you can also make a base backup using the low level API (see Section 23.3.3).

It is not necessary to be concerned about the amount of time it takes to make a base backup. However, if you normally run the server with `full_page_writes` disabled, you might notice a drop in performance while the backup runs since `full_page_writes` is effectively forced on during backup mode.

To make use of the backup, you will need to keep all the WAL segment files generated during and after the file system backup. To aid you in doing this, the base backup process creates a *backup history file* that is immediately stored into the WAL archive area. This file is named after the first WAL segment file that you need for the file system backup. For example, if the starting WAL file is `0000000100001234000055CD` the backup history file will be named something like `0000000100001234000055CD.007C9330.backup`. (The second part of the file name stands for an exact position within the WAL file, and can ordinarily be ignored.) Once you have safely archived the file system backup and the WAL segment files used during the backup (as specified in the backup history file), all archived WAL segments with names numerically less are no longer needed to recover the file system backup and can be deleted. However, you should consider keeping several backup sets to be absolutely certain that you can recover your data.

The backup history file is just a small text file. It contains the label string you gave to `lt_basebackup`, as well as the starting and ending times and WAL segments of the backup. If you used the label to identify the associated dump file, then the archived history file is enough to tell you which dump file to restore.

Since you have to keep around all the archived WAL files back to your last base backup, the interval between base backups should usually be chosen based on how much storage you want to expend on archived WAL files. You should also consider how long you are prepared to spend recovering, if recovery should be necessary — the system will have to replay all those WAL segments, and that could take awhile if it has been a long time since the last base backup.

## 23.3.3. Making a Base Backup Using the Low Level API

The procedure for making a base backup using the low level APIs contains a few more steps than the `lt_basebackup` method, but is relatively simple. It is very important that these steps are executed in sequence, and that the success of a step is verified before proceeding to the next step.

Low level base backups can be made in a non-exclusive or an exclusive way. The non-exclusive method is recommended and the exclusive one is deprecated and will eventually be removed.

### 23.3.3.1. Making a Non-Exclusive Low-Level Backup

A non-exclusive low level backup is one that allows other concurrent backups to be running (both those started using the same backup API and those started using `lt_basebackup`).

1. Ensure that WAL archiving is enabled and working.
2. Connect to the server (it does not matter which database) as a user with rights to run `pg_start_backup` (superuser, or a user who has been granted EXECUTE on the function) and issue the command:

```
SELECT pg_start_backup('label', false, false);
```

where `label` is any string you want to use to uniquely identify this backup operation. The connection calling `pg_start_backup` must be maintained until the end of the backup, or the backup will be automatically aborted.

By default, `pg_start_backup` can take a long time to finish. This is because it performs a checkpoint, and the I/O required for the checkpoint will be spread out over a significant period of time, by default half your inter-checkpoint interval (see the configuration parameter `checkpoint_completion_target`). This is usually what you want, because it minimizes the impact on query processing. If you want to start the backup as soon as possible, change the second parameter to `true`, which will issue an immediate checkpoint using as much I/O as available.

The third parameter being `false` tells `pg_start_backup` to initiate a non-exclusive base backup.

3. Perform the backup, using any convenient file-system-backup tool such as `tar` or `cpio` (not `lt_dump` or `lt_dumpall`). It is neither necessary nor desirable to stop normal operation of the database while you do this. See Section 23.3.3.3 for things to consider during this backup.
4. In the same connection as before, issue the command:

```
SELECT * FROM pg_stop_backup(false, true);
```

This terminates backup mode. On a primary, it also performs an automatic switch to the next WAL segment. On a standby, it is not possible to automatically switch WAL segments, so you may wish to run `pg_switch_wal` on the primary to perform a manual switch. The reason for the switch is to arrange for the last WAL segment file written during the backup interval to be ready to archive.

The `pg_stop_backup` will return one row with three values. The second of these fields should be written to a file named `backup_label` in the root directory of the backup. The third field should be written to a file named `tablespace_map` unless the field is empty. These files are vital to the backup working and must be written byte for byte without modification, which may require opening the file in binary mode.

5. Once the WAL segment files active during the backup are archived, you are done. The file identified by `pg_stop_backup`'s first return value is the last segment that is required to form a complete set of backup files. On a primary, if `archive_mode` is enabled and the `wait_for_archive` parameter is `true`, `pg_stop_backup` does not return until the last segment has been archived. On a standby, `archive_mode` must be `always` in order for `pg_stop_backup` to wait. Archiving of these files happens automatically since you have already configured `archive_command`. In most cases this happens quickly, but you are advised to monitor your archive system to ensure there are no delays. If the archive process has fallen behind because of failures of the archive command, it will keep retrying until the archive succeeds and the backup is complete. If you wish to place a time limit on the execution of `pg_stop_backup`, set an appropriate `statement_timeout` value, but make note that if `pg_stop_backup` terminates because of this your backup may not be valid.



If the backup process monitors and ensures that all WAL segment files required for the backup are successfully archived then the `wait_for_archive` parameter (which defaults to true) can be set to false to have `pg_stop_backup` return as soon as the stop backup record is written to the WAL. By default, `pg_stop_backup` will wait until all WAL has been archived, which can take some time. This option must be used with caution: if WAL archiving is not monitored correctly then the backup might not include all of the WAL files and will therefore be incomplete and not able to be restored.

### 23.3.3.2. Making an Exclusive Low-Level Backup

#### Note

The exclusive backup method is deprecated and should be avoided. Prior to LightDB 9.6, this was the only low-level method available, but it is now recommended that all users upgrade their scripts to use non-exclusive backups.

The process for an exclusive backup is mostly the same as for a non-exclusive one, but it differs in a few key steps. This type of backup can only be taken on a primary and does not allow concurrent backups. Moreover, because it creates a backup label file, as described below, it can block automatic restart of the master server after a crash. On the other hand, the erroneous removal of this file from a backup or standby is a common mistake, which can result in serious data corruption. If it is necessary to use this method, the following steps may be used.

1. Ensure that WAL archiving is enabled and working.
2. Connect to the server (it does not matter which database) as a user with rights to run `pg_start_backup` (superuser, or a user who has been granted EXECUTE on the function) and issue the command:

```
SELECT pg_start_backup('label');
```

where `label` is any string you want to use to uniquely identify this backup operation. `pg_start_backup` creates a *backup label* file, called `backup_label`, in the cluster directory with information about your backup, including the start time and label string. The function also creates a *tablespace map* file, called `tablespace_map`, in the cluster directory with information about tablespace symbolic links in `lt_tblspc/` if one or more such link is present. Both files are critical to the integrity of the backup, should you need to restore from it.

By default, `pg_start_backup` can take a long time to finish. This is because it performs a checkpoint, and the I/O required for the checkpoint will be spread out over a significant period of time, by default half your inter-checkpoint interval (see the configuration parameter `checkpoint_completion_target`). This is usually what you want, because it minimizes the impact on query processing. If you want to start the backup as soon as possible, use:

```
SELECT pg_start_backup('label', true);
```

This forces the checkpoint to be done as quickly as possible.

3. Perform the backup, using any convenient file-system-backup tool such as tar or cpio (not `lt_dump` or `lt_dumpall`). It is neither necessary nor desirable to stop normal operation of the database while you do this. See Section 23.3.3.3 for things to consider during this backup.

As noted above, if the server crashes during the backup it may not be possible to restart until the `backup_label` file has been manually deleted from the `LTDATA` directory. Note that it is very important to never remove the `backup_label` file when restoring a backup, because this will

result in corruption. Confusion about when it is appropriate to remove this file is a common cause of data corruption when using this method; be very certain that you remove the file only on an existing master and never when building a standby or restoring a backup, even if you are building a standby that will subsequently be promoted to a new master.

4. Again connect to the database as a user with rights to run `pg_stop_backup` (superuser, or a user who has been granted EXECUTE on the function), and issue the command:

```
SELECT pg_stop_backup();
```

This function terminates backup mode and performs an automatic switch to the next WAL segment. The reason for the switch is to arrange for the last WAL segment written during the backup interval to be ready to archive.

5. Once the WAL segment files active during the backup are archived, you are done. The file identified by `pg_stop_backup`'s result is the last segment that is required to form a complete set of backup files. If `archive_mode` is enabled, `pg_stop_backup` does not return until the last segment has been archived. Archiving of these files happens automatically since you have already configured `archive_command`. In most cases this happens quickly, but you are advised to monitor your archive system to ensure there are no delays. If the archive process has fallen behind because of failures of the archive command, it will keep retrying until the archive succeeds and the backup is complete.

When using exclusive backup mode, it is absolutely imperative to ensure that `pg_stop_backup` completes successfully at the end of the backup. Even if the backup itself fails, for example due to lack of disk space, failure to call `pg_stop_backup` will leave the server in backup mode indefinitely, causing future backups to fail and increasing the risk of a restart failure during the time that `backup_label` exists.

### 23.3.3.3. Backing Up the Data Directory

Some file system backup tools emit warnings or errors if the files they are trying to copy change while the copy proceeds. When taking a base backup of an active database, this situation is normal and not an error. However, you need to ensure that you can distinguish complaints of this sort from real errors. For example, some versions of `rsync` return a separate exit code for “vanished source files”, and you can write a driver script to accept this exit code as a non-error case. Also, some versions of GNU `tar` return an error code indistinguishable from a fatal error if a file was truncated while `tar` was copying it. Fortunately, GNU `tar` versions 1.16 and later exit with 1 if a file was changed during the backup, and 2 for other errors. With GNU `tar` version 1.23 and later, you can use the warning options `--warning=no-file-changed` `--warning=no-file-removed` to hide the related warning messages.

Be certain that your backup includes all of the files under the database cluster directory (e.g., `/usr/local/lightdb-x/data`). If you are using tablespaces that do not reside underneath this directory, be careful to include them as well (and be sure that your backup archives symbolic links as links, otherwise the restore will corrupt your tablespaces).

You should, however, omit from the backup the files within the cluster's `lt_wal/` subdirectory. This slight adjustment is worthwhile because it reduces the risk of mistakes when restoring. This is easy to arrange if `lt_wal/` is a symbolic link pointing to someplace outside the cluster directory, which is a common setup anyway for performance reasons. You might also want to exclude `lightdb.pid` and `lightdb.opts`, which record information about the running postmaster, not about the postmaster which will eventually use this backup. (These files can confuse `lt_ctl`.)

It is often a good idea to also omit from the backup the files within the cluster's `lt_replslot/` directory, so that replication slots that exist on the master do not become part of the backup. Otherwise, the subsequent use of the backup to create a standby may result in indefinite retention of WAL files on the standby, and possibly bloat on the master if hot standby feedback is enabled, because the clients that are using those replication slots will still be connecting to and updating the slots on the master,

not the standby. Even if the backup is only intended for use in creating a new master, copying the replication slots isn't expected to be particularly useful, since the contents of those slots will likely be badly out of date by the time the new master comes on line.

The contents of the directories `lt_dynshmem/`, `lt_notify/`, `lt_serial/`, `lt_snapshots/`, `lt_stat_tmp/`, and `lt_subtrans/` (but not the directories themselves) can be omitted from the backup as they will be initialized on postmaster startup. If `stats_temp_directory` is set and is under the data directory then the contents of that directory can also be omitted.

Any file or directory beginning with `ltsql_tmp` can be omitted from the backup. These files are removed on postmaster start and the directories will be recreated as needed.

`lt_internal.init` files can be omitted from the backup whenever a file of that name is found. These files contain relation cache data that is always rebuilt when recovering.

The backup label file includes the label string you gave to `pg_start_backup`, as well as the time at which `pg_start_backup` was run, and the name of the starting WAL file. In case of confusion it is therefore possible to look inside a backup file and determine exactly which backup session the dump file came from. The tablespace map file includes the symbolic link names as they exist in the directory `lt_tblspc/` and the full path of each symbolic link. These files are not merely for your information; their presence and contents are critical to the proper operation of the system's recovery process.

It is also possible to make a backup while the server is stopped. In this case, you obviously cannot use `pg_start_backup` or `pg_stop_backup`, and you will therefore be left to your own devices to keep track of which backup is which and how far back the associated WAL files go. It is generally better to follow the continuous archiving procedure above.

## 23.3.4. Recovering Using a Continuous Archive Backup

Okay, the worst has happened and you need to recover from your backup. Here is the procedure:

1. Stop the server, if it's running.
2. If you have the space to do so, copy the whole cluster data directory and any tablespaces to a temporary location in case you need them later. Note that this precaution will require that you have enough free space on your system to hold two copies of your existing database. If you do not have enough space, you should at least save the contents of the cluster's `lt_wal` subdirectory, as it might contain logs which were not archived before the system went down.
3. Remove all existing files and subdirectories under the cluster data directory and under the root directories of any tablespaces you are using.
4. Restore the database files from your file system backup. Be sure that they are restored with the right ownership (the database system user, not `root!`) and with the right permissions. If you are using tablespaces, you should verify that the symbolic links in `lt_tblspc/` were correctly restored.
5. Remove any files present in `lt_wal/`; these came from the file system backup and are therefore probably obsolete rather than current. If you didn't archive `lt_wal/` at all, then recreate it with proper permissions, being careful to ensure that you re-establish it as a symbolic link if you had it set up that way before.
6. If you have unarchived WAL segment files that you saved in step 2, copy them into `lt_wal/`. (It is best to copy them, not move them, so you still have the unmodified files if a problem occurs and you have to start over.)
7. Set recovery configuration settings in `lightdb.conf` (see Section 17.5.4) and create a file `recovery.signal` in the cluster data directory. You might also want to temporarily modify `lt_hba.conf` to prevent ordinary users from connecting until you are sure the recovery was successful.

8. Start the server. The server will go into recovery mode and proceed to read through the archived WAL files it needs. Should the recovery be terminated because of an external error, the server can simply be restarted and it will continue recovery. Upon completion of the recovery process, the server will remove `recovery.signal` (to prevent accidentally re-entering recovery mode later) and then commence normal database operations.
9. Inspect the contents of the database to ensure you have recovered to the desired state. If not, return to step 1. If all is well, allow your users to connect by restoring `lt_hba.conf` to normal.

The key part of all this is to set up a recovery configuration that describes how you want to recover and how far the recovery should run. The one thing that you absolutely must specify is the `restore_command`, which tells LightDB how to retrieve archived WAL file segments. Like the `archive_command`, this is a shell command string. It can contain `%f`, which is replaced by the name of the desired log file, and `%p`, which is replaced by the path name to copy the log file to. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Write `%%` if you need to embed an actual `%` character in the command. The simplest useful command is something like:

```
restore_command = 'cp /mnt/server/archivedir/%f %p'
```

which will copy previously archived WAL segments from the directory `/mnt/server/archivedir`. Of course, you can use something much more complicated, perhaps even a shell script that requests the operator to mount an appropriate tape.

It is important that the command return nonzero exit status on failure. The command *will* be called requesting files that are not present in the archive; it must return nonzero when so asked. This is not an error condition. An exception is that if the command was terminated by a signal (other than `SIGTERM`, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

Not all of the requested files will be WAL segment files; you should also expect requests for files with a suffix of `.history`. Also be aware that the base name of the `%p` path will be different from `%f`; do not expect them to be interchangeable.

WAL segments that cannot be found in the archive will be sought in `lt_wal/`; this allows use of recent un-archived segments. However, segments that are available from the archive will be used in preference to files in `lt_wal/`.

Normally, recovery will proceed through all available WAL segments, thereby restoring the database to the current point in time (or as close as possible given the available WAL segments). Therefore, a normal recovery will end with a “file not found” message, the exact text of the error message depending upon your choice of `restore_command`. You may also see an error message at the start of recovery for a file named something like `00000001.history`. This is also normal and does not indicate a problem in simple recovery situations; see Section 23.3.5 for discussion.

If you want to recover to some previous point in time (say, right before the junior DBA dropped your main transaction table), just specify the required stopping point. You can specify the stop point, known as the “recovery target”, either by date/time, named restore point or by completion of a specific transaction ID. As of this writing only the date/time and named restore point options are very usable, since there are no tools to help you identify with any accuracy which transaction ID to use.

### Note

The stop point must be after the ending time of the base backup, i.e., the end time of `pg_stop_backup`. You cannot use a base backup to recover to a time when that backup was in progress. (To recover to such a time, you must go back to your previous base backup and roll forward from there.)

If recovery finds corrupted WAL data, recovery will halt at that point and the server will not start. In such a case the recovery process could be re-run from the beginning, specifying a “recovery target” before the point of corruption so that recovery can complete normally. If recovery fails for an external reason, such as a system crash or if the WAL archive has become inaccessible, then the recovery can simply be restarted and it will restart almost from where it failed. Recovery restart works much like checkpointing in normal operation: the server periodically forces all its state to disk, and then updates the `lt_control` file to indicate that the already-processed WAL data need not be scanned again.

### 23.3.5. Timelines

The ability to restore the database to a previous point in time creates some complexities that are akin to science-fiction stories about time travel and parallel universes. For example, in the original history of the database, suppose you dropped a critical table at 5:15PM on Tuesday evening, but didn't realize your mistake until Wednesday noon. Unfazed, you get out your backup, restore to the point-in-time 5:14PM Tuesday evening, and are up and running. In *this* history of the database universe, you never dropped the table. But suppose you later realize this wasn't such a great idea, and would like to return to sometime Wednesday morning in the original history. You won't be able to if, while your database was up-and-running, it overwrote some of the WAL segment files that led up to the time you now wish you could get back to. Thus, to avoid this, you need to distinguish the series of WAL records generated after you've done a point-in-time recovery from those that were generated in the original database history.

To deal with this problem, LightDB has a notion of *timelines*. Whenever an archive recovery completes, a new timeline is created to identify the series of WAL records generated after that recovery. The timeline ID number is part of WAL segment file names so a new timeline does not overwrite the WAL data generated by previous timelines. It is in fact possible to archive many different timelines. While that might seem like a useless feature, it's often a lifesaver. Consider the situation where you aren't quite sure what point-in-time to recover to, and so have to do several point-in-time recoveries by trial and error until you find the best place to branch off from the old history. Without timelines this process would soon generate an unmanageable mess. With timelines, you can recover to *any* prior state, including states in timeline branches that you abandoned earlier.

Every time a new timeline is created, LightDB creates a “timeline history” file that shows which timeline it branched off from and when. These history files are necessary to allow the system to pick the right WAL segment files when recovering from an archive that contains multiple timelines. Therefore, they are archived into the WAL archive area just like WAL segment files. The history files are just small text files, so it's cheap and appropriate to keep them around indefinitely (unlike the segment files which are large). You can, if you like, add comments to a history file to record your own notes about how and why this particular timeline was created. Such comments will be especially valuable when you have a thicket of different timelines as a result of experimentation.

The default behavior of recovery is to recover to the latest timeline found in the archive. If you wish to recover to the timeline that was current when the base backup was taken or into a specific child timeline (that is, you want to return to some state that was itself generated after a recovery attempt), you need to specify `current` or the target timeline ID in `recovery_target_timeline`. You cannot recover into timelines that branched off earlier than the base backup.

### 23.3.6. Tips and Examples

Some tips for configuring continuous archiving are given here.

#### 23.3.6.1. Standalone Hot Backups

It is possible to use LightDB's backup facilities to produce standalone hot backups. These are backups that cannot be used for point-in-time recovery, yet are typically much faster to backup and restore than `lt_dump` dumps. (They are also much larger than `lt_dump` dumps, so in some cases the speed advantage might be negated.)

As with base backups, the easiest way to produce a standalone hot backup is to use the `lt_basebackup` tool. If you include the `-X` parameter when calling it, all the write-ahead log required to use the backup will be included in the backup automatically, and no special action is required to restore the backup.

If more flexibility in copying the backup files is needed, a lower level process can be used for standalone hot backups as well. To prepare for low level standalone hot backups, make sure `wal_level` is set to `replica` or higher, `archive_mode` to `on`, and set up an `archive_command` that performs archiving only when a *switch file* exists. For example:

```
archive_command = 'test ! -f /var/lib/lightdb-x/backup_in_progress
|| (test ! -f /var/lib/lightdb-x/archive/%f && cp %p /var/lib/
lightdb-x/archive/%f)'
```

This command will perform archiving when `/var/lib/lightdb-x/backup_in_progress` exists, and otherwise silently return zero exit status (allowing LightDB to recycle the unwanted WAL file).

With this preparation, a backup can be taken using a script like the following:

```
touch /var/lib/lightdb-x/backup_in_progress
ltsql -c "select pg_start_backup('hot_backup');"
tar -cf /var/lib/lightdb-x/backup.tar /var/lib/lightdb-x/data/
ltsql -c "select pg_stop_backup();"
rm /var/lib/lightdb-x/backup_in_progress
tar -rf /var/lib/lightdb-x/backup.tar /var/lib/lightdb-x/archive/
```

The switch file `/var/lib/lightdb-x/backup_in_progress` is created first, enabling archiving of completed WAL files to occur. After the backup the switch file is removed. Archived WAL files are then added to the backup so that both base backup and all required WAL files are part of the same tar file. Please remember to add error handling to your backup scripts.

### 23.3.6.2. Compressed Archive Logs

If archive storage size is a concern, you can use `gzip` to compress the archive files:

```
archive_command = 'gzip < %p > /var/lib/lightdb-x/archive/%f'
```

You will then need to use `gunzip` during recovery:

```
restore_command = 'gunzip < /mnt/server/archivedir/%f > %p'
```

### 23.3.6.3. archive\_command Scripts

Many people choose to use scripts to define their `archive_command`, so that their `lightdb.conf` entry looks very simple:

```
archive_command = 'local_backup_script.sh "%p" "%f"'
```

Using a separate script file is advisable any time you want to use more than a single command in the archiving process. This allows all complexity to be managed within the script, which can be written in a popular scripting language such as `bash` or `perl`.

Examples of requirements that might be solved within a script include:

- Copying data to secure off-site data storage

- Batching WAL files so that they are transferred every three hours, rather than one at a time
- Interfacing with other backup and recovery software
- Interfacing with monitoring software to report errors

**Tip**

When using an `archive_command` script, it's desirable to enable `logging_collector`. Any messages written to `stderr` from the script will then appear in the database server log, allowing complex configurations to be diagnosed easily if they fail.

### 23.3.7. Caveats

At this writing, there are several limitations of the continuous archiving technique. These will probably be fixed in future releases:

- If a `CREATE DATABASE` command is executed while a base backup is being taken, and then the template database that the `CREATE DATABASE` copied is modified while the base backup is still in progress, it is possible that recovery will cause those modifications to be propagated into the created database as well. This is of course undesirable. To avoid this risk, it is best not to modify any template databases while taking a base backup.
- `CREATE TABLESPACE` commands are WAL-logged with the literal absolute path, and will therefore be replayed as tablespace creations with the same absolute path. This might be undesirable if the log is being replayed on a different machine. It can be dangerous even if the log is being replayed on the same machine, but into a new data directory: the replay will still overwrite the contents of the original tablespace. To avoid potential gotchas of this sort, the best practice is to take a new base backup after creating or dropping tablespaces.

It should also be noted that the default WAL format is fairly bulky since it includes many disk page snapshots. These page snapshots are designed to support crash recovery, since we might need to fix partially-written disk pages. Depending on your system hardware and software, the risk of partial writes might be small enough to ignore, in which case you can significantly reduce the total volume of archived logs by turning off page snapshots using the `full_page_writes` parameter. (Read the notes and warnings in Chapter 27 before you do so.) Turning off page snapshots does not prevent use of the logs for PITR operations. An area for future development is to compress archived WAL data by removing unnecessary page copies even when `full_page_writes` is on. In the meantime, administrators might wish to reduce the number of page snapshots included in WAL by increasing the checkpoint interval parameters as much as feasible.

---

# Chapter 24. High Availability, Load Balancing, and Replication

Database servers can work together to allow a second server to take over quickly if the primary server fails (high availability), or to allow several computers to serve the same data (load balancing). Ideally, database servers could work together seamlessly. Web servers serving static web pages can be combined quite easily by merely load-balancing web requests to multiple machines. In fact, read-only database servers can be combined relatively easily too. Unfortunately, most database servers have a read/write mix of requests, and read/write servers are much harder to combine. This is because though read-only data needs to be placed on each server only once, a write to any server has to be propagated to all servers so that future read requests to those servers return consistent results.

This synchronization problem is the fundamental difficulty for servers working together. Because there is no single solution that eliminates the impact of the sync problem for all use cases, there are multiple solutions. Each solution addresses this problem in a different way, and minimizes its impact for a specific workload.

Some solutions deal with synchronization by allowing only one server to modify the data. Servers that can modify data are called read/write, *master* or *primary* servers. Servers that track changes in the master are called *standby* or *secondary* servers. A standby server that cannot be connected to until it is promoted to a master server is called a *warm standby* server, and one that can accept connections and serves read-only queries is called a *hot standby* server.

Some solutions are synchronous, meaning that a data-modifying transaction is not considered committed until all servers have committed the transaction. This guarantees that a failover will not lose any data and that all load-balanced servers will return consistent results no matter which server is queried. In contrast, asynchronous solutions allow some delay between the time of a commit and its propagation to the other servers, opening the possibility that some transactions might be lost in the switch to a backup server, and that load balanced servers might return slightly stale results. Asynchronous communication is used when synchronous would be too slow.

Solutions can also be categorized by their granularity. Some solutions can deal only with an entire database server, while others allow control at the per-table or per-database level.

Performance must be considered in any choice. There is usually a trade-off between functionality and performance. For example, a fully synchronous solution over a slow network might cut performance by more than half, while an asynchronous one might have a minimal performance impact.

The remainder of this section outlines various failover, replication, and load balancing solutions.

## 24.1. Comparison of Different Solutions

### Shared Disk Failover

Shared disk failover avoids synchronization overhead by having only one copy of the database. It uses a single disk array that is shared by multiple servers. If the main database server fails, the standby server is able to mount and start the database as though it were recovering from a database crash. This allows rapid failover with no data loss.

Shared hardware functionality is common in network storage devices. Using a network file system is also possible, though care must be taken that the file system has full POSIX behavior (see Section 16.2.2.1). One significant limitation of this method is that if the shared disk array fails or becomes corrupt, the primary and standby servers are both nonfunctional. Another issue is that the standby server should never access the shared storage while the primary server is running.



### File System (Block Device) Replication

A modified version of shared hardware functionality is file system replication, where all changes to a file system are mirrored to a file system residing on another computer. The only restriction is that the mirroring must be done in a way that ensures the standby server has a consistent copy of the file system — specifically, writes to the standby must be done in the same order as those on the master. DRBD is a popular file system replication solution for Linux.

### Write-Ahead Log Shipping

Warm and hot standby servers can be kept current by reading a stream of write-ahead log (WAL) records. If the main server fails, the standby contains almost all of the data of the main server, and can be quickly made the new master database server. This can be synchronous or asynchronous and can only be done for the entire database server.

A standby server can be implemented using file-based log shipping (Section 24.2) or streaming replication (see Section 24.2.5), or a combination of both. For information on hot standby, see Section 24.5.

### Logical Replication

Logical replication allows a database server to send a stream of data modifications to another server. LightDB logical replication constructs a stream of logical data modifications from the WAL. Logical replication allows the data changes from individual tables to be replicated. Logical replication doesn't require a particular server to be designated as a master or a replica but allows data to flow in multiple directions. For more information on logical replication, see Chapter 28. Through the logical decoding interface (Chapter 45), third-party extensions can also provide similar functionality.

### Trigger-Based Master-Standby Replication

A master-standby replication setup sends all data modification queries to the master server. The master server asynchronously sends data changes to the standby server. The standby can answer read-only queries while the master server is running. The standby server is ideal for data warehouse queries.

Slony-I is an example of this type of replication, with per-table granularity, and support for multiple standby servers. Because it updates the standby server asynchronously (in batches), there is possible data loss during fail over.

### SQL-Based Replication Middleware

With SQL-based replication middleware, a program intercepts every SQL query and sends it to one or all servers. Each server operates independently. Read-write queries must be sent to all servers, so that every server receives any changes. But read-only queries can be sent to just one server, allowing the read workload to be distributed among them.

If queries are simply broadcast unmodified, functions like `random()`, `CURRENT_TIMESTAMP`, and sequences can have different values on different servers. This is because each server operates independently, and because SQL queries are broadcast (and not actual modified rows). If this is unacceptable, either the middleware or the application must query such values from a single server and then use those values in write queries. Another option is to use this replication option with a traditional master-standby setup, i.e., data modification queries are sent only to the master and are propagated to the standby servers via master-standby replication, not by the replication middleware. Care must also be taken that all transactions either commit or abort on all servers, perhaps using two-phase commit (`PREPARE TRANSACTION` and `COMMIT PREPARED`). Pgpool-II and Continuent Tungsten are examples of this type of replication.

### Asynchronous Multimaster Replication

For servers that are not regularly connected or have slow communication links, like laptops or remote servers, keeping data consistent among servers is a challenge. Using asynchronous

multimaster replication, each server works independently, and periodically communicates with the other servers to identify conflicting transactions. The conflicts can be resolved by users or conflict resolution rules. Bucardo is an example of this type of replication.

#### Synchronous Multimaster Replication

In synchronous multimaster replication, each server can accept write requests, and modified data is transmitted from the original server to every other server before each transaction commits. Heavy write activity can cause excessive locking and commit delays, leading to poor performance. Read requests can be sent to any server. Some implementations use shared disk to reduce the communication overhead. Synchronous multimaster replication is best for mostly read workloads, though its big advantage is that any server can accept write requests — there is no need to partition workloads between master and standby servers, and because the data changes are sent from one server to another, there is no problem with non-deterministic functions like `random()`.

LightDB does not offer this type of replication, though LightDB two-phase commit (PREPARE TRANSACTION and COMMIT PREPARED) can be used to implement this in application code or middleware.

Table 24.1 summarizes the capabilities of the various solutions listed above.

**Table 24.1. High Availability, Load Balancing, and Replication Feature Matrix**

Feature	Shared Disk	File System Repl.	Write-Ahead Log Shipping	Logical Repl.	Trigger-Based Repl.	SQL Repl. Middle-ware	Async. MM Repl.	Sync. MM Repl.
Popular examples	NAS	DRBD	built-in streaming repl.	built-in logical repl., pglogical	Londiste, Slony	pgpool-II	Bucardo	
Comm. method	shared disk	disk blocks	WAL	logical decoding	table rows	SQL	table rows	table rows and row locks
No special hardware required		•	•	•	•	•	•	•
Allows multiple master servers				•		•	•	•
No master server overhead	•		•	•		•		
No waiting for multiple servers	•		with sync off	with sync off	•		•	
Master failure will never lose data	•	•	with sync on	with sync on		•		•
Replicas accept read-only queries			with hot standby	•	•	•	•	•

Feature	Shared Disk	File System Repl.	Write-Ahead Log Shipping	Logical Repl.	Trigger-Based Repl.	SQL Repl. Middle-ware	Async. MM Repl.	Sync. MM Repl.
Per-table granularity				•	•		•	•
No conflict resolution necessary	•	•	•		•	•		•

There are a few solutions that do not fit into the above categories:

#### Data Partitioning

Data partitioning splits tables into data sets. Each set can be modified by only one server. For example, data can be partitioned by offices, e.g., London and Paris, with a server in each office. If queries combining London and Paris data are necessary, an application can query both servers, or master/standby replication can be used to keep a read-only copy of the other office's data on each server.

#### Multiple-Server Parallel Query Execution

Many of the above solutions allow multiple servers to handle multiple queries, but none allow a single query to use multiple servers to complete faster. This solution allows multiple servers to work concurrently on a single query. It is usually accomplished by splitting the data among servers and having each server execute its part of the query and return results to a central server where they are combined and returned to the user. This can be implemented using the PL/Proxy tool set.

It should also be noted that because LightDB is open source and easily extended, a number of companies have taken LightDB and created commercial closed-source solutions with unique failover, replication, and load balancing capabilities. These are not discussed here.

## 24.2. Log-Shipping Standby Servers

Continuous archiving can be used to create a *high availability* (HA) cluster configuration with one or more *standby servers* ready to take over operations if the primary server fails. This capability is widely referred to as *warm standby* or *log shipping*.

The primary and standby server work together to provide this capability, though the servers are only loosely coupled. The primary server operates in continuous archiving mode, while each standby server operates in continuous recovery mode, reading the WAL files from the primary. No changes to the database tables are required to enable this capability, so it offers low administration overhead compared to some other replication solutions. This configuration also has relatively low performance impact on the primary server.

Directly moving WAL records from one database server to another is typically described as log shipping. LightDB implements file-based log shipping by transferring WAL records one file (WAL segment) at a time. WAL files (16MB) can be shipped easily and cheaply over any distance, whether it be to an adjacent system, another system at the same site, or another system on the far side of the globe. The bandwidth required for this technique varies according to the transaction rate of the primary server. Record-based log shipping is more granular and streams WAL changes incrementally over a network connection (see Section 24.2.5).

It should be noted that log shipping is asynchronous, i.e., the WAL records are shipped after transaction commit. As a result, there is a window for data loss should the primary server suffer a catastrophic failure; transactions not yet shipped will be lost. The size of the data loss window in file-based log

shipping can be limited by use of the `archive_timeout` parameter, which can be set as low as a few seconds. However such a low setting will substantially increase the bandwidth required for file shipping. Streaming replication (see Section 24.2.5) allows a much smaller window of data loss.

Recovery performance is sufficiently good that the standby will typically be only moments away from full availability once it has been activated. As a result, this is called a warm standby configuration which offers high availability. Restoring a server from an archived base backup and rollforward will take considerably longer, so that technique only offers a solution for disaster recovery, not high availability. A standby server can also be used for read-only queries, in which case it is called a Hot Standby server. See Section 24.5 for more information.

## 24.2.1. Planning

It is usually wise to create the primary and standby servers so that they are as similar as possible, at least from the perspective of the database server. In particular, the path names associated with tablespaces will be passed across unmodified, so both primary and standby servers must have the same mount paths for tablespaces if that feature is used. Keep in mind that if `CREATE TABLESPACE` is executed on the primary, any new mount point needed for it must be created on the primary and all standby servers before the command is executed. Hardware need not be exactly the same, but experience shows that maintaining two identical systems is easier than maintaining two dissimilar ones over the lifetime of the application and system. In any case the hardware architecture must be the same — shipping from, say, a 32-bit to a 64-bit system will not work.

In general, log shipping between servers running different major LightDB release levels is not possible. It is the policy of the LightDB Global Development Group not to make changes to disk formats during minor release upgrades, so it is likely that running different minor release levels on primary and standby servers will work successfully. However, no formal support for that is offered and you are advised to keep primary and standby servers at the same release level as much as possible. When updating to a new minor release, the safest policy is to update the standby servers first — a new minor release is more likely to be able to read WAL files from a previous minor release than vice versa.

## 24.2.2. Standby Server Operation

A server enters standby mode if a `standby.signal` file exists in the data directory when the server is started.

In standby mode, the server continuously applies WAL received from the master server. The standby server can read WAL from a WAL archive (see `restore_command`) or directly from the master over a TCP connection (streaming replication). The standby server will also attempt to restore any WAL found in the standby cluster's `lt_wal` directory. That typically happens after a server restart, when the standby replays again WAL that was streamed from the master before the restart, but you can also manually copy files to `lt_wal` at any time to have them replayed.

At startup, the standby begins by restoring all WAL available in the archive location, calling `restore_command`. Once it reaches the end of WAL available there and `restore_command` fails, it tries to restore any WAL available in the `lt_wal` directory. If that fails, and streaming replication has been configured, the standby tries to connect to the primary server and start streaming WAL from the last valid record found in archive or `lt_wal`. If that fails or streaming replication is not configured, or if the connection is later disconnected, the standby goes back to step 1 and tries to restore the file from the archive again. This loop of retries from the archive, `lt_wal`, and via streaming replication goes on until the server is stopped or failover is triggered by a trigger file.

Standby mode is exited and the server switches to normal operation when `lt_ctl promote` is run, `pg_promote()` is called, or a trigger file is found (`promote_trigger_file`). Before failover, any WAL immediately available in the archive or in `lt_wal` will be restored, but no attempt is made to connect to the master.

### 24.2.3. Preparing the Master for Standby Servers

Set up continuous archiving on the primary to an archive directory accessible from the standby, as described in Section 23.3. The archive location should be accessible from the standby even when the master is down, i.e., it should reside on the standby server itself or another trusted server, not on the master server.

If you want to use streaming replication, set up authentication on the primary server to allow replication connections from the standby server(s); that is, create a role and provide a suitable entry or entries in `lt_hba.conf` with the database field set to `replication`. Also ensure `max_wal_senders` is set to a sufficiently large value in the configuration file of the primary server. If replication slots will be used, ensure that `max_replication_slots` is set sufficiently high as well.

Take a base backup as described in Section 23.3.2 to bootstrap the standby server.

### 24.2.4. Setting Up a Standby Server

To set up the standby server, restore the base backup taken from primary server (see Section 23.3.4). Create a file `standby.signal` in the standby's cluster data directory. Set `restore_command` to a simple command to copy files from the WAL archive. If you plan to have multiple standby servers for high availability purposes, make sure that `recovery_target_timeline` is set to `latest` (the default), to make the standby server follow the timeline change that occurs at failover to another standby.

#### Note

Do not use `lt_standby` or similar tools with the built-in standby mode described here. `restore_command` should return immediately if the file does not exist; the server will retry the command again if necessary. See Section 24.4 for using tools like `lt_standby`.

If you want to use streaming replication, fill in `primary_conninfo` with a `libpq` connection string, including the host name (or IP address) and any additional details needed to connect to the primary server. If the primary needs a password for authentication, the password needs to be specified in `primary_conninfo` as well.

If you're setting up the standby server for high availability purposes, set up WAL archiving, connections and authentication like the primary server, because the standby server will work as a primary server after failover.

If you're using a WAL archive, its size can be minimized using the `archive_cleanup_command` parameter to remove files that are no longer required by the standby server. The `lt_archivecleanup` utility is designed specifically to be used with `archive_cleanup_command` in typical single-standby configurations, see `lt_archivecleanup`. Note however, that if you're using the archive for backup purposes, you need to retain files needed to recover from at least the latest base backup, even if they're no longer needed by the standby.

A simple example of configuration is:

```
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass options='-c wal_sender_timeout=5000''
restore_command = 'cp /path/to/archive/%f %p'
archive_cleanup_command = 'lt_archivecleanup /path/to/archive %r'
```

You can have any number of standby servers, but if you use streaming replication, make sure you set `max_wal_senders` high enough in the primary to allow them to be connected simultaneously.

## 24.2.5. Streaming Replication

Streaming replication allows a standby server to stay more up-to-date than is possible with file-based log shipping. The standby connects to the primary, which streams WAL records to the standby as they're generated, without waiting for the WAL file to be filled.

Streaming replication is asynchronous by default (see Section 24.2.8), in which case there is a small delay between committing a transaction in the primary and the changes becoming visible in the standby. This delay is however much smaller than with file-based log shipping, typically under one second assuming the standby is powerful enough to keep up with the load. With streaming replication, `archive_timeout` is not required to reduce the data loss window.

If you use streaming replication without file-based continuous archiving, the server might recycle old WAL segments before the standby has received them. If this occurs, the standby will need to be reinitialized from a new base backup. You can avoid this by setting `wal_keep_size` to a value large enough to ensure that WAL segments are not recycled too early, or by configuring a replication slot for the standby. If you set up a WAL archive that's accessible from the standby, these solutions are not required, since the standby can always use the archive to catch up provided it retains enough segments.

To use streaming replication, set up a file-based log-shipping standby server as described in Section 24.2. The step that turns a file-based log-shipping standby into streaming replication standby is setting the `primary_conninfo` setting to point to the primary server. Set `listen_addresses` and authentication options (see `lt_hba.conf`) on the primary so that the standby server can connect to the replication pseudo-database on the primary server (see Section 24.2.5.1).

On systems that support the `keepalive socket` option, setting `tcp_keepalives_idle`, `tcp_keepalives_interval` and `tcp_keepalives_count` helps the primary promptly notice a broken connection.

Set the maximum number of concurrent connections from the standby servers (see `max_wal_senders` for details).

When the standby is started and `primary_conninfo` is set correctly, the standby will connect to the primary after replaying all WAL files available in the archive. If the connection is established successfully, you will see a `walreceiver` in the standby, and a corresponding `walsender` process in the primary.

### 24.2.5.1. Authentication

It is very important that the access privileges for replication be set up so that only trusted users can read the WAL stream, because it is easy to extract privileged information from it. Standby servers must authenticate to the primary as an account that has the `REPLICATION` privilege or a superuser. It is recommended to create a dedicated user account with `REPLICATION` and `LOGIN` privileges for replication. While `REPLICATION` privilege gives very high permissions, it does not allow the user to modify any data on the primary system, which the `SUPERUSER` privilege does.

Client authentication for replication is controlled by a `lt_hba.conf` record specifying `replication` in the `database` field. For example, if the standby is running on host IP 192.168.1.100 and the account name for replication is `foo`, the administrator can add the following line to the `lt_hba.conf` file on the primary:

```
# Allow the user "foo" from host 192.168.1.100 to connect to the
primary
# as a replication standby if the user's password is correctly
supplied.
#
# TYPE DATABASE          USER          ADDRESS
METHOD
```

```
host      replication    foo          192.168.1.100/32    md5
```

The host name and port number of the primary, connection user name, and password are specified in the `primary_conninfo`. The password can also be set in the `~/.pgpass` file on the standby (specify `replication` in the `database` field). For example, if the primary is running on host IP `192.168.1.50`, port `5432`, the account name for replication is `foo`, and the password is `foopass`, the administrator can add the following line to the `lightdb.conf` file on the standby:

```
# The standby connects to the primary that is running on host
192.168.1.50
# and port 5432 as the user "foo" whose password is "foopass".
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass'
```

## 24.2.5.2. Monitoring

An important health indicator of streaming replication is the amount of WAL records generated in the primary, but not yet applied in the standby. You can calculate this lag by comparing the current WAL write location on the primary with the last WAL location received by the standby. These locations can be retrieved using `pg_current_wal_lsn` on the primary and `pg_last_wal_receive_lsn` on the standby, respectively (see Table 9.86 and Table 9.87 for details). The last WAL receive location in the standby is also displayed in the process status of the WAL receiver process, displayed using the `ps` command (see Section 25.1 for details).

You can retrieve a list of WAL sender processes via the `pg_stat_replication` view. Large differences between `pg_current_wal_lsn` and the view's `sent_lsn` field might indicate that the master server is under heavy load, while differences between `sent_lsn` and `pg_last_wal_receive_lsn` on the standby might indicate network delay, or that the standby is under heavy load.

On a hot standby, the status of the WAL receiver process can be retrieved via the `pg_stat_wal_receiver` view. A large difference between `pg_last_wal_replay_lsn` and the view's `flushed_lsn` indicates that WAL is being received faster than it can be replayed.

## 24.2.6. Replication Slots

Replication slots provide an automated way to ensure that the master does not remove WAL segments until they have been received by all standbys, and that the master does not remove rows which could cause a recovery conflict even when the standby is disconnected.

In lieu of using replication slots, it is possible to prevent the removal of old WAL segments using `wal_keep_size`, or by storing the segments in an archive using `archive_command`. However, these methods often result in retaining more WAL segments than required, whereas replication slots retain only the number of segments known to be needed. On the other hand, replication slots can retain so many WAL segments that they fill up the space allocated for `lt_wal`; `max_slot_wal_keep_size` limits the size of WAL files retained by replication slots.

Similarly, `hot_standby_feedback` and `vacuum_defer_cleanup_age` provide protection against relevant rows being removed by vacuum, but the former provides no protection during any time period when the standby is not connected, and the latter often needs to be set to a high value to provide adequate protection. Replication slots overcome these disadvantages.

### 24.2.6.1. Querying and Manipulating Replication Slots

Each replication slot has a name, which can contain lower-case letters, numbers, and the underscore character.

Existing replication slots and their state can be seen in the `pg_replication_slots` view.

Slots can be created and dropped either via the streaming replication protocol (see Section 49.4) or via SQL functions (see Section 9.27.6).

### 24.2.6.2. Configuration Example

You can create a replication slot like this:

```
lightdb@postgres=# SELECT * FROM
pg_create_physical_replication_slot('node_a_slot');
 slot_name | lsn
-----+-----
node_a_slot |
```

```
lightdb@postgres=# SELECT slot_name, slot_type, active FROM
pg_replication_slots;
 slot_name | slot_type | active
-----+-----+-----
node_a_slot | physical  | f
(1 row)
```

To configure the standby to use this slot, `primary_slot_name` should be configured on the standby. Here is a simple example:

```
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass'
primary_slot_name = 'node_a_slot'
```

### 24.2.7. Cascading Replication

The cascading replication feature allows a standby server to accept replication connections and stream WAL records to other standbys, acting as a relay. This can be used to reduce the number of direct connections to the master and also to minimize inter-site bandwidth overheads.

A standby acting as both a receiver and a sender is known as a cascading standby. Standbys that are more directly connected to the master are known as upstream servers, while those standby servers further away are downstream servers. Cascading replication does not place limits on the number or arrangement of downstream servers, though each standby connects to only one upstream server which eventually links to a single master/primary server.

A cascading standby sends not only WAL records received from the master but also those restored from the archive. So even if the replication connection in some upstream connection is terminated, streaming replication continues downstream for as long as new WAL records are available.

Cascading replication is currently asynchronous. Synchronous replication (see Section 24.2.8) settings have no effect on cascading replication at present.

Hot Standby feedback propagates upstream, whatever the cascaded arrangement.

If an upstream standby server is promoted to become new master, downstream servers will continue to stream from the new master if `recovery_target_timeline` is set to 'latest' (the default).

To use cascading replication, set up the cascading standby so that it can accept replication connections (that is, set `max_wal_senders` and `hot_standby`, and configure host-based authentication). You will also need to set `primary_conninfo` in the downstream standby to point to the cascading standby.

### 24.2.8. Synchronous Replication



LightDB streaming replication is asynchronous by default. If the primary server crashes then some transactions that were committed may not have been replicated to the standby server, causing data loss. The amount of data loss is proportional to the replication delay at the time of failover.

Synchronous replication offers the ability to confirm that all changes made by a transaction have been transferred to one or more synchronous standby servers. This extends that standard level of durability offered by a transaction commit. This level of protection is referred to as 2-safe replication in computer science theory, and group-1-safe (group-safe and 1-safe) when `synchronous_commit` is set to `remote_write`.

When requesting synchronous replication, each commit of a write transaction will wait until confirmation is received that the commit has been written to the write-ahead log on disk of both the primary and standby server. The only possibility that data can be lost is if both the primary and the standby suffer crashes at the same time. This can provide a much higher level of durability, though only if the sysadmin is cautious about the placement and management of the two servers. Waiting for confirmation increases the user's confidence that the changes will not be lost in the event of server crashes but it also necessarily increases the response time for the requesting transaction. The minimum wait time is the round-trip time between primary and standby.

Read only transactions and transaction rollbacks need not wait for replies from standby servers. Subtransaction commits do not wait for responses from standby servers, only top-level commits. Long running actions such as data loading or index building do not wait until the very final commit message. All two-phase commit actions require commit waits, including both prepare and commit.

A synchronous standby can be a physical replication standby or a logical replication subscriber. It can also be any other physical or logical WAL replication stream consumer that knows how to send the appropriate feedback messages. Besides the built-in physical and logical replication systems, this includes special programs such as `pg_receivewal` and `pg_recvlogical` as well as some third-party replication systems and custom programs. Check the respective documentation for details on synchronous replication support.

### 24.2.8.1. Basic Configuration

Once streaming replication has been configured, configuring synchronous replication requires only one additional configuration step: `synchronous_standby_names` must be set to a non-empty value. `synchronous_commit` must also be set to `on`, but since this is the default value, typically no change is required. (See Section 17.5.1 and Section 17.6.2.) This configuration will cause each commit to wait for confirmation that the standby has written the commit record to durable storage. `synchronous_commit` can be set by individual users, so it can be configured in the configuration file, for particular users or databases, or dynamically by applications, in order to control the durability guarantee on a per-transaction basis.

After a commit record has been written to disk on the primary, the WAL record is then sent to the standby. The standby sends reply messages each time a new batch of WAL data is written to disk, unless `wal_receiver_status_interval` is set to zero on the standby. In the case that `synchronous_commit` is set to `remote_apply`, the standby sends reply messages when the commit record is replayed, making the transaction visible. If the standby is chosen as a synchronous standby, according to the setting of `synchronous_standby_names` on the primary, the reply messages from that standby will be considered along with those from other synchronous standbys to decide when to release transactions waiting for confirmation that the commit record has been received. These parameters allow the administrator to specify which standby servers should be synchronous standbys. Note that the configuration of synchronous replication is mainly on the master. Named standbys must be directly connected to the master; the master knows nothing about downstream standby servers using cascaded replication.

Setting `synchronous_commit` to `remote_write` will cause each commit to wait for confirmation that the standby has received the commit record and written it out to its own operating system, but not for the data to be flushed to disk on the standby. This setting provides a weaker guarantee of durability than `on` does: the standby could lose the data in the event of an operating

system crash, though not a LightDB crash. However, it's a useful setting in practice because it can decrease the response time for the transaction. Data loss could only occur if both the primary and the standby crash and the database of the primary gets corrupted at the same time.

Setting `synchronous_commit` to `remote_apply` will cause each commit to wait until the current synchronous standbys report that they have replayed the transaction, making it visible to user queries. In simple cases, this allows for load balancing with causal consistency.

Users will stop waiting if a fast shutdown is requested. However, as when using asynchronous replication, the server will not fully shutdown until all outstanding WAL records are transferred to the currently connected standby servers.

### 24.2.8.2. Multiple Synchronous Standbys

Synchronous replication supports one or more synchronous standby servers; transactions will wait until all the standby servers which are considered as synchronous confirm receipt of their data. The number of synchronous standbys that transactions must wait for replies from is specified in `synchronous_standby_names`. This parameter also specifies a list of standby names and the method (`FIRST` and `ANY`) to choose synchronous standbys from the listed ones.

The method `FIRST` specifies a priority-based synchronous replication and makes transaction commits wait until their WAL records are replicated to the requested number of synchronous standbys chosen based on their priorities. The standbys whose names appear earlier in the list are given higher priority and will be considered as synchronous. Other standby servers appearing later in this list represent potential synchronous standbys. If any of the current synchronous standbys disconnects for whatever reason, it will be replaced immediately with the next-highest-priority standby.

An example of `synchronous_standby_names` for a priority-based multiple synchronous standbys is:

```
synchronous_standby_names = 'FIRST 2 (s1, s2, s3)'
```

In this example, if four standby servers `s1`, `s2`, `s3` and `s4` are running, the two standbys `s1` and `s2` will be chosen as synchronous standbys because their names appear early in the list of standby names. `s3` is a potential synchronous standby and will take over the role of synchronous standby when either of `s1` or `s2` fails. `s4` is an asynchronous standby since its name is not in the list.

The method `ANY` specifies a quorum-based synchronous replication and makes transaction commits wait until their WAL records are replicated to *at least* the requested number of synchronous standbys in the list.

An example of `synchronous_standby_names` for a quorum-based multiple synchronous standbys is:

```
synchronous_standby_names = 'ANY 2 (s1, s2, s3)'
```

In this example, if four standby servers `s1`, `s2`, `s3` and `s4` are running, transaction commits will wait for replies from at least any two standbys of `s1`, `s2` and `s3`. `s4` is an asynchronous standby since its name is not in the list.

The synchronous states of standby servers can be viewed using the `pg_stat_replication` view.

### 24.2.8.3. Planning for Performance

Synchronous replication usually requires carefully planned and placed standby servers to ensure applications perform acceptably. Waiting doesn't utilize system resources, but transaction locks continue to be held until the transfer is confirmed. As a result, incautious use of synchronous

replication will reduce performance for database applications because of increased response times and higher contention.

LightDB allows the application developer to specify the durability level required via replication. This can be specified for the system overall, though it can also be specified for specific users or connections, or even individual transactions.

For example, an application workload might consist of: 10% of changes are important customer details, while 90% of changes are less important data that the business can more easily survive if it is lost, such as chat messages between users.

With synchronous replication options specified at the application level (on the primary) we can offer synchronous replication for the most important changes, without slowing down the bulk of the total workload. Application level options are an important and practical tool for allowing the benefits of synchronous replication for high performance applications.

You should consider that the network bandwidth must be higher than the rate of generation of WAL data.

#### 24.2.8.4. Planning for High Availability

`synchronous_standby_names` specifies the number and names of synchronous standbys that transaction commits made when `synchronous_commit` is set to `on`, `remote_apply` or `remote_write` will wait for responses from. Such transaction commits may never be completed if any one of synchronous standbys should crash.

The best solution for high availability is to ensure you keep as many synchronous standbys as requested. This can be achieved by naming multiple potential synchronous standbys using `synchronous_standby_names`.

In a priority-based synchronous replication, the standbys whose names appear earlier in the list will be used as synchronous standbys. Standbys listed after these will take over the role of synchronous standby if one of current ones should fail.

In a quorum-based synchronous replication, all the standbys appearing in the list will be used as candidates for synchronous standbys. Even if one of them should fail, the other standbys will keep performing the role of candidates of synchronous standby.

When a standby first attaches to the primary, it will not yet be properly synchronized. This is described as `catchup` mode. Once the lag between standby and primary reaches zero for the first time we move to real-time `streaming` state. The catch-up duration may be long immediately after the standby has been created. If the standby is shut down, then the catch-up period will increase according to the length of time the standby has been down. The standby is only able to become a synchronous standby once it has reached `streaming` state. This state can be viewed using the `pg_stat_replication` view.

If primary restarts while commits are waiting for acknowledgment, those waiting transactions will be marked fully committed once the primary database recovers. There is no way to be certain that all standbys have received all outstanding WAL data at time of the crash of the primary. Some transactions may not show as committed on the standby, even though they show as committed on the primary. The guarantee we offer is that the application will not receive explicit acknowledgment of the successful commit of a transaction until the WAL data is known to be safely received by all the synchronous standbys.

If you really cannot keep as many synchronous standbys as requested then you should decrease the number of synchronous standbys that transaction commits must wait for responses from in `synchronous_standby_names` (or disable it) and reload the configuration file on the primary server.

If the primary is isolated from remaining standby servers you should fail over to the best candidate of those other remaining standby servers.

If you need to re-create a standby server while transactions are waiting, make sure that the commands `pg_start_backup()` and `pg_stop_backup()` are run in a session with `synchronous_commit = off`, otherwise those requests will wait forever for the standby to appear.

## 24.2.9. Continuous Archiving in Standby

When continuous WAL archiving is used in a standby, there are two different scenarios: the WAL archive can be shared between the primary and the standby, or the standby can have its own WAL archive. When the standby has its own WAL archive, set `archive_mode` to `always`, and the standby will call the archive command for every WAL segment it receives, whether it's by restoring from the archive or by streaming replication. The shared archive can be handled similarly, but the `archive_command` must test if the file being archived exists already, and if the existing file has identical contents. This requires more care in the `archive_command`, as it must be careful to not overwrite an existing file with different contents, but return success if the exactly same file is archived twice. And all that must be done free of race conditions, if two servers attempt to archive the same file at the same time.

If `archive_mode` is set to `on`, the archiver is not enabled during recovery or standby mode. If the standby server is promoted, it will start archiving after the promotion, but will not archive any WAL or timeline history files that it did not generate itself. To get a complete series of WAL files in the archive, you must ensure that all WAL is archived, before it reaches the standby. This is inherently true with file-based log shipping, as the standby can only restore files that are found in the archive, but not if streaming replication is enabled. When a server is not in recovery mode, there is no difference between `on` and `always` modes.

## 24.3. Failover

If the primary server fails then the standby server should begin failover procedures.

If the standby server fails then no failover need take place. If the standby server can be restarted, even some time later, then the recovery process can also be restarted immediately, taking advantage of restartable recovery. If the standby server cannot be restarted, then a full new standby server instance should be created.

If the primary server fails and the standby server becomes the new primary, and then the old primary restarts, you must have a mechanism for informing the old primary that it is no longer the primary. This is sometimes known as STONITH (Shoot The Other Node In The Head), which is necessary to avoid situations where both systems think they are the primary, which will lead to confusion and ultimately data loss.

Many failover systems use just two systems, the primary and the standby, connected by some kind of heartbeat mechanism to continually verify the connectivity between the two and the viability of the primary. It is also possible to use a third system (called a witness server) to prevent some cases of inappropriate failover, but the additional complexity might not be worthwhile unless it is set up with sufficient care and rigorous testing.

LightDB does not provide the system software required to identify a failure on the primary and notify the standby database server. Many such tools exist and are well integrated with the operating system facilities required for successful failover, such as IP address migration.

Once failover to the standby occurs, there is only a single server in operation. This is known as a degenerate state. The former standby is now the primary, but the former primary is down and might stay down. To return to normal operation, a standby server must be recreated, either on the former primary system when it comes up, or on a third, possibly new, system. The `lt_rewind` utility can be used to speed up this process on large clusters. Once complete, the primary and standby can be considered to have switched roles. Some people choose to use a third server to provide backup for the new primary until the new standby server is recreated, though clearly this complicates the system configuration and operational processes.

So, switching from primary to standby server can be fast but requires some time to re-prepare the failover cluster. Regular switching from primary to standby is useful, since it allows regular downtime on each system for maintenance. This also serves as a test of the failover mechanism to ensure that it will really work when you need it. Written administration procedures are advised.

To trigger failover of a log-shipping standby server, run `lt_ctl promote`, call `pg_promote()`, or create a trigger file with the file name and path specified by the `promote_trigger_file`. If you're planning to use `lt_ctl promote` or to call `pg_promote()` to fail over, `promote_trigger_file` is not required. If you're setting up the reporting servers that are only used to offload read-only queries from the primary, not for high availability purposes, you don't need to promote it.

LightDB's high availability provide virtual ip by default using keepalived, clients connect to virtual ip rather than physical ip. When failover occurs, the virtual ip should follow the correct primary. However, in special scenarios such as maintenance, you need to disable automatic failover and do not want the virtual ip to move. In this case, you can run `ltcluster service pause` (see `ltcluster`<sup>1</sup> for detail) to disable automatic failover. Then create a `$LTDATA/primary.maintain` file on the primary to prevent virtual ip automatic movement. After the maintenance is complete, call `ltcluster service unpause` to enable automatic failover and remove `$LTDATA/primary.maintain` file.

After `ltcluster` automatically promote standby to primary, the file `$LTDATA/standby.promotion` is created to indicate that the standby server is promoted. If multiple primary occur (for example, after the standby is promoted, the old primary returns to normal), the `ltclusterd` daemon will keep database instance with `$LTDATA/standby.promotion` file and stop primary instance without this file to avoid data inconsistency risks caused by multiple primary.

## 24.4. Alternative Method for Log Shipping

An alternative to the built-in standby mode described in the previous sections is to use a `restore_command` that polls the archive location. This was the only option available in versions 8.4 and below. See the `lt_standby` module for a reference implementation of this.

Note that in this mode, the server will apply WAL one file at a time, so if you use the standby server for queries (see Hot Standby), there is a delay between an action in the master and when the action becomes visible in the standby, corresponding to the time it takes to fill up the WAL file. `archive_timeout` can be used to make that delay shorter. Also note that you can't combine streaming replication with this method.

The operations that occur on both primary and standby servers are normal continuous archiving and recovery tasks. The only point of contact between the two database servers is the archive of WAL files that both share: primary writing to the archive, standby reading from the archive. Care must be taken to ensure that WAL archives from separate primary servers do not become mixed together or confused. The archive need not be large if it is only required for standby operation.

The magic that makes the two loosely coupled servers work together is simply a `restore_command` used on the standby that, when asked for the next WAL file, waits for it to become available from the primary. Normal recovery processing would request a file from the WAL archive, reporting failure if the file was unavailable. For standby processing it is normal for the next WAL file to be unavailable, so the standby must wait for it to appear. For files ending in `.history` there is no need to wait, and a non-zero return code must be returned. A waiting `restore_command` can be written as a custom script that loops after polling for the existence of the next WAL file. There must also be some way to trigger failover, which should interrupt the `restore_command`, break the loop and return a file-not-found error to the standby server. This ends recovery and the standby will then come up as a normal server.

Pseudocode for a suitable `restore_command` is:

---

<sup>1</sup> <http://www.light-pg.com/docs/ltcluster/current/index.html>

```
triggered = false;
while (!NextWALFileReady() && !triggered)
{
    sleep(100000L);          /* wait for ~0.1 sec */
    if (CheckForExternalTrigger())
        triggered = true;
}
if (!triggered)
    CopyWALFileForRecovery();
```

A working example of a waiting `restore_command` is provided in the `lt_standby` module. It should be used as a reference on how to correctly implement the logic described above. It can also be extended as needed to support specific configurations and environments.

The method for triggering failover is an important part of planning and design. One potential option is the `restore_command` command. It is executed once for each WAL file, but the process running the `restore_command` is created and dies for each file, so there is no daemon or server process, and signals or a signal handler cannot be used. Therefore, the `restore_command` is not suitable to trigger failover. It is possible to use a simple timeout facility, especially if used in conjunction with a known `archive_timeout` setting on the primary. However, this is somewhat error prone since a network problem or busy primary server might be sufficient to initiate failover. A notification mechanism such as the explicit creation of a trigger file is ideal, if this can be arranged.

## 24.4.1. Implementation

The short procedure for configuring a standby server using this alternative method is as follows. For full details of each step, refer to previous sections as noted.

1. Set up primary and standby systems as nearly identical as possible, including two identical copies of LightDB at the same release level.
2. Set up continuous archiving from the primary to a WAL archive directory on the standby server. Ensure that `archive_mode`, `archive_command` and `archive_timeout` are set appropriately on the primary (see Section 23.3.1).
3. Make a base backup of the primary server (see Section 23.3.2), and load this data onto the standby.
4. Begin recovery on the standby server from the local WAL archive, using `restore_command` that waits as described previously (see Section 23.3.4).

Recovery treats the WAL archive as read-only, so once a WAL file has been copied to the standby system it can be copied to tape at the same time as it is being read by the standby database server. Thus, running a standby server for high availability can be performed at the same time as files are stored for longer term disaster recovery purposes.

For testing purposes, it is possible to run both primary and standby servers on the same system. This does not provide any worthwhile improvement in server robustness, nor would it be described as HA.

## 24.4.2. Record-Based Log Shipping

It is also possible to implement record-based log shipping using this alternative method, though this requires custom development, and changes will still only become visible to hot standby queries after a full WAL file has been shipped.

An external program can call the `pg_walfile_name_offset()` function (see Section 9.27) to find out the file name and the exact byte offset within it of the current end of WAL. It can then access the WAL file directly and copy the data from the last known end of WAL through the current end over to the standby servers. With this approach, the window for data loss is the polling cycle time of the

copying program, which can be very small, and there is no wasted bandwidth from forcing partially-used segment files to be archived. Note that the standby servers' `restore_command` scripts can only deal with whole WAL files, so the incrementally copied data is not ordinarily made available to the standby servers. It is of use only when the primary dies — then the last partial WAL file is fed to the standby before allowing it to come up. The correct implementation of this process requires cooperation of the `restore_command` script with the data copying program.

Starting with LightDB version 9.0, you can use streaming replication (see Section 24.2.5) to achieve the same benefits with less effort.

## 24.5. Hot Standby

Hot Standby is the term used to describe the ability to connect to the server and run read-only queries while the server is in archive recovery or standby mode. This is useful both for replication purposes and for restoring a backup to a desired state with great precision. The term Hot Standby also refers to the ability of the server to move from recovery through to normal operation while users continue running queries and/or keep their connections open.

Running queries in hot standby mode is similar to normal query operation, though there are several usage and administrative differences explained below.

### 24.5.1. User's Overview

When the `hot_standby` parameter is set to `true` on a standby server, it will begin accepting connections once the recovery has brought the system to a consistent state. All such connections are strictly read-only; not even temporary tables may be written.

The data on the standby takes some time to arrive from the primary server so there will be a measurable delay between primary and standby. Running the same query nearly simultaneously on both primary and standby might therefore return differing results. We say that data on the standby is *eventually consistent* with the primary. Once the commit record for a transaction is replayed on the standby, the changes made by that transaction will be visible to any new snapshots taken on the standby. Snapshots may be taken at the start of each query or at the start of each transaction, depending on the current transaction isolation level. For more details, see Section 13.2.

Transactions started during hot standby may issue the following commands:

- Query access: `SELECT`, `COPY TO`
- Cursor commands: `DECLARE`, `FETCH`, `CLOSE`
- Settings: `SHOW`, `SET`, `RESET`
- Transaction management commands:
  - `BEGIN`, `END`, `ABORT`, `START TRANSACTION`
  - `SAVEPOINT`, `RELEASE`, `ROLLBACK TO SAVEPOINT`
  - `EXCEPTION` blocks and other internal subtransactions
- `LOCK TABLE`, though only when explicitly in one of these modes: `ACCESS SHARE`, `ROW SHARE` or `ROW EXCLUSIVE`.
- Plans and resources: `PREPARE`, `EXECUTE`, `DEALLOCATE`, `DISCARD`
- Plugins and extensions: `LOAD`
- `UNLISTEN`

Transactions started during hot standby will never be assigned a transaction ID and cannot write to the system write-ahead log. Therefore, the following actions will produce error messages:

- Data Manipulation Language (DML): `INSERT`, `UPDATE`, `DELETE`, `COPY FROM`, `TRUNCATE`. Note that there are no allowed actions that result in a trigger being executed during recovery. This restriction applies even to temporary tables, because table rows cannot be read or written without assigning a transaction ID, which is currently not possible in a Hot Standby environment.
- Data Definition Language (DDL): `CREATE`, `DROP`, `ALTER`, `COMMENT`. This restriction applies even to temporary tables, because carrying out these operations would require updating the system catalog tables.
- `SELECT ... FOR SHARE | UPDATE`, because row locks cannot be taken without updating the underlying data files.
- Rules on `SELECT` statements that generate DML commands.
- `LOCK` that explicitly requests a mode higher than `ROW EXCLUSIVE MODE`.
- `LOCK` in short default form, since it requests `ACCESS EXCLUSIVE MODE`.
- Transaction management commands that explicitly set non-read-only state:
  - `BEGIN READ WRITE`, `START TRANSACTION READ WRITE`
  - `SET TRANSACTION READ WRITE`, `SET SESSION CHARACTERISTICS AS TRANSACTION READ WRITE`
  - `SET transaction_read_only = off`
- Two-phase commit commands: `PREPARE TRANSACTION`, `COMMIT PREPARED`, `ROLLBACK PREPARED` because even read-only transactions need to write WAL in the prepare phase (the first phase of two phase commit).
- Sequence updates: `nextval()`, `setval()`
- `LISTEN`, `NOTIFY`

In normal operation, “read-only” transactions are allowed to use `LISTEN` and `NOTIFY`, so Hot Standby sessions operate under slightly tighter restrictions than ordinary read-only sessions. It is possible that some of these restrictions might be loosened in a future release.

During hot standby, the parameter `transaction_read_only` is always true and may not be changed. But as long as no attempt is made to modify the database, connections during hot standby will act much like any other database connection. If failover or switchover occurs, the database will switch to normal processing mode. Sessions will remain connected while the server changes mode. Once hot standby finishes, it will be possible to initiate read-write transactions (even from a session begun during hot standby).

Users will be able to tell whether their session is read-only by issuing `SHOW transaction_read_only`. In addition, a set of functions (Table 9.87) allow users to access information about the standby server. These allow you to write programs that are aware of the current state of the database. These can be used to monitor the progress of recovery, or to allow you to write complex programs that restore the database to particular states.

## 24.5.2. Handling Query Conflicts

The primary and standby servers are in many ways loosely connected. Actions on the primary will have an effect on the standby. As a result, there is potential for negative interactions or conflicts between them. The easiest conflict to understand is performance: if a huge data load is taking place on the



primary then this will generate a similar stream of WAL records on the standby, so standby queries may contend for system resources, such as I/O.

There are also additional types of conflict that can occur with Hot Standby. These conflicts are *hard conflicts* in the sense that queries might need to be canceled and, in some cases, sessions disconnected to resolve them. The user is provided with several ways to handle these conflicts. Conflict cases include:

- Access Exclusive locks taken on the primary server, including both explicit LOCK commands and various DDL actions, conflict with table accesses in standby queries.
- Dropping a tablespace on the primary conflicts with standby queries using that tablespace for temporary work files.
- Dropping a database on the primary conflicts with sessions connected to that database on the standby.
- Application of a vacuum cleanup record from WAL conflicts with standby transactions whose snapshots can still “see” any of the rows to be removed.
- Application of a vacuum cleanup record from WAL conflicts with queries accessing the target page on the standby, whether or not the data to be removed is visible.

On the primary server, these cases simply result in waiting; and the user might choose to cancel either of the conflicting actions. However, on the standby there is no choice: the WAL-logged action already occurred on the primary so the standby must not fail to apply it. Furthermore, allowing WAL application to wait indefinitely may be very undesirable, because the standby's state will become increasingly far behind the primary's. Therefore, a mechanism is provided to forcibly cancel standby queries that conflict with to-be-applied WAL records.

An example of the problem situation is an administrator on the primary server running DROP TABLE on a table that is currently being queried on the standby server. Clearly the standby query cannot continue if the DROP TABLE is applied on the standby. If this situation occurred on the primary, the DROP TABLE would wait until the other query had finished. But when DROP TABLE is run on the primary, the primary doesn't have information about what queries are running on the standby, so it will not wait for any such standby queries. The WAL change records come through to the standby while the standby query is still running, causing a conflict. The standby server must either delay application of the WAL records (and everything after them, too) or else cancel the conflicting query so that the DROP TABLE can be applied.

When a conflicting query is short, it's typically desirable to allow it to complete by delaying WAL application for a little bit; but a long delay in WAL application is usually not desirable. So the cancel mechanism has parameters, max\_standby\_archive\_delay and max\_standby\_streaming\_delay, that define the maximum allowed delay in WAL application. Conflicting queries will be canceled once it has taken longer than the relevant delay setting to apply any newly-received WAL data. There are two parameters so that different delay values can be specified for the case of reading WAL data from an archive (i.e., initial recovery from a base backup or “catching up” a standby server that has fallen far behind) versus reading WAL data via streaming replication.

In a standby server that exists primarily for high availability, it's best to set the delay parameters relatively short, so that the server cannot fall far behind the primary due to delays caused by standby queries. However, if the standby server is meant for executing long-running queries, then a high or even infinite delay value may be preferable. Keep in mind however that a long-running query could cause other sessions on the standby server to not see recent changes on the primary, if it delays application of WAL records.

Once the delay specified by max\_standby\_archive\_delay or max\_standby\_streaming\_delay has been exceeded, conflicting queries will be canceled. This usually results just in a cancellation error, although in the case of replaying a DROP DATABASE the entire conflicting session will be terminated. Also, if the conflict is over a lock held by an idle transaction, the conflicting session is terminated (this behavior might change in the future).

Canceled queries may be retried immediately (after beginning a new transaction, of course). Since query cancellation depends on the nature of the WAL records being replayed, a query that was canceled may well succeed if it is executed again.

Keep in mind that the delay parameters are compared to the elapsed time since the WAL data was received by the standby server. Thus, the grace period allowed to any one query on the standby is never more than the delay parameter, and could be considerably less if the standby has already fallen behind as a result of waiting for previous queries to complete, or as a result of being unable to keep up with a heavy update load.

The most common reason for conflict between standby queries and WAL replay is “early cleanup”. Normally, LightDB allows cleanup of old row versions when there are no transactions that need to see them to ensure correct visibility of data according to MVCC rules. However, this rule can only be applied for transactions executing on the master. So it is possible that cleanup on the master will remove row versions that are still visible to a transaction on the standby.

Experienced users should note that both row version cleanup and row version freezing will potentially conflict with standby queries. Running a manual `VACUUM FREEZE` is likely to cause conflicts even on tables with no updated or deleted rows.

Users should be clear that tables that are regularly and heavily updated on the primary server will quickly cause cancellation of longer running queries on the standby. In such cases the setting of a finite value for `max_standby_archive_delay` or `max_standby_streaming_delay` can be considered similar to setting `statement_timeout`.

Remedial possibilities exist if the number of standby-query cancellations is found to be unacceptable. The first option is to set the parameter `hot_standby_feedback`, which prevents `VACUUM` from removing recently-dead rows and so cleanup conflicts do not occur. If you do this, you should note that this will delay cleanup of dead rows on the primary, which may result in undesirable table bloat. However, the cleanup situation will be no worse than if the standby queries were running directly on the primary server, and you are still getting the benefit of off-loading execution onto the standby. If standby servers connect and disconnect frequently, you might want to make adjustments to handle the period when `hot_standby_feedback` feedback is not being provided. For example, consider increasing `max_standby_archive_delay` so that queries are not rapidly canceled by conflicts in WAL archive files during disconnected periods. You should also consider increasing `max_standby_streaming_delay` to avoid rapid cancellations by newly-arrived streaming WAL entries after reconnection.

Another option is to increase `vacuum_defer_cleanup_age` on the primary server, so that dead rows will not be cleaned up as quickly as they normally would be. This will allow more time for queries to execute before they are canceled on the standby, without having to set a high `max_standby_streaming_delay`. However it is difficult to guarantee any specific execution-time window with this approach, since `vacuum_defer_cleanup_age` is measured in transactions executed on the primary server.

The number of query cancels and the reason for them can be viewed using the `pg_stat_database_conflicts` system view on the standby server. The `pg_stat_database` system view also contains summary information.

### 24.5.3. Administrator's Overview

If `hot_standby` is on in `lightdb.conf` (the default value) and there is a `standby.signal` file present, the server will run in Hot Standby mode. However, it may take some time for Hot Standby connections to be allowed, because the server will not accept connections until it has completed sufficient recovery to provide a consistent state against which queries can run. During this period, clients that attempt to connect will be refused with an error message. To confirm the server has come up, either loop trying to connect from the application, or look for these messages in the server logs:

LOG: entering standby mode

... then some time later ...

LOG: consistent recovery state reached

LOG: database system is ready to accept read only connections

Consistency information is recorded once per checkpoint on the primary. It is not possible to enable hot standby when reading WAL written during a period when `wal_level` was not set to `replica` or `logical` on the primary. Reaching a consistent state can also be delayed in the presence of both of these conditions:

- A write transaction has more than 64 subtransactions
- Very long-lived write transactions

If you are running file-based log shipping ("warm standby"), you might need to wait until the next WAL file arrives, which could be as long as the `archive_timeout` setting on the primary.

The setting of some parameters on the standby will need reconfiguration if they have been changed on the primary. For these parameters, the value on the standby must be equal to or greater than the value on the primary. Therefore, if you want to increase these values, you should do so on all standby servers first, before applying the changes to the primary server. Conversely, if you want to decrease these values, you should do so on the primary server first, before applying the changes to all standby servers. If these parameters are not set high enough then the standby will refuse to start. Higher values can then be supplied and the server restarted to begin recovery again. These parameters are:

- `max_connections`
- `max_prepared_transactions`
- `max_locks_per_transaction`
- `max_wal_senders`
- `max_worker_processes`

It is important that the administrator select appropriate settings for `max_standby_archive_delay` and `max_standby_streaming_delay`. The best choices vary depending on business priorities. For example if the server is primarily tasked as a High Availability server, then you will want low delay settings, perhaps even zero, though that is a very aggressive setting. If the standby server is tasked as an additional server for decision support queries then it might be acceptable to set the maximum delay values to many hours, or even -1 which means wait forever for queries to complete.

Transaction status "hint bits" written on the primary are not WAL-logged, so data on the standby will likely re-write the hints again on the standby. Thus, the standby server will still perform disk writes even though all users are read-only; no changes occur to the data values themselves. Users will still write large sort temporary files and re-generate relcache info files, so no part of the database is truly read-only during hot standby mode. Note also that writes to remote databases using `dblink` module, and other operations outside the database using PL functions will still be possible, even though the transaction is read-only locally.

The following types of administration commands are not accepted during recovery mode:

- Data Definition Language (DDL): e.g., `CREATE INDEX`
- Privilege and Ownership: `GRANT`, `REVOKE`, `REASSIGN`
- Maintenance commands: `ANALYZE`, `VACUUM`, `CLUSTER`, `REINDEX`

Again, note that some of these commands are actually allowed during "read only" mode transactions on the primary.

As a result, you cannot create additional indexes that exist solely on the standby, nor statistics that exist solely on the standby. If these administration commands are needed, they should be executed on the primary, and eventually those changes will propagate to the standby.

`pg_cancel_backend()` and `pg_terminate_backend()` will work on user backends, but not the Startup process, which performs recovery. `pg_stat_activity` does not show recovering transactions as active. As a result, `pg_prepared_xacts` is always empty during recovery. If you wish to resolve in-doubt prepared transactions, view `pg_prepared_xacts` on the primary and issue commands to resolve transactions there or resolve them after the end of recovery.

`pg_locks` will show locks held by backends, as normal. `pg_locks` also shows a virtual transaction managed by the Startup process that owns all `AccessExclusiveLocks` held by transactions being replayed by recovery. Note that the Startup process does not acquire locks to make database changes, and thus locks other than `AccessExclusiveLocks` do not show in `pg_locks` for the Startup process; they are just presumed to exist.

The Nagios plugin `check_pgsql` will work, because the simple information it checks for exists. The `check_postgres` monitoring script will also work, though some reported values could give different or confusing results. For example, last vacuum time will not be maintained, since no vacuum occurs on the standby. Vacuums running on the primary do still send their changes to the standby.

WAL file control commands will not work during recovery, e.g., `pg_start_backup`, `pg_switch_wal` etc.

Dynamically loadable modules work, including `lt_stat_statements`.

Advisory locks work normally in recovery, including deadlock detection. Note that advisory locks are never WAL logged, so it is impossible for an advisory lock on either the primary or the standby to conflict with WAL replay. Nor is it possible to acquire an advisory lock on the primary and have it initiate a similar advisory lock on the standby. Advisory locks relate only to the server on which they are acquired.

Trigger-based replication systems such as Slony, Londiste and Bucardo won't run on the standby at all, though they will run happily on the primary server as long as the changes are not sent to standby servers to be applied. WAL replay is not trigger-based so you cannot relay from the standby to any system that requires additional database writes or relies on the use of triggers.

New OIDs cannot be assigned, though some UUID generators may still work as long as they do not rely on writing new status to the database.

Currently, temporary table creation is not allowed during read only transactions, so in some cases existing scripts will not run correctly. This restriction might be relaxed in a later release. This is both a SQL standard compliance issue and a technical issue.

`DROP TABLESPACE` can only succeed if the tablespace is empty. Some standby users may be actively using the tablespace via their `temp_tablespaces` parameter. If there are temporary files in the tablespace, all active queries are canceled to ensure that temporary files are removed, so the tablespace can be removed and WAL replay can continue.

Running `DROP DATABASE` or `ALTER DATABASE ... SET TABLESPACE` on the primary will generate a WAL entry that will cause all users connected to that database on the standby to be forcibly disconnected. This action occurs immediately, whatever the setting of `max_standby_streaming_delay`. Note that `ALTER DATABASE ... RENAME` does not disconnect users, which in most cases will go unnoticed, though might in some cases cause a program confusion if it depends in some way upon database name.

In normal (non-recovery) mode, if you issue `DROP USER` or `DROP ROLE` for a role with login capability while that user is still connected then nothing happens to the connected user — they remain connected. The user cannot reconnect however. This behavior applies in recovery also, so a `DROP USER` on the primary does not disconnect that user on the standby.

The statistics collector is active during recovery. All scans, reads, blocks, index usage, etc., will be recorded normally on the standby. Replayed actions will not duplicate their effects on primary, so replaying an insert will not increment the Inserts column of `pg_stat_user_tables`. The stats file is deleted at the start of recovery, so stats from primary and standby will differ; this is considered a feature, not a bug.

Autovacuum is not active during recovery. It will start normally at the end of recovery.

The checkpoint process and the background writer process are active during recovery. The checkpoint process will perform restartpoints (similar to checkpoints on the primary) and the background writer process will perform normal block cleaning activities. This can include updates of the hint bit information stored on the standby server. The `CHECKPOINT` command is accepted during recovery, though it performs a restartpoint rather than a new checkpoint.

## 24.5.4. Hot Standby Parameter Reference

Various parameters have been mentioned above in Section 24.5.2 and Section 24.5.3.

On the primary, parameters `wal_level` and `vacuum_defer_cleanup_age` can be used. `max_standby_archive_delay` and `max_standby_streaming_delay` have no effect if set on the primary.

On the standby, parameters `hot_standby`, `max_standby_archive_delay` and `max_standby_streaming_delay` can be used. `vacuum_defer_cleanup_age` has no effect as long as the server remains in standby mode, though it will become relevant if the standby becomes primary.

## 24.5.5. Caveats

There are several limitations of Hot Standby. These can and probably will be fixed in future releases:

- Full knowledge of running transactions is required before snapshots can be taken. Transactions that use large numbers of subtransactions (currently greater than 64) will delay the start of read only connections until the completion of the longest running write transaction. If this situation occurs, explanatory messages will be sent to the server log.
- Valid starting points for standby queries are generated at each checkpoint on the master. If the standby is shut down while the master is in a shutdown state, it might not be possible to re-enter Hot Standby until the primary is started up, so that it generates further starting points in the WAL logs. This situation isn't a problem in the most common situations where it might happen. Generally, if the primary is shut down and not available anymore, that's likely due to a serious failure that requires the standby being converted to operate as the new primary anyway. And in situations where the primary is being intentionally taken down, coordinating to make sure the standby becomes the new primary smoothly is also standard procedure.
- At the end of recovery, `AccessExclusiveLocks` held by prepared transactions will require twice the normal number of lock table entries. If you plan on running either a large number of concurrent prepared transactions that normally take `AccessExclusiveLocks`, or you plan on having one large transaction that takes many `AccessExclusiveLocks`, you are advised to select a larger value of `max_locks_per_transaction`, perhaps as much as twice the value of the parameter on the primary server. You need not consider this at all if your setting of `max_prepared_transactions` is 0.
- The Serializable transaction isolation level is not yet available in hot standby. (See Section 13.2.3 and Section 13.4.1 for details.) An attempt to set a transaction to the serializable isolation level in hot standby mode will generate an error.

---

# Chapter 25. Monitoring Database Activity

A database administrator frequently wonders, “What is the system doing right now?” This chapter discusses how to find that out.

Several tools are available for monitoring database activity and analyzing performance. Most of this chapter is devoted to describing LightDB's statistics collector, but one should not neglect regular Unix monitoring programs such as `ps`, `top`, `iostat`, and `vmstat`. Also, once one has identified a poorly-performing query, further investigation might be needed using LightDB's `EXPLAIN` command. Section 14.1 discusses `EXPLAIN` and other methods for understanding the behavior of an individual query.

## 25.1. Standard Unix Tools

On most Unix platforms, LightDB modifies its command title as reported by `ps`, so that individual server processes can readily be identified. A sample display is

```
$ ps auxww | grep ^lightdb
lightdb 15551 0.0 0.1 57536 7132 pts/0 S 18:02 0:00
lightdb -i
lightdb 15554 0.0 0.0 57536 1184 ? Ss 18:02 0:00
lightdb: background writer
lightdb 15555 0.0 0.0 57536 916 ? Ss 18:02 0:00
lightdb: checkpointer
lightdb 15556 0.0 0.0 57536 916 ? Ss 18:02 0:00
lightdb: walwriter
lightdb 15557 0.0 0.0 58504 2244 ? Ss 18:02 0:00
lightdb: autovacuum launcher
lightdb 15558 0.0 0.0 17512 1068 ? Ss 18:02 0:00
lightdb: stats collector
lightdb 15582 0.0 0.0 58772 3080 ? Ss 18:04 0:00
lightdb: joe runbug 127.0.0.1 idle
lightdb 15606 0.0 0.0 58772 3052 ? Ss 18:07 0:00
lightdb: tgl regression [local] SELECT waiting
lightdb 15610 0.0 0.0 58772 3056 ? Ss 18:07 0:00
lightdb: tgl regression [local] idle in transaction
```

(The appropriate invocation of `ps` varies across different platforms, as do the details of what is shown. This example is from a recent Linux system.) The first process listed here is the master server process. The command arguments shown for it are the same ones used when it was launched. The next five processes are background worker processes automatically launched by the master process. (The “stats collector” process will not be present if you have set the system not to start the statistics collector; likewise the “autovacuum launcher” process can be disabled.) Each of the remaining processes is a server process handling one client connection. Each such process sets its command line display in the form

```
lightdb: user database host activity
```

The user, database, and (client) host items remain the same for the life of the client connection, but the activity indicator changes. The activity can be `idle` (i.e., waiting for a client command), `idle in transaction` (waiting for client inside a `BEGIN` block), or a command type name such as `SELECT`. Also, `waiting` is appended if the server process is presently waiting on a lock held by

another session. In the above example we can infer that process 15606 is waiting for process 15610 to complete its transaction and thereby release some lock. (Process 15610 must be the blocker, because there is no other active session. In more complicated cases it would be necessary to look into the `pg_locks` system view to determine who is blocking whom.)

If `cluster_name` has been configured the cluster name will also be shown in `ps` output:

```
$ ltsql -c 'SHOW cluster_name'
 cluster_name
-----
 server1
(1 row)

$ ps aux|grep server1
lightdb  27093  0.0  0.0  30096  2752 ?          Ss   11:34   0:00
lightdb: server1: background writer
...
```

If you have turned off `update_process_title` then the activity indicator is not updated; the process title is set only once when a new process is launched. On some platforms this saves a measurable amount of per-command overhead; on others it's insignificant.

### Tip

Solaris requires special handling. You must use `/usr/ucb/ps`, rather than `/bin/ps`. You also must use two `w` flags, not just one. In addition, your original invocation of the `lightdb` command must have a shorter `ps` status display than that provided by each server process. If you fail to do all three things, the `ps` output for each server process will be the original `lightdb` command line.

## 25.2. The Statistics Collector

LightDB's *statistics collector* is a subsystem that supports collection and reporting of information about server activity. Presently, the collector can count accesses to tables and indexes in both disk-block and individual-row terms. It also tracks the total number of rows in each table, and information about vacuum and analyze actions for each table. It can also count calls to user-defined functions and the total time spent in each one.

LightDB also supports reporting dynamic information about exactly what is going on in the system right now, such as the exact command currently being executed by other server processes, and which other connections exist in the system. This facility is independent of the collector process.

### 25.2.1. Statistics Collection Configuration

Since collection of statistics adds some overhead to query execution, the system can be configured to collect or not collect information. This is controlled by configuration parameters that are normally set in `lightdb.conf`. (See Chapter 17 for details about setting configuration parameters.)

The parameter `track_activities` enables monitoring of the current command being executed by any server process.

The parameter `track_counts` controls whether statistics are collected about table and index accesses.

The parameter `track_functions` enables tracking of usage of user-defined functions.

The parameter `track_io_timing` enables monitoring of block read and write times.

Normally these parameters are set in `lightdb.conf` so that they apply to all server processes, but it is possible to turn them on or off in individual sessions using the `SET` command. (To prevent ordinary users from hiding their activity from the administrator, only superusers are allowed to change these parameters with `SET`.)

The statistics collector transmits the collected information to other LightDB processes through temporary files. These files are stored in the directory named by the `stats_temp_directory` parameter, `lt_stat_tmp` by default. For better performance, `stats_temp_directory` can be pointed at a RAM-based file system, decreasing physical I/O requirements. When the server shuts down cleanly, a permanent copy of the statistics data is stored in the `lt_stat` subdirectory, so that statistics can be retained across server restarts. When recovery is performed at server start (e.g., after immediate shutdown, server crash, and point-in-time recovery), all statistics counters are reset.

## 25.2.2. Viewing Statistics

Several predefined views, listed in Table 25.1, are available to show the current state of the system. There are also several other views, listed in Table 25.2, available to show the results of statistics collection. Alternatively, one can build custom views using the underlying statistics functions, as discussed in Section 25.2.20.

When using the statistics to monitor collected data, it is important to realize that the information does not update instantaneously. Each individual server process transmits new statistical counts to the collector just before going idle; so a query or transaction still in progress does not affect the displayed totals. Also, the collector itself emits a new report at most once per `PGSTAT_STAT_INTERVAL` milliseconds (500 ms unless altered while building the server). So the displayed information lags behind actual activity. However, current-query information collected by `track_activities` is always up-to-date.

Another important point is that when a server process is asked to display any of these statistics, it first fetches the most recent report emitted by the collector process and then continues to use this snapshot for all statistical views and functions until the end of its current transaction. So the statistics will show static information as long as you continue the current transaction. Similarly, information about the current queries of all sessions is collected when any such information is first requested within a transaction, and the same information will be displayed throughout the transaction. This is a feature, not a bug, because it allows you to perform several queries on the statistics and correlate the results without worrying that the numbers are changing underneath you. But if you want to see new results with each query, be sure to do the queries outside any transaction block. Alternatively, you can invoke `pg_stat_clear_snapshot()`, which will discard the current transaction's statistics snapshot (if any). The next use of statistical information will cause a new snapshot to be fetched.

A transaction can also see its own statistics (as yet untransmitted to the collector) in the views `pg_stat_xact_all_tables`, `pg_stat_xact_sys_tables`, `pg_stat_xact_user_tables`, and `pg_stat_xact_user_functions`. These numbers do not act as stated above; instead they update continuously throughout the transaction.

Some of the information in the dynamic statistics views shown in Table 25.1 is security restricted. Ordinary users can only see all the information about their own sessions (sessions belonging to a role that they are a member of). In rows about other sessions, many columns will be null. Note, however, that the existence of a session and its general properties such as its sessions user and database are visible to all users. Superusers and members of the built-in role `pg_read_all_stats` (see also Section 19.5) can see all the information about all sessions.

**Table 25.1. Dynamic Statistics Views**

View Name	Description
<code>pg_stat_activity</code>	One row per server process, showing information related to the current activity of that



View Name	Description
	process, such as state and current query. See <code>pg_stat_activity</code> for details.
<code>pg_stat_replication</code>	One row per WAL sender process, showing statistics about replication to that sender's connected standby server. See <code>pg_stat_replication</code> for details.
<code>pg_stat_wal_receiver</code>	Only one row, showing statistics about the WAL receiver from that receiver's connected server. See <code>pg_stat_wal_receiver</code> for details.
<code>pg_stat_subscription</code>	At least one row per subscription, showing information about the subscription workers. See <code>pg_stat_subscription</code> for details.
<code>pg_stat_ssl</code>	One row per connection (regular and replication), showing information about SSL used on this connection. See <code>pg_stat_ssl</code> for details.
<code>pg_stat_gssapi</code>	One row per connection (regular and replication), showing information about GSSAPI authentication and encryption used on this connection. See <code>pg_stat_gssapi</code> for details.
<code>pg_stat_progress_analyze</code>	One row for each backend (including autovacuum worker processes) running ANALYZE, showing current progress. See Section 25.4.1.
<code>pg_stat_progress_create_index</code>	One row for each backend running CREATE INDEX or REINDEX, showing current progress. See Section 25.4.2.
<code>pg_stat_progress_vacuum</code>	One row for each backend (including autovacuum worker processes) running VACUUM, showing current progress. See Section 25.4.3.
<code>pg_stat_progress_cluster</code>	One row for each backend running CLUSTER or VACUUM FULL, showing current progress. See Section 25.4.4.
<code>pg_stat_progress_basebackup</code>	One row for each WAL sender process streaming a base backup, showing current progress. See Section 25.4.5.

**Table 25.2. Collected Statistics Views**

View Name	Description
<code>pg_stat_archiver</code>	One row only, showing statistics about the WAL archiver process's activity. See <code>pg_stat_archiver</code> for details.
<code>pg_stat_bgwriter</code>	One row only, showing statistics about the background writer process's activity. See <code>pg_stat_bgwriter</code> for details.
<code>pg_stat_database</code>	One row per database, showing database-wide statistics. See <code>pg_stat_database</code> for details.

View Name	Description
<code>pg_stat_database_conflicts</code>	One row per database, showing database-wide statistics about query cancels due to conflict with recovery on standby servers. See <code>pg_stat_database_conflicts</code> for details.
<code>pg_stat_all_tables</code>	One row for each table in the current database, showing statistics about accesses to that specific table. See <code>pg_stat_all_tables</code> for details.
<code>pg_stat_sys_tables</code>	Same as <code>pg_stat_all_tables</code> , except that only system tables are shown.
<code>pg_stat_user_tables</code>	Same as <code>pg_stat_all_tables</code> , except that only user tables are shown.
<code>pg_stat_xact_all_tables</code>	Similar to <code>pg_stat_all_tables</code> , but counts actions taken so far within the current transaction (which are <i>not</i> yet included in <code>pg_stat_all_tables</code> and related views). The columns for numbers of live and dead rows and vacuum and analyze actions are not present in this view.
<code>pg_stat_xact_sys_tables</code>	Same as <code>pg_stat_xact_all_tables</code> , except that only system tables are shown.
<code>pg_stat_xact_user_tables</code>	Same as <code>pg_stat_xact_all_tables</code> , except that only user tables are shown.
<code>pg_stat_all_indexes</code>	One row for each index in the current database, showing statistics about accesses to that specific index. See <code>pg_stat_all_indexes</code> for details.
<code>pg_stat_sys_indexes</code>	Same as <code>pg_stat_all_indexes</code> , except that only indexes on system tables are shown.
<code>pg_stat_user_indexes</code>	Same as <code>pg_stat_all_indexes</code> , except that only indexes on user tables are shown.
<code>pg_statio_all_tables</code>	One row for each table in the current database, showing statistics about I/O on that specific table. See <code>pg_statio_all_tables</code> for details.
<code>pg_statio_sys_tables</code>	Same as <code>pg_statio_all_tables</code> , except that only system tables are shown.
<code>pg_statio_user_tables</code>	Same as <code>pg_statio_all_tables</code> , except that only user tables are shown.
<code>pg_statio_all_indexes</code>	One row for each index in the current database, showing statistics about I/O on that specific index. See <code>pg_statio_all_indexes</code> for details.
<code>pg_statio_sys_indexes</code>	Same as <code>pg_statio_all_indexes</code> , except that only indexes on system tables are shown.
<code>pg_statio_user_indexes</code>	Same as <code>pg_statio_all_indexes</code> , except that only indexes on user tables are shown.
<code>pg_statio_all_sequences</code>	One row for each sequence in the current database, showing statistics

View Name	Description
	about I/O on that specific sequence. See <code>pg_statio_all_sequences</code> for details.
<code>pg_statio_sys_sequences</code>	Same as <code>pg_statio_all_sequences</code> , except that only system sequences are shown. (Presently, no system sequences are defined, so this view is always empty.)
<code>pg_statio_user_sequences</code>	Same as <code>pg_statio_all_sequences</code> , except that only user sequences are shown.
<code>pg_stat_user_functions</code>	One row for each tracked function, showing statistics about executions of that function. See <code>pg_stat_user_functions</code> for details.
<code>pg_stat_xact_user_functions</code>	Similar to <code>pg_stat_user_functions</code> , but counts only calls during the current transaction (which are <i>not</i> yet included in <code>pg_stat_user_functions</code> ).
<code>pg_stat_slru</code>	One row per SLRU, showing statistics of operations. See <code>pg_stat_slru</code> for details.

The per-index statistics are particularly useful to determine which indexes are being used and how effective they are.

The `pg_statio_` views are primarily useful to determine the effectiveness of the buffer cache. When the number of actual disk reads is much smaller than the number of buffer hits, then the cache is satisfying most read requests without invoking a kernel call. However, these statistics do not give the entire story: due to the way in which LightDB handles disk I/O, data that is not in the LightDB buffer cache might still reside in the kernel's I/O cache, and might therefore still be fetched without requiring a physical read. Users interested in obtaining more detailed information on LightDB I/O behavior are advised to use the LightDB statistics collector in combination with operating system utilities that allow insight into the kernel's handling of I/O.

### 25.2.3. `pg_stat_activity`

The `pg_stat_activity` view will have one row per server process, showing information related to the current activity of that process.

**Table 25.3. `pg_stat_activity` View**

Column	Type	Description
<code>datid</code>	oid	OID of the database this backend is connected to
<code>datname</code>	name	Name of the database this backend is connected to
<code>pid</code>	integer	Process ID of this backend
<code>leader_pid</code>	integer	Process ID of the parallel group leader, if this process is a parallel query worker. NULL if this process is a parallel group leader or does not participate in parallel query.
<code>usesysid</code>	oid	OID of the user logged into this backend
<code>username</code>	name	Name of the user logged into this backend
<code>application_name</code>	text	

<b>Column Type</b>	<b>Description</b>
	Name of the application that is connected to this backend
<code>client_addr</code> inet	IP address of the client connected to this backend. If this field is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum.
<code>client_hostname</code> text	Host name of the connected client, as reported by a reverse DNS lookup of <code>client_addr</code> . This field will only be non-null for IP connections, and only when <code>log_hostname</code> is enabled.
<code>client_port</code> integer	TCP port number that the client is using for communication with this backend, or <code>-1</code> if a Unix socket is used. If this field is null, it indicates that this is an internal server process.
<code>backend_start</code> timestamp with time zone	Time when this process was started. For client backends, this is the time the client connected to the server.
<code>xact_start</code> timestamp with time zone	Time when this process' current transaction was started, or null if no transaction is active. If the current query is the first of its transaction, this column is equal to the <code>query_start</code> column.
<code>query_start</code> timestamp with time zone	Time when the currently active query was started, or if <code>state</code> is not active, when the last query was started
<code>state_change</code> timestamp with time zone	Time when the state was last changed
<code>wait_event_type</code> text	The type of event for which the backend is waiting, if any; otherwise NULL. See Table 25.4.
<code>wait_event</code> text	Wait event name if backend is currently waiting, otherwise NULL. See Table 25.5 through Table 25.13.
<code>state</code> text	Current overall state of this backend. Possible values are: <ul style="list-style-type: none"> <li>• <code>active</code>: The backend is executing a query.</li> <li>• <code>idle</code>: The backend is waiting for a new client command.</li> <li>• <code>idle in transaction</code>: The backend is in a transaction, but is not currently executing a query.</li> <li>• <code>idle in transaction (aborted)</code>: This state is similar to <code>idle in transaction</code>, except one of the statements in the transaction caused an error.</li> <li>• <code>fastpath function call</code>: The backend is executing a fast-path function.</li> <li>• <code>disabled</code>: This state is reported if <code>track_activities</code> is disabled in this backend.</li> </ul>
<code>backend_xid</code> xid	Top-level transaction identifier of this backend, if any.
<code>backend_xmin</code> xid	The current backend's xmin horizon.
<code>query</code> text	

Column Type	Description
	Text of this backend's most recent query. If <code>state</code> is <code>active</code> this field shows the currently executing query. In all other states, it shows the last query that was executed. By default the query text is truncated at 1024 bytes; this value can be changed via the parameter <code>track_activity_query_size</code> .
<code>backend_type</code> text	Type of current backend. Possible types are <code>autovacuum launcher</code> , <code>autovacuum worker</code> , <code>logical replication launcher</code> , <code>logical replication worker</code> , <code>parallel worker</code> , <code>background writer</code> , <code>client backend</code> , <code>checkpointer</code> , <code>startup</code> , <code>walreceiver</code> , <code>walsender</code> and <code>walwriter</code> . In addition, background workers registered by extensions may have additional types.

### Note

The `wait_event` and `state` columns are independent. If a backend is in the `active` state, it may or may not be waiting on some event. If the state is `active` and `wait_event` is non-null, it means that a query is being executed, but is being blocked somewhere in the system.

**Table 25.4. Wait Event Types**

Wait Event Type	Description
<code>Activity</code>	The server process is idle. This event type indicates a process waiting for activity in its main processing loop. <code>wait_event</code> will identify the specific wait point; see Table 25.5.
<code>BufferPin</code>	The server process is waiting for exclusive access to a data buffer. Buffer pin waits can be protracted if another process holds an open cursor that last read data from the buffer in question. See Table 25.6.
<code>Client</code>	The server process is waiting for activity on a socket connected to a user application. Thus, the server expects something to happen that is independent of its internal processes. <code>wait_event</code> will identify the specific wait point; see Table 25.7.
<code>Extension</code>	The server process is waiting for some condition defined by an extension module. See Table 25.8.
<code>IO</code>	The server process is waiting for an I/O operation to complete. <code>wait_event</code> will identify the specific wait point; see Table 25.9.
<code>IPC</code>	The server process is waiting for some interaction with another server process. <code>wait_event</code> will identify the specific wait point; see Table 25.10.
<code>Lock</code>	The server process is waiting for a heavyweight lock. Heavyweight locks, also known as lock manager locks or simply locks, primarily protect SQL-visible objects such as tables. However, they are also used to ensure mutual exclusion for certain internal operations such as relation

Wait Event Type	Description
	extension. <code>wait_event</code> will identify the type of lock awaited; see Table 25.11.
LWLock	The server process is waiting for a lightweight lock. Most such locks protect a particular data structure in shared memory. <code>wait_event</code> will contain a name identifying the purpose of the lightweight lock. (Some locks have specific names; others are part of a group of locks each with a similar purpose.) See Table 25.12.
Timeout	The server process is waiting for a timeout to expire. <code>wait_event</code> will identify the specific wait point; see Table 25.13.

**Table 25.5. Wait Events of Type Activity**

Activity Wait Event	Description
ArchiverMain	Waiting in main loop of archiver process.
AutoVacuumMain	Waiting in main loop of autovacuum launcher process.
BgWriterHibernate	Waiting in background writer process, hibernating.
BgWriterMain	Waiting in main loop of background writer process.
CheckpointerMain	Waiting in main loop of checkpointer process.
LogicalApplyMain	Waiting in main loop of logical replication apply process.
LogicalLauncherMain	Waiting in main loop of logical replication launcher process.
PgStatMain	Waiting in main loop of statistics collector process.
RecoveryWalStream	Waiting in main loop of startup process for WAL to arrive, during streaming recovery.
SysLoggerMain	Waiting in main loop of sysloger process.
WalReceiverMain	Waiting in main loop of WAL receiver process.
WalSenderMain	Waiting in main loop of WAL sender process.
WalWriterMain	Waiting in main loop of WAL writer process.

**Table 25.6. Wait Events of Type BufferPin**

BufferPin Wait Event	Description
BufferPin	Waiting to acquire an exclusive pin on a buffer.

**Table 25.7. Wait Events of Type Client**

Client Wait Event	Description
ClientRead	Waiting to read data from the client.
ClientWrite	Waiting to write data to the client.
GSSOpenServer	Waiting to read data from the client while establishing a GSSAPI session.

Client Wait Event	Description
LibPQWalReceiverConnect	Waiting in WAL receiver to establish connection to remote server.
LibPQWalReceiverReceive	Waiting in WAL receiver to receive data from remote server.
SSLOpenServer	Waiting for SSL while attempting connection.
WalReceiverWaitStart	Waiting for startup process to send initial data for streaming replication.
WalSenderWaitForWAL	Waiting for WAL to be flushed in WAL sender process.
WalSenderWriteData	Waiting for any activity when processing replies from WAL receiver in WAL sender process.

**Table 25.8. Wait Events of Type Extension**

Extension Wait Event	Description
Extension	Waiting in an extension.

**Table 25.9. Wait Events of Type IO**

IO Wait Event	Description
BufFileRead	Waiting for a read from a buffered file.
BufFileWrite	Waiting for a write to a buffered file.
ControlFileRead	Waiting for a read from the <code>lt_control</code> file.
ControlFileSync	Waiting for the <code>lt_control</code> file to reach durable storage.
ControlFileSyncUpdate	Waiting for an update to the <code>lt_control</code> file to reach durable storage.
ControlFileWrite	Waiting for a write to the <code>lt_control</code> file.
ControlFileWriteUpdate	Waiting for a write to update the <code>lt_control</code> file.
CopyFileRead	Waiting for a read during a file copy operation.
CopyFileWrite	Waiting for a write during a file copy operation.
DSMFillZeroWrite	Waiting to fill a dynamic shared memory backing file with zeroes.
DataFileExtend	Waiting for a relation data file to be extended.
DataFileFlush	Waiting for a relation data file to reach durable storage.
DataFileImmediateSync	Waiting for an immediate synchronization of a relation data file to durable storage.
DataFilePrefetch	Waiting for an asynchronous prefetch from a relation data file.
DataFileRead	Waiting for a read from a relation data file.
DataFileSync	Waiting for changes to a relation data file to reach durable storage.
DataFileTruncate	Waiting for a relation data file to be truncated.
DataFileWrite	Waiting for a write to a relation data file.

<b>IO Wait Event</b>	<b>Description</b>
LockFileAddToDataDirRead	Waiting for a read while adding a line to the data directory lock file.
LockFileAddToDataDirSync	Waiting for data to reach durable storage while adding a line to the data directory lock file.
LockFileAddToDataDirWrite	Waiting for a write while adding a line to the data directory lock file.
LockFileCreateRead	Waiting to read while creating the data directory lock file.
LockFileCreateSync	Waiting for data to reach durable storage while creating the data directory lock file.
LockFileCreateWrite	Waiting for a write while creating the data directory lock file.
LockFileReCheckDataDirRead	Waiting for a read during recheck of the data directory lock file.
LogicalRewriteCheckpointSync	Waiting for logical rewrite mappings to reach durable storage during a checkpoint.
LogicalRewriteMappingSync	Waiting for mapping data to reach durable storage during a logical rewrite.
LogicalRewriteMappingWrite	Waiting for a write of mapping data during a logical rewrite.
LogicalRewriteSync	Waiting for logical rewrite mappings to reach durable storage.
LogicalRewriteTruncate	Waiting for truncate of mapping data during a logical rewrite.
LogicalRewriteWrite	Waiting for a write of logical rewrite mappings.
RelationMapRead	Waiting for a read of the relation map file.
RelationMapSync	Waiting for the relation map file to reach durable storage.
RelationMapWrite	Waiting for a write to the relation map file.
ReorderBufferRead	Waiting for a read during reorder buffer management.
ReorderBufferWrite	Waiting for a write during reorder buffer management.
ReorderLogicalMappingRead	Waiting for a read of a logical mapping during reorder buffer management.
ReplicationSlotRead	Waiting for a read from a replication slot control file.
ReplicationSlotRestoreSync	Waiting for a replication slot control file to reach durable storage while restoring it to memory.
ReplicationSlotSync	Waiting for a replication slot control file to reach durable storage.
ReplicationSlotWrite	Waiting for a write to a replication slot control file.
SLRUFlushSync	Waiting for SLRU data to reach durable storage during a checkpoint or database shutdown.
SLRURead	Waiting for a read of an SLRU page.



<b>IO Wait Event</b>	<b>Description</b>
SLRUSync	Waiting for SLRU data to reach durable storage following a page write.
SLRUWrite	Waiting for a write of an SLRU page.
SnapbuildRead	Waiting for a read of a serialized historical catalog snapshot.
SnapbuildSync	Waiting for a serialized historical catalog snapshot to reach durable storage.
SnapbuildWrite	Waiting for a write of a serialized historical catalog snapshot.
TimelineHistoryFileSync	Waiting for a timeline history file received via streaming replication to reach durable storage.
TimelineHistoryFileWrite	Waiting for a write of a timeline history file received via streaming replication.
TimelineHistoryRead	Waiting for a read of a timeline history file.
TimelineHistorySync	Waiting for a newly created timeline history file to reach durable storage.
TimelineHistoryWrite	Waiting for a write of a newly created timeline history file.
TwophaseFileRead	Waiting for a read of a two phase state file.
TwophaseFileSync	Waiting for a two phase state file to reach durable storage.
TwophaseFileWrite	Waiting for a write of a two phase state file.
WALBootstrapSync	Waiting for WAL to reach durable storage during bootstrapping.
WALBootstrapWrite	Waiting for a write of a WAL page during bootstrapping.
WALCopyRead	Waiting for a read when creating a new WAL segment by copying an existing one.
WALCopySync	Waiting for a new WAL segment created by copying an existing one to reach durable storage.
WALCopyWrite	Waiting for a write when creating a new WAL segment by copying an existing one.
WALInitSync	Waiting for a newly initialized WAL file to reach durable storage.
WALInitWrite	Waiting for a write while initializing a new WAL file.
WALRead	Waiting for a read from a WAL file.
WALSenderTimelineHistoryRead	Waiting for a read from a timeline history file during a walsender timeline command.
WALSync	Waiting for a WAL file to reach durable storage.
WALSyncMethodAssign	Waiting for data to reach durable storage while assigning a new WAL sync method.
WALWrite	Waiting for a write to a WAL file.

**Table 25.10. Wait Events of Type IPC**

<b>IPC Wait Event</b>	<b>Description</b>
BackupWaitWalArchive	Waiting for WAL files required for a backup to be successfully archived.
BgWorkerShutdown	Waiting for background worker to shut down.
BgWorkerStartup	Waiting for background worker to start up.
BtreePage	Waiting for the page number needed to continue a parallel B-tree scan to become available.
CheckpointDone	Waiting for a checkpoint to complete.
CheckpointStart	Waiting for a checkpoint to start.
ExecuteGather	Waiting for activity from a child process while executing a Gather plan node.
HashBatchAllocate	Waiting for an elected Parallel Hash participant to allocate a hash table.
HashBatchElect	Waiting to elect a Parallel Hash participant to allocate a hash table.
HashBatchLoad	Waiting for other Parallel Hash participants to finish loading a hash table.
HashBuildAllocate	Waiting for an elected Parallel Hash participant to allocate the initial hash table.
HashBuildElect	Waiting to elect a Parallel Hash participant to allocate the initial hash table.
HashBuildHashInner	Waiting for other Parallel Hash participants to finish hashing the inner relation.
HashBuildHashOuter	Waiting for other Parallel Hash participants to finish partitioning the outer relation.
HashGrowBatchesAllocate	Waiting for an elected Parallel Hash participant to allocate more batches.
HashGrowBatchesDecide	Waiting to elect a Parallel Hash participant to decide on future batch growth.
HashGrowBatchesElect	Waiting to elect a Parallel Hash participant to allocate more batches.
HashGrowBatchesFinish	Waiting for an elected Parallel Hash participant to decide on future batch growth.
HashGrowBatchesRepartition	Waiting for other Parallel Hash participants to finish repartitioning.
HashGrowBucketsAllocate	Waiting for an elected Parallel Hash participant to finish allocating more buckets.
HashGrowBucketsElect	Waiting to elect a Parallel Hash participant to allocate more buckets.
HashGrowBucketsReinsert	Waiting for other Parallel Hash participants to finish inserting tuples into new buckets.
LogicalSyncData	Waiting for a logical replication remote server to send data for initial table synchronization.
LogicalSyncStateChange	Waiting for a logical replication remote server to change state.

<b>IPC Wait Event</b>	<b>Description</b>
MessageQueueInternal	Waiting for another process to be attached to a shared message queue.
MessageQueuePutMessage	Waiting to write a protocol message to a shared message queue.
MessageQueueReceive	Waiting to receive bytes from a shared message queue.
MessageQueueSend	Waiting to send bytes to a shared message queue.
ParallelBitmapScan	Waiting for parallel bitmap scan to become initialized.
ParallelCreateIndexScan	Waiting for parallel CREATE INDEX workers to finish heap scan.
ParallelFinish	Waiting for parallel workers to finish computing.
ProcArrayGroupUpdate	Waiting for the group leader to clear the transaction ID at end of a parallel operation.
ProcSignalBarrier	Waiting for a barrier event to be processed by all backends.
Promote	Waiting for standby promotion.
RecoveryConflictSnapshot	Waiting for recovery conflict resolution for a vacuum cleanup.
RecoveryConflictTablespace	Waiting for recovery conflict resolution for dropping a tablespace.
RecoveryPause	Waiting for recovery to be resumed.
ReplicationOriginDrop	Waiting for a replication origin to become inactive so it can be dropped.
ReplicationSlotDrop	Waiting for a replication slot to become inactive so it can be dropped.
SafeSnapshot	Waiting to obtain a valid snapshot for a READ ONLY DEFERRABLE transaction.
SyncRep	Waiting for confirmation from a remote server during synchronous replication.
XactGroupUpdate	Waiting for the group leader to update transaction status at end of a parallel operation.

**Table 25.11. Wait Events of Type Lock**

<b>Lock Wait Event</b>	<b>Description</b>
advisory	Waiting to acquire an advisory user lock.
extend	Waiting to extend a relation.
frozenid	Waiting to update pg_database.datfrozenxid and pg_database.datminmxid.
object	Waiting to acquire a lock on a non-relation database object.
page	Waiting to acquire a lock on a page of a relation.
relation	Waiting to acquire a lock on a relation.
spectoken	Waiting to acquire a speculative insertion lock.

Lock Wait Event	Description
transactionid	Waiting for a transaction to finish.
tuple	Waiting to acquire a lock on a tuple.
userlock	Waiting to acquire a user lock.
virtualxid	Waiting to acquire a virtual transaction ID lock.

**Table 25.12. Wait Events of Type LWLock**

LWLock Wait Event	Description
AddinShmemInit	Waiting to manage an extension's space allocation in shared memory.
AutoFile	Waiting to update the <code>lightdb.auto.conf</code> file.
Autovacuum	Waiting to read or update the current state of autovacuum workers.
AutovacuumSchedule	Waiting to ensure that a table selected for autovacuum still needs vacuuming.
BackgroundWorker	Waiting to read or update background worker state.
BtreeVacuum	Waiting to read or update vacuum-related information for a B-tree index.
BufferContent	Waiting to access a data page in memory.
BufferIO	Waiting for I/O on a data page.
BufferMapping	Waiting to associate a data block with a buffer in the buffer pool.
Checkpoint	Waiting to begin a checkpoint.
CheckpointInterComm	Waiting to manage fsync requests.
CommitTs	Waiting to read or update the last value set for a transaction commit timestamp.
CommitTsBuffer	Waiting for I/O on a commit timestamp SLRU buffer.
CommitTsSLRU	Waiting to access the commit timestamp SLRU cache.
ControlFile	Waiting to read or update the <code>lt_control</code> file or create a new WAL file.
DynamicSharedMemoryControl	Waiting to read or update dynamic shared memory allocation information.
LockFastPath	Waiting to read or update a process' fast-path lock information.
LockManager	Waiting to read or update information about "heavyweight" locks.
LogicalRepWorker	Waiting to read or update the state of logical replication workers.
MultiXactGen	Waiting to read or update shared multixact state.
MultiXactMemberBuffer	Waiting for I/O on a multixact member SLRU buffer.
MultiXactMemberSLRU	Waiting to access the multixact member SLRU cache.

<b>LWLock Wait Event</b>	<b>Description</b>
MultiXactOffsetBuffer	Waiting for I/O on a multixact offset SLRU buffer.
MultiXactOffsetSLRU	Waiting to access the multixact offset SLRU cache.
MultiXactTruncation	Waiting to read or truncate multixact information.
NotifyBuffer	Waiting for I/O on a NOTIFY message SLRU buffer.
NotifyQueue	Waiting to read or update NOTIFY messages.
NotifyQueueTail	Waiting to update limit on NOTIFY message storage.
NotifySLRU	Waiting to access the NOTIFY message SLRU cache.
OidGen	Waiting to allocate a new OID.
OldSnapshotTimeMap	Waiting to read or update old snapshot control information.
ParallelAppend	Waiting to choose the next subplan during Parallel Append plan execution.
ParallelHashJoin	Waiting to synchronize workers during Parallel Hash Join plan execution.
ParallelQueryDSA	Waiting for parallel query dynamic shared memory allocation.
PerSessionDSA	Waiting for parallel query dynamic shared memory allocation.
PerSessionRecordType	Waiting to access a parallel query's information about composite types.
PerSessionRecordTypmod	Waiting to access a parallel query's information about type modifiers that identify anonymous record types.
PerXactPredicateList	Waiting to access the list of predicate locks held by the current serializable transaction during a parallel query.
PredicateLockManager	Waiting to access predicate lock information used by serializable transactions.
ProcArray	Waiting to access the shared per-process data structures (typically, to get a snapshot or report a session's transaction ID).
RelationMapping	Waiting to read or update a <code>lt_filenode.map</code> file (used to track the filenode assignments of certain system catalogs).
RelCacheInit	Waiting to read or update a <code>lt_internal.init</code> relation cache initialization file.
ReplicationOrigin	Waiting to create, drop or use a replication origin.
ReplicationOriginState	Waiting to read or update the progress of one replication origin.
ReplicationSlotAllocation	Waiting to allocate or free a replication slot.

<b>LWLock Wait Event</b>	<b>Description</b>
ReplicationSlotControl	Waiting to read or update replication slot state.
ReplicationSlotIO	Waiting for I/O on a replication slot.
SerialBuffer	Waiting for I/O on a serializable transaction conflict SLRU buffer.
SerializableFinishedList	Waiting to access the list of finished serializable transactions.
SerializablePredicateList	Waiting to access the list of predicate locks held by serializable transactions.
SerializableXactHash	Waiting to read or update information about serializable transactions.
SerialSLRU	Waiting to access the serializable transaction conflict SLRU cache.
SharedTidBitmap	Waiting to access a shared TID bitmap during a parallel bitmap index scan.
SharedTupleStore	Waiting to access a shared tuple store during parallel query.
ShmemIndex	Waiting to find or allocate space in shared memory.
SInvalRead	Waiting to retrieve messages from the shared catalog invalidation queue.
SInvalWrite	Waiting to add a message to the shared catalog invalidation queue.
SubtransBuffer	Waiting for I/O on a sub-transaction SLRU buffer.
SubtransSLRU	Waiting to access the sub-transaction SLRU cache.
SyncRep	Waiting to read or update information about the state of synchronous replication.
SyncScan	Waiting to select the starting location of a synchronized table scan.
TablespaceCreate	Waiting to create or drop a tablespace.
TwoPhaseState	Waiting to read or update the state of prepared transactions.
WALBufMapping	Waiting to replace a page in WAL buffers.
WALInsert	Waiting to insert WAL data into a memory buffer.
WALWrite	Waiting for WAL buffers to be written to disk.
WrapLimitsVacuum	Waiting to update limits on transaction id and multixact consumption.
XactBuffer	Waiting for I/O on a transaction status SLRU buffer.
XactSLRU	Waiting to access the transaction status SLRU cache.
XactTruncation	Waiting to execute <code>pg_xact_status</code> or update the oldest transaction ID available to it.
XidGen	Waiting to allocate a new transaction ID.

LWLock Wait Event	Description
LTNameLock	Waiting to get lock information for creating or renaming a table, package or schema.

### Note

Extensions can add LWLock types to the list shown in Table 25.12. In some cases, the name assigned by an extension will not be available in all server processes; so an LWLock wait event might be reported as just “extension” rather than the extension-assigned name.

**Table 25.13. Wait Events of Type Timeout**

Timeout Wait Event	Description
BaseBackupThrottle	Waiting during base backup when throttling activity.
PgSleep	Waiting due to a call to <code>pg_sleep</code> or a sibling function.
RecoveryApplyDelay	Waiting to apply WAL during recovery because of a delay setting.
RecoveryRetrieveRetryInterval	Waiting during recovery when WAL data is not available from any source ( <code>lt_wal</code> , archive or stream).
RegisterSyncRequest	Waiting while sending synchronization requests to the checkpointer, because the request queue is full.
VacuumDelay	Waiting in a cost-based vacuum delay point.

Here is an example of how wait events can be viewed:

```
SELECT pid, wait_event_type, wait_event FROM pg_stat_activity WHERE
wait_event IS NOT NULL;
 pid | wait_event_type | wait_event
-----+-----+-----
 2540 | Lock            | relation
 6644 | LWLock         | ProcArray
(2 rows)
```

## 25.2.4. pg\_stat\_replication

The `pg_stat_replication` view will contain one row per WAL sender process, showing statistics about replication to that sender's connected standby server. Only directly connected standbys are listed; no information is available about downstream standby servers.

**Table 25.14. pg\_stat\_replication View**

Column Type	Description
<code>pid</code> integer	Process ID of a WAL sender process
<code>usesysid</code> oid	OID of the user logged into this WAL sender process

<b>Column Type</b>	<b>Description</b>
username name	Name of the user logged into this WAL sender process
application_name text	Name of the application that is connected to this WAL sender
client_addr inet	IP address of the client connected to this WAL sender. If this field is null, it indicates that the client is connected via a Unix socket on the server machine.
client_hostname text	Host name of the connected client, as reported by a reverse DNS lookup of <code>client_addr</code> . This field will only be non-null for IP connections, and only when <code>log_hostname</code> is enabled.
client_port integer	TCP port number that the client is using for communication with this WAL sender, or <code>-1</code> if a Unix socket is used
backend_start timestamp with time zone	Time when this process was started, i.e., when the client connected to this WAL sender
backend_xmin xid	This standby's xmin horizon reported by <code>hot_standby_feedback</code> .
state text	Current WAL sender state. Possible values are: <ul style="list-style-type: none"> <li>• <code>startup</code>: This WAL sender is starting up.</li> <li>• <code>catchup</code>: This WAL sender's connected standby is catching up with the primary.</li> <li>• <code>streaming</code>: This WAL sender is streaming changes after its connected standby server has caught up with the primary.</li> <li>• <code>backup</code>: This WAL sender is sending a backup.</li> <li>• <code>stopping</code>: This WAL sender is stopping.</li> </ul>
sent_lsn pg_lsn	Last write-ahead log location sent on this connection
write_lsn pg_lsn	Last write-ahead log location written to disk by this standby server
flush_lsn pg_lsn	Last write-ahead log location flushed to disk by this standby server
replay_lsn pg_lsn	Last write-ahead log location replayed into the database on this standby server
write_lag interval	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written it (but not yet flushed it or applied it). This can be used to gauge the delay that <code>synchronous_commit</code> level <code>remote_write</code> incurred while committing if this server was configured as a synchronous standby.
flush_lag interval	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written and flushed it (but not yet applied it). This can be used to gauge the delay that <code>synchronous_commit</code> level on incurred while committing if this server was configured as a synchronous standby.
replay_lag interval	



Column Type	Description
	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written, flushed and applied it. This can be used to gauge the delay that <code>synchronous_commit</code> level <code>remote_apply</code> incurred while committing if this server was configured as a synchronous standby.
<code>sync_priority</code> integer	Priority of this standby server for being chosen as the synchronous standby in a priority-based synchronous replication. This has no effect in a quorum-based synchronous replication.
<code>sync_state</code> text	Synchronous state of this standby server. Possible values are: <ul style="list-style-type: none"> <li>• <code>async</code>: This standby server is asynchronous.</li> <li>• <code>potential</code>: This standby server is now asynchronous, but can potentially become synchronous if one of current synchronous ones fails.</li> <li>• <code>sync</code>: This standby server is synchronous.</li> <li>• <code>quorum</code>: This standby server is considered as a candidate for quorum standbys.</li> </ul>
<code>reply_time</code> timestamp with time zone	Send time of last reply message received from standby server

The lag times reported in the `pg_stat_replication` view are measurements of the time taken for recent WAL to be written, flushed and replayed and for the sender to know about it. These times represent the commit delay that was (or would have been) introduced by each synchronous commit level, if the remote server was configured as a synchronous standby. For an asynchronous standby, the `replay_lag` column approximates the delay before recent transactions became visible to queries. If the standby server has entirely caught up with the sending server and there is no more WAL activity, the most recently measured lag times will continue to be displayed for a short time and then show NULL.

Lag times work automatically for physical replication. Logical decoding plugins may optionally emit tracking messages; if they do not, the tracking mechanism will simply display NULL lag.

### Note

The reported lag times are not predictions of how long it will take for the standby to catch up with the sending server assuming the current rate of replay. Such a system would show similar times while new WAL is being generated, but would differ when the sender becomes idle. In particular, when the standby has caught up completely, `pg_stat_replication` shows the time taken to write, flush and replay the most recent reported WAL location rather than zero as some users might expect. This is consistent with the goal of measuring synchronous commit and transaction visibility delays for recent write transactions. To reduce confusion for users expecting a different model of lag, the lag columns revert to NULL after a short time on a fully replayed idle system. Monitoring systems should choose whether to represent this as missing data, zero or continue to display the last known value.

## 25.2.5. `pg_stat_wal_receiver`

The `pg_stat_wal_receiver` view will contain only one row, showing statistics about the WAL receiver from that receiver's connected server.

**Table 25.15. pg\_stat\_wal\_receiver View**

<b>Column Type</b>	<b>Description</b>
pid integer	Process ID of the WAL receiver process
status text	Activity status of the WAL receiver process
receive_start_lsn pg_lsn	First write-ahead log location used when WAL receiver is started
receive_start_tli integer	First timeline number used when WAL receiver is started
written_lsn pg_lsn	Last write-ahead log location already received and written to disk, but not flushed. This should not be used for data integrity checks.
flushed_lsn pg_lsn	Last write-ahead log location already received and flushed to disk, the initial value of this field being the first log location used when WAL receiver is started
received_tli integer	Timeline number of last write-ahead log location received and flushed to disk, the initial value of this field being the timeline number of the first log location used when WAL receiver is started
last_msg_send_time timestamp with time zone	Send time of last message received from origin WAL sender
last_msg_receipt_time timestamp with time zone	Receipt time of last message received from origin WAL sender
latest_end_lsn pg_lsn	Last write-ahead log location reported to origin WAL sender
latest_end_time timestamp with time zone	Time of last write-ahead log location reported to origin WAL sender
slot_name text	Replication slot name used by this WAL receiver
sender_host text	Host of the LightDB instance this WAL receiver is connected to. This can be a host name, an IP address, or a directory path if the connection is via Unix socket. (The path case can be distinguished because it will always be an absolute path, beginning with /.)
sender_port integer	Port number of the LightDB instance this WAL receiver is connected to.
conninfo text	Connection string used by this WAL receiver, with security-sensitive fields obfuscated.

## 25.2.6. pg\_stat\_subscription

The `pg_stat_subscription` view will contain one row per subscription for main worker (with null PID if the worker is not running), and additional rows for workers handling the initial data copy of the subscribed tables.

**Table 25.16. pg\_stat\_subscription View**

<b>Column Type</b>	<b>Description</b>
subid oid	

Column Type	Description
	OID of the subscription
subname name	Name of the subscription
pid integer	Process ID of the subscription worker process
relid oid	OID of the relation that the worker is synchronizing; null for the main apply worker
received_lsn pg_lsn	Last write-ahead log location received, the initial value of this field being 0
last_msg_send_time timestamp with time zone	Send time of last message received from origin WAL sender
last_msg_receipt_time timestamp with time zone	Receipt time of last message received from origin WAL sender
latest_end_lsn pg_lsn	Last write-ahead log location reported to origin WAL sender
latest_end_time timestamp with time zone	Time of last write-ahead log location reported to origin WAL sender

## 25.2.7. pg\_stat\_ssl

The `pg_stat_ssl` view will contain one row per backend or WAL sender process, showing statistics about SSL usage on this connection. It can be joined to `pg_stat_activity` or `pg_stat_replication` on the `pid` column to get more details about the connection.

**Table 25.17. pg\_stat\_ssl View**

Column Type	Description
pid integer	Process ID of a backend or WAL sender process
ssl boolean	True if SSL is used on this connection
version text	Version of SSL in use, or NULL if SSL is not in use on this connection
cipher text	Name of SSL cipher in use, or NULL if SSL is not in use on this connection
bits integer	Number of bits in the encryption algorithm used, or NULL if SSL is not used on this connection
compression boolean	True if SSL compression is in use, false if not, or NULL if SSL is not in use on this connection
client_dn text	Distinguished Name (DN) field from the client certificate used, or NULL if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated if the DN field is longer than <code>NAMEDATALEN</code> (64 characters in a standard build).
client_serial numeric	Serial number of the client certificate, or NULL if no client certificate was supplied or if SSL is not in use on this connection. The combination of certificate serial number and

Column Type	Description
	certificate issuer uniquely identifies a certificate (unless the issuer erroneously reuses serial numbers).
issuer_dn text	DN of the issuer of the client certificate, or NULL if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated like <code>client_dn</code> .

## 25.2.8. pg\_stat\_gssapi

The `pg_stat_gssapi` view will contain one row per backend, showing information about GSSAPI usage on this connection. It can be joined to `pg_stat_activity` or `pg_stat_replication` on the `pid` column to get more details about the connection.

**Table 25.18. pg\_stat\_gssapi View**

Column Type	Description
pid integer	Process ID of a backend
gss_authenticated boolean	True if GSSAPI authentication was used for this connection
principal text	Principal used to authenticate this connection, or NULL if GSSAPI was not used to authenticate this connection. This field is truncated if the principal is longer than <code>NAMEDATALEN</code> (64 characters in a standard build).
encrypted boolean	True if GSSAPI encryption is in use on this connection

## 25.2.9. pg\_stat\_archiver

The `pg_stat_archiver` view will always have a single row, containing data about the archiver process of the cluster.

**Table 25.19. pg\_stat\_archiver View**

Column Type	Description
archived_count bigint	Number of WAL files that have been successfully archived
last_archived_wal text	Name of the last WAL file successfully archived
last_archived_time timestamp with time zone	Time of the last successful archive operation
failed_count bigint	Number of failed attempts for archiving WAL files
last_failed_wal text	Name of the WAL file of the last failed archival operation
last_failed_time timestamp with time zone	Time of the last failed archival operation
stats_reset timestamp with time zone	Time at which these statistics were last reset

## 25.2.10. pg\_stat\_bgwriter

The `pg_stat_bgwriter` view will always have a single row, containing global data for the cluster.

**Table 25.20. pg\_stat\_bgwriter View**

Column	Type	Description
<code>checkpoints_timed</code>	<code>bigint</code>	Number of scheduled checkpoints that have been performed
<code>checkpoints_req</code>	<code>bigint</code>	Number of requested checkpoints that have been performed
<code>checkpoint_write_time</code>	<code>double precision</code>	Total amount of time that has been spent in the portion of checkpoint processing where files are written to disk, in milliseconds
<code>checkpoint_sync_time</code>	<code>double precision</code>	Total amount of time that has been spent in the portion of checkpoint processing where files are synchronized to disk, in milliseconds
<code>buffers_checkpoint</code>	<code>bigint</code>	Number of buffers written during checkpoints
<code>buffers_clean</code>	<code>bigint</code>	Number of buffers written by the background writer
<code>maxwritten_clean</code>	<code>bigint</code>	Number of times the background writer stopped a cleaning scan because it had written too many buffers
<code>buffers_backend</code>	<code>bigint</code>	Number of buffers written directly by a backend
<code>buffers_backend_fsync</code>	<code>bigint</code>	Number of times a backend had to execute its own <code>fsync</code> call (normally the background writer handles those even when the backend does its own write)
<code>buffers_alloc</code>	<code>bigint</code>	Number of buffers allocated
<code>stats_reset</code>	<code>timestamp with time zone</code>	Time at which these statistics were last reset

## 25.2.11. pg\_stat\_database

The `pg_stat_database` view will contain one row for each database in the cluster, plus one for shared objects, showing database-wide statistics.

**Table 25.21. pg\_stat\_database View**

Column	Type	Description
<code>datid</code>	<code>oid</code>	OID of this database, or 0 for objects belonging to a shared relation
<code>datname</code>	<code>name</code>	Name of this database, or NULL for shared objects.
<code>numbackends</code>	<code>integer</code>	Number of backends currently connected to this database, or NULL for shared objects. This is the only column in this view that returns a value reflecting current state; all other columns return the accumulated values since the last reset.

<b>Column Type</b>	<b>Description</b>
xact_commit bigint	Number of transactions in this database that have been committed
xact_rollback bigint	Number of transactions in this database that have been rolled back
blks_read bigint	Number of disk blocks read in this database
blks_hit bigint	Number of times disk blocks were found already in the buffer cache, so that a read was not necessary (this only includes hits in the LightDB buffer cache, not the operating system's file system cache)
tup_returned bigint	Number of rows returned by queries in this database
tup_fetched bigint	Number of rows fetched by queries in this database
tup_inserted bigint	Number of rows inserted by queries in this database
tup_updated bigint	Number of rows updated by queries in this database
tup_deleted bigint	Number of rows deleted by queries in this database
conflicts bigint	Number of queries canceled due to conflicts with recovery in this database. (Conflicts occur only on standby servers; see <code>pg_stat_database_conflicts</code> for details.)
temp_files bigint	Number of temporary files created by queries in this database. All temporary files are counted, regardless of why the temporary file was created (e.g., sorting or hashing), and regardless of the <code>log_temp_files</code> setting.
temp_bytes bigint	Total amount of data written to temporary files by queries in this database. All temporary files are counted, regardless of why the temporary file was created, and regardless of the <code>log_temp_files</code> setting.
deadlocks bigint	Number of deadlocks detected in this database
checksum_failures bigint	Number of data page checksum failures detected in this database (or on a shared object), or NULL if data checksums are not enabled.
checksum_last_failure timestamp with time zone	Time at which the last data page checksum failure was detected in this database (or on a shared object), or NULL if data checksums are not enabled.
blk_read_time double precision	Time spent reading data file blocks by backends in this database, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)
blk_write_time double precision	Time spent writing data file blocks by backends in this database, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)
stats_reset timestamp with time zone	Time at which these statistics were last reset

## 25.2.12. pg\_stat\_database\_conflicts

The `pg_stat_database_conflicts` view will contain one row per database, showing database-wide statistics about query cancels occurring due to conflicts with recovery on standby servers. This view will only contain information on standby servers, since conflicts do not occur on master servers.

**Table 25.22. pg\_stat\_database\_conflicts View**

Column	Type	Description
<code>datid</code>	<code>oid</code>	OID of a database
<code>datname</code>	<code>name</code>	Name of this database
<code>confl_tablespace</code>	<code>bigint</code>	Number of queries in this database that have been canceled due to dropped tablespaces
<code>confl_lock</code>	<code>bigint</code>	Number of queries in this database that have been canceled due to lock timeouts
<code>confl_snapshot</code>	<code>bigint</code>	Number of queries in this database that have been canceled due to old snapshots
<code>confl_bufferpin</code>	<code>bigint</code>	Number of queries in this database that have been canceled due to pinned buffers
<code>confl_deadlock</code>	<code>bigint</code>	Number of queries in this database that have been canceled due to deadlocks

## 25.2.13. pg\_stat\_all\_tables

The `pg_stat_all_tables` view will contain one row for each table in the current database (including TOAST tables), showing statistics about accesses to that specific table. The `pg_stat_user_tables` and `pg_stat_sys_tables` views contain the same information, but filtered to only show user and system tables respectively.

**Table 25.23. pg\_stat\_all\_tables View**

Column	Type	Description
<code>relid</code>	<code>oid</code>	OID of a table
<code>schemaname</code>	<code>name</code>	Name of the schema that this table is in
<code>relname</code>	<code>name</code>	Name of this table
<code>seq_scan</code>	<code>bigint</code>	Number of sequential scans initiated on this table
<code>seq_tup_read</code>	<code>bigint</code>	Number of live rows fetched by sequential scans
<code>idx_scan</code>	<code>bigint</code>	Number of index scans initiated on this table
<code>idx_tup_fetch</code>	<code>bigint</code>	Number of live rows fetched by index scans
<code>n_tup_ins</code>	<code>bigint</code>	

<b>Column Type</b>	<b>Description</b>
	Number of rows inserted
n_tup_upd bigint	Number of rows updated (includes HOT updated rows)
n_tup_del bigint	Number of rows deleted
n_tup_hot_upd bigint	Number of rows HOT updated (i.e., with no separate index update required)
n_live_tup bigint	Estimated number of live rows
n_dead_tup bigint	Estimated number of dead rows
n_mod_since_analyze bigint	Estimated number of rows modified since this table was last analyzed
n_ins_since_vacuum bigint	Estimated number of rows inserted since this table was last vacuumed
last_vacuum timestamp with time zone	Last time at which this table was manually vacuumed (not counting VACUUM FULL)
last_autovacuum timestamp with time zone	Last time at which this table was vacuumed by the autovacuum daemon
last_analyze timestamp with time zone	Last time at which this table was manually analyzed
last_autoanalyze timestamp with time zone	Last time at which this table was analyzed by the autovacuum daemon
vacuum_count bigint	Number of times this table has been manually vacuumed (not counting VACUUM FULL)
autovacuum_count bigint	Number of times this table has been vacuumed by the autovacuum daemon
analyze_count bigint	Number of times this table has been manually analyzed
autoanalyze_count bigint	Number of times this table has been analyzed by the autovacuum daemon

## 25.2.14. pg\_stat\_all\_indexes

The `pg_stat_all_indexes` view will contain one row for each index in the current database, showing statistics about accesses to that specific index. The `pg_stat_user_indexes` and `pg_stat_sys_indexes` views contain the same information, but filtered to only show user and system indexes respectively.

**Table 25.24. pg\_stat\_all\_indexes View**

<b>Column Type</b>	<b>Description</b>
relid oid	OID of the table for this index
indexrelid oid	OID of this index
schemaname name	



Column Type	Description
	Name of the schema this index is in
relname name	Name of the table for this index
indexrelname name	Name of this index
idx_scan bigint	Number of index scans initiated on this index
idx_tup_read bigint	Number of index entries returned by scans on this index
idx_tup_fetch bigint	Number of live table rows fetched by simple index scans using this index

Indexes can be used by simple index scans, “bitmap” index scans, and the optimizer. In a bitmap scan the output of several indexes can be combined via AND or OR rules, so it is difficult to associate individual heap row fetches with specific indexes when a bitmap scan is used. Therefore, a bitmap scan increments the `pg_stat_all_indexes.idx_tup_read` count(s) for the index(es) it uses, and it increments the `pg_stat_all_tables.idx_tup_fetch` count for the table, but it does not affect `pg_stat_all_indexes.idx_tup_fetch`. The optimizer also accesses indexes to check for supplied constants whose values are outside the recorded range of the optimizer statistics because the optimizer statistics might be stale.

### Note

The `idx_tup_read` and `idx_tup_fetch` counts can be different even without any use of bitmap scans, because `idx_tup_read` counts index entries retrieved from the index while `idx_tup_fetch` counts live rows fetched from the table. The latter will be less if any dead or not-yet-committed rows are fetched using the index, or if any heap fetches are avoided by means of an index-only scan.

## 25.2.15. pg\_statio\_all\_tables

The `pg_statio_all_tables` view will contain one row for each table in the current database (including TOAST tables), showing statistics about I/O on that specific table. The `pg_statio_user_tables` and `pg_statio_sys_tables` views contain the same information, but filtered to only show user and system tables respectively.

**Table 25.25. pg\_statio\_all\_tables View**

Column Type	Description
relid oid	OID of a table
schemaname name	Name of the schema that this table is in
relname name	Name of this table
heap_blks_read bigint	Number of disk blocks read from this table
heap_blks_hit bigint	

Column Type	Description
	Number of buffer hits in this table
idx_blks_read bigint	Number of disk blocks read from all indexes on this table
idx_blks_hit bigint	Number of buffer hits in all indexes on this table
toast_blks_read bigint	Number of disk blocks read from this table's TOAST table (if any)
toast_blks_hit bigint	Number of buffer hits in this table's TOAST table (if any)
tidx_blks_read bigint	Number of disk blocks read from this table's TOAST table indexes (if any)
tidx_blks_hit bigint	Number of buffer hits in this table's TOAST table indexes (if any)

## 25.2.16. pg\_statio\_all\_indexes

The `pg_statio_all_indexes` view will contain one row for each index in the current database, showing statistics about I/O on that specific index. The `pg_statio_user_indexes` and `pg_statio_sys_indexes` views contain the same information, but filtered to only show user and system indexes respectively.

**Table 25.26. pg\_statio\_all\_indexes View**

Column Type	Description
relid oid	OID of the table for this index
indexrelid oid	OID of this index
schemaname name	Name of the schema this index is in
relname name	Name of the table for this index
indexrelname name	Name of this index
idx_blks_read bigint	Number of disk blocks read from this index
idx_blks_hit bigint	Number of buffer hits in this index

## 25.2.17. pg\_statio\_all\_sequences

The `pg_statio_all_sequences` view will contain one row for each sequence in the current database, showing statistics about I/O on that specific sequence.

**Table 25.27. pg\_statio\_all\_sequences View**

Column Type	Description
relid oid	

Column Type	Description
OID	OID of a sequence
schemaname name	Name of the schema this sequence is in
relname name	Name of this sequence
blks_read bigint	Number of disk blocks read from this sequence
blks_hit bigint	Number of buffer hits in this sequence

## 25.2.18. pg\_stat\_user\_functions

The `pg_stat_user_functions` view will contain one row for each tracked function, showing statistics about executions of that function. The `track_functions` parameter controls exactly which functions are tracked.

**Table 25.28. pg\_stat\_user\_functions View**

Column Type	Description
funcid oid	OID of a function
schemaname name	Name of the schema this function is in
funcname name	Name of this function
calls bigint	Number of times this function has been called
total_time double precision	Total time spent in this function and all other functions called by it, in milliseconds
self_time double precision	Total time spent in this function itself, not including other functions called by it, in milliseconds

## 25.2.19. pg\_stat\_slru

LightDB accesses certain on-disk information via *SLRU* (simple least-recently-used) caches. The `pg_stat_slru` view will contain one row for each tracked SLRU cache, showing statistics about access to cached pages.

**Table 25.29. pg\_stat\_slru View**

Column Type	Description
name text	Name of the SLRU
blks_zeroed bigint	Number of blocks zeroed during initializations
blks_hit bigint	

<b>Column Type</b>	<b>Description</b>
	Number of times disk blocks were found already in the SLRU, so that a read was not necessary (this only includes hits in the SLRU, not the operating system's file system cache)
<code>blks_read</code> bigint	Number of disk blocks read for this SLRU
<code>blks_written</code> bigint	Number of disk blocks written for this SLRU
<code>blks_exists</code> bigint	Number of blocks checked for existence for this SLRU
<code>flushes</code> bigint	Number of flushes of dirty data for this SLRU
<code>truncates</code> bigint	Number of truncates for this SLRU
<code>stats_reset</code> timestamp with time zone	Time at which these statistics were last reset

## 25.2.20. Statistics Functions

Other ways of looking at the statistics can be set up by writing queries that use the same underlying statistics access functions used by the standard views shown above. For details such as the functions' names, consult the definitions of the standard views. (For example, in `ltsql` you could issue `\d+ pg_stat_activity`.) The access functions for per-database statistics take a database OID as an argument to identify which database to report on. The per-table and per-index functions take a table or index OID. The functions for per-function statistics take a function OID. Note that only tables, indexes, and functions in the current database can be seen with these functions.

Additional functions related to statistics collection are listed in Table 25.30.

**Table 25.30. Additional Statistics Functions**

<b>Function</b>	<b>Description</b>
<code>pg_backend_pid ()</code> → integer	Returns the process ID of the server process attached to the current session.
<code>pg_stat_get_activity ( integer )</code> → setof record	Returns a record of information about the backend with the specified process ID, or one record for each active backend in the system if <code>NULL</code> is specified. The fields returned are a subset of those in the <code>pg_stat_activity</code> view.
<code>pg_stat_get_snapshot_timestamp ()</code> → timestamp with time zone	Returns the timestamp of the current statistics snapshot.
<code>pg_stat_clear_snapshot ()</code> → void	Discards the current statistics snapshot.
<code>pg_stat_reset ()</code> → void	Resets all statistics counters for the current database to zero. This function is restricted to superusers by default, but other users can be granted <code>EXECUTE</code> to run the function.
<code>pg_stat_reset_shared ( text )</code> → void	Resets some cluster-wide statistics counters to zero, depending on the argument. The argument can be <code>bgwriter</code> to reset all the counters shown in the

<b>Function</b>	<b>Description</b>
	<code>pg_stat_bgwriter</code> view, or <code>archiver</code> to reset all the counters shown in the <code>pg_stat_archiver</code> view. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_stat_reset_single_table_counters ( oid ) → void</code>	Resets statistics for a single table or index in the current database to zero. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_stat_reset_single_function_counters ( oid ) → void</code>	Resets statistics for a single function in the current database to zero. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_stat_reset_slru ( text ) → void</code>	Resets statistics to zero for a single SLRU cache, or for all SLRUs in the cluster. If the argument is NULL, all counters shown in the <code>pg_stat_slru</code> view for all SLRU caches are reset. The argument can be one of <code>CommitTs</code> , <code>MultiXactMember</code> , <code>MultiXactOffset</code> , <code>Notify</code> , <code>Serial</code> , <code>Subtrans</code> , or <code>Xact</code> to reset the counters for only that entry. If the argument is other (or indeed, any unrecognized name), then the counters for all other SLRU caches, such as extension-defined caches, are reset. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

`pg_stat_get_activity`, the underlying function of the `pg_stat_activity` view, returns a set of records containing all the available information about each backend process. Sometimes it may be more convenient to obtain just a subset of this information. In such cases, an older set of per-backend statistics access functions can be used; these are shown in Table 25.31. These access functions use a backend ID number, which ranges from one to the number of currently active backends. The function `pg_stat_get_backend_idset` provides a convenient way to generate one row for each active backend for invoking these functions. For example, to show the PIDs and current queries of all backends:

```
SELECT pg_stat_get_backend_pid(s.backendid) AS pid,
       pg_stat_get_backend_activity(s.backendid) AS query
FROM (SELECT pg_stat_get_backend_idset() AS backendid) AS s;
```

**Table 25.31. Per-Backend Statistics Functions**

<b>Function</b>	<b>Description</b>
<code>pg_stat_get_backend_idset () → setof integer</code>	Returns the set of currently active backend ID numbers (from 1 to the number of active backends).
<code>pg_stat_get_backend_activity ( integer ) → text</code>	Returns the text of this backend's most recent query.
<code>pg_stat_get_backend_activity_start ( integer ) → timestamp with time zone</code>	Returns the time when the backend's most recent query was started.
<code>pg_stat_get_backend_client_addr ( integer ) → inet</code>	Returns the IP address of the client connected to this backend.

Function	Description
<code>pg_stat_get_backend_client_port ( integer ) → integer</code>	Returns the TCP port number that the client is using for communication.
<code>pg_stat_get_backend_dbid ( integer ) → oid</code>	Returns the OID of the database this backend is connected to.
<code>pg_stat_get_backend_pid ( integer ) → integer</code>	Returns the process ID of this backend.
<code>pg_stat_get_backend_start ( integer ) → timestamp with time zone</code>	Returns the time when this process was started.
<code>pg_stat_get_backend_userid ( integer ) → oid</code>	Returns the OID of the user logged into this backend.
<code>pg_stat_get_backend_wait_event_type ( integer ) → text</code>	Returns the wait event type name if this backend is currently waiting, otherwise NULL. See Table 25.4 for details.
<code>pg_stat_get_backend_wait_event ( integer ) → text</code>	Returns the wait event name if this backend is currently waiting, otherwise NULL. See Table 25.5 through Table 25.13.
<code>pg_stat_get_backend_xact_start ( integer ) → timestamp with time zone</code>	Returns the time when the backend's current transaction was started.

## 25.3. Viewing Locks

Another useful tool for monitoring database activity is the `pg_locks` system table. It allows the database administrator to view information about the outstanding locks in the lock manager. For example, this capability can be used to:

- View all the locks currently outstanding, all the locks on relations in a particular database, all the locks on a particular relation, or all the locks held by a particular LightDB session.
- Determine the relation in the current database with the most ungranted locks (which might be a source of contention among database clients).
- Determine the effect of lock contention on overall database performance, as well as the extent to which contention varies with overall database traffic.

Details of the `pg_locks` view appear in Section 48.81. For more information on locking and managing concurrency with LightDB, refer to Chapter 13.

## 25.4. Progress Reporting

LightDB has the ability to report the progress of certain commands during command execution. Currently, the only commands which support progress reporting are `ANALYZE`, `CLUSTER`, `CREATE INDEX`, `VACUUM`, and `BASE_BACKUP` (i.e., replication command that `lt_basebackup` issues to take a base backup). This may be expanded in the future.

### 25.4.1. ANALYZE Progress Reporting

Whenever `ANALYZE` is running, the `pg_stat_progress_analyze` view will contain a row for each backend that is currently running that command. The tables below describe the information that will be reported and provide information about how to interpret it.

**Table 25.32. pg\_stat\_progress\_analyze View**

<b>Column Type</b>	<b>Description</b>
pid integer	Process ID of backend.
datid oid	OID of the database to which this backend is connected.
datname name	Name of the database to which this backend is connected.
relid oid	OID of the table being analyzed.
phase text	Current processing phase. See Table 25.33.
sample_blks_total bigint	Total number of heap blocks that will be sampled.
sample_blks_scanned bigint	Number of heap blocks scanned.
ext_stats_total bigint	Number of extended statistics.
ext_stats_computed bigint	Number of extended statistics computed. This counter only advances when the phase is computing extended statistics.
child_tables_total bigint	Number of child tables.
child_tables_done bigint	Number of child tables scanned. This counter only advances when the phase is acquiring inherited sample rows.
current_child_table_relid oid	OID of the child table currently being scanned. This field is only valid when the phase is acquiring inherited sample rows.

**Table 25.33. ANALYZE Phases**

<b>Phase</b>	<b>Description</b>
initializing	The command is preparing to begin scanning the heap. This phase is expected to be very brief.
acquiring sample rows	The command is currently scanning the table given by relid to obtain sample rows.
acquiring inherited sample rows	The command is currently scanning child tables to obtain sample rows. Columns child_tables_total, child_tables_done, and current_child_table_relid contain the progress information for this phase.
computing statistics	The command is computing statistics from the sample rows obtained during the table scan.
computing extended statistics	The command is computing extended statistics from the sample rows obtained during the table scan.
finalizing analyze	The command is updating pg_class. When this phase is completed, ANALYZE will end.

**Note**

Note that when `ANALYZE` is run on a partitioned table, all of its partitions are also recursively analyzed as also mentioned in `ANALYZE`. In that case, `ANALYZE` progress is reported first for the parent table, whereby its inheritance statistics are collected, followed by that for each partition.

**25.4.2. CREATE INDEX Progress Reporting**

Whenever `CREATE INDEX` or `REINDEX` is running, the `pg_stat_progress_create_index` view will contain one row for each backend that is currently creating indexes. The tables below describe the information that will be reported and provide information about how to interpret it.

**Table 25.34. `pg_stat_progress_create_index` View**

<b>Column</b>	<b>Type</b>	<b>Description</b>
<code>pid</code>	integer	Process ID of backend.
<code>datid</code>	oid	OID of the database to which this backend is connected.
<code>datname</code>	name	Name of the database to which this backend is connected.
<code>relid</code>	oid	OID of the table on which the index is being created.
<code>index_relid</code>	oid	OID of the index being created or reindexed. During a non-concurrent <code>CREATE INDEX</code> , this is 0.
<code>command</code>	text	The command that is running: <code>CREATE INDEX</code> , <code>CREATE INDEX CONCURRENTLY</code> , <code>REINDEX</code> , or <code>REINDEX CONCURRENTLY</code> .
<code>phase</code>	text	Current processing phase of index creation. See Table 25.35.
<code>lockers_total</code>	bigint	Total number of lockers to wait for, when applicable.
<code>lockers_done</code>	bigint	Number of lockers already waited for.
<code>current_locker_pid</code>	bigint	Process ID of the locker currently being waited for.
<code>blocks_total</code>	bigint	Total number of blocks to be processed in the current phase.
<code>blocks_done</code>	bigint	Number of blocks already processed in the current phase.
<code>tuples_total</code>	bigint	Total number of tuples to be processed in the current phase.
<code>tuples_done</code>	bigint	Number of tuples already processed in the current phase.
<code>partitions_total</code>	bigint	When creating an index on a partitioned table, this column is set to the total number of partitions on which the index is to be created.



Column Type	Description
partitions_done bigint	When creating an index on a partitioned table, this column is set to the number of partitions on which the index has been completed.

**Table 25.35. CREATE INDEX Phases**

Phase	Description
initializing	CREATE INDEX or REINDEX is preparing to create the index. This phase is expected to be very brief.
waiting for writers before build	CREATE INDEX CONCURRENTLY or REINDEX CONCURRENTLY is waiting for transactions with write locks that can potentially see the table to finish. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.
building index	The index is being built by the access method-specific code. In this phase, access methods that support progress reporting fill in their own progress data, and the subphase is indicated in this column. Typically, blocks_total and blocks_done will contain progress data, as well as potentially tuples_total and tuples_done.
waiting for writers before validation	CREATE INDEX CONCURRENTLY or REINDEX CONCURRENTLY is waiting for transactions with write locks that can potentially write into the table to finish. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.
index validation: scanning index	CREATE INDEX CONCURRENTLY is scanning the index searching for tuples that need to be validated. This phase is skipped when not in concurrent mode. Columns blocks_total (set to the total size of the index) and blocks_done contain the progress information for this phase.
index validation: sorting tuples	CREATE INDEX CONCURRENTLY is sorting the output of the index scanning phase.
index validation: scanning table	CREATE INDEX CONCURRENTLY is scanning the table to validate the index tuples collected in the previous two phases. This phase is skipped when not in concurrent mode. Columns blocks_total (set to the total size of the table) and blocks_done contain the progress information for this phase.
waiting for old snapshots	CREATE INDEX CONCURRENTLY or REINDEX CONCURRENTLY is waiting for transactions that can potentially see the table to release their snapshots. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.
waiting for readers before marking dead	REINDEX CONCURRENTLY is waiting for transactions with read locks on the table to finish, before marking the old index dead. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.

Phase	Description
waiting for readers before dropping	REINDEX CONCURRENTLY is waiting for transactions with read locks on the table to finish, before dropping the old index. This phase is skipped when not in concurrent mode. Columns <code>lockers_total</code> , <code>lockers_done</code> and <code>current_locker_pid</code> contain the progress information for this phase.

### 25.4.3. VACUUM Progress Reporting

Whenever VACUUM is running, the `pg_stat_progress_vacuum` view will contain one row for each backend (including autovacuum worker processes) that is currently vacuuming. The tables below describe the information that will be reported and provide information about how to interpret it. Progress for VACUUM FULL commands is reported via `pg_stat_progress_cluster` because both VACUUM FULL and CLUSTER rewrite the table, while regular VACUUM only modifies it in place. See Section 25.4.4.

**Table 25.36. `pg_stat_progress_vacuum` View**

Column Type	Description
<code>pid</code> integer	Process ID of backend.
<code>datid</code> oid	OID of the database to which this backend is connected.
<code>datname</code> name	Name of the database to which this backend is connected.
<code>relid</code> oid	OID of the table being vacuumed.
<code>phase</code> text	Current processing phase of vacuum. See Table 25.37.
<code>heap_blks_total</code> bigint	Total number of heap blocks in the table. This number is reported as of the beginning of the scan; blocks added later will not be (and need not be) visited by this VACUUM.
<code>heap_blks_scanned</code> bigint	Number of heap blocks scanned. Because the visibility map is used to optimize scans, some blocks will be skipped without inspection; skipped blocks are included in this total, so that this number will eventually become equal to <code>heap_blks_total</code> when the vacuum is complete. This counter only advances when the phase is scanning heap.
<code>heap_blks_vacuumed</code> bigint	Number of heap blocks vacuumed. Unless the table has no indexes, this counter only advances when the phase is vacuuming heap. Blocks that contain no dead tuples are skipped, so the counter may sometimes skip forward in large increments.
<code>index_vacuum_count</code> bigint	Number of completed index vacuum cycles.
<code>max_dead_tuples</code> bigint	Number of dead tuples that we can store before needing to perform an index vacuum cycle, based on <code>maintenance_work_mem</code> .
<code>num_dead_tuples</code> bigint	Number of dead tuples collected since the last index vacuum cycle.

**Table 25.37. VACUUM Phases**

Phase	Description
initializing	VACUUM is preparing to begin scanning the heap. This phase is expected to be very brief.
scanning heap	VACUUM is currently scanning the heap. It will prune and defragment each page if required, and possibly perform freezing activity. The <code>heap_blks_scanned</code> column can be used to monitor the progress of the scan.
vacuuming indexes	VACUUM is currently vacuuming the indexes. If a table has any indexes, this will happen at least once per vacuum, after the heap has been completely scanned. It may happen multiple times per vacuum if <code>maintenance_work_mem</code> (or, in the case of autovacuum, <code>autovacuum_work_mem</code> if set) is insufficient to store the number of dead tuples found.
vacuuming heap	VACUUM is currently vacuuming the heap. Vacuuming the heap is distinct from scanning the heap, and occurs after each instance of vacuuming indexes. If <code>heap_blks_scanned</code> is less than <code>heap_blks_total</code> , the system will return to scanning the heap after this phase is completed; otherwise, it will begin cleaning up indexes after this phase is completed.
cleaning up indexes	VACUUM is currently cleaning up indexes. This occurs after the heap has been completely scanned and all vacuuming of the indexes and the heap has been completed.
truncating heap	VACUUM is currently truncating the heap so as to return empty pages at the end of the relation to the operating system. This occurs after cleaning up indexes.
performing final cleanup	VACUUM is performing final cleanup. During this phase, VACUUM will vacuum the free space map, update statistics in <code>pg_class</code> , and report statistics to the statistics collector. When this phase is completed, VACUUM will end.

## 25.4.4. CLUSTER Progress Reporting

Whenever `CLUSTER` or `VACUUM FULL` is running, the `pg_stat_progress_cluster` view will contain a row for each backend that is currently running either command. The tables below describe the information that will be reported and provide information about how to interpret it.

**Table 25.38. pg\_stat\_progress\_cluster View**

Column	Type	Description
<code>pid</code>	integer	Process ID of backend.
<code>datid</code>	oid	OID of the database to which this backend is connected.
<code>datname</code>	name	Name of the database to which this backend is connected.
<code>relid</code>	oid	OID of the table being clustered.
<code>command</code>	text	The command that is running. Either <code>CLUSTER</code> or <code>VACUUM FULL</code> .
<code>phase</code>	text	

Column Type	Description
	Current processing phase. See Table 25.39.
cluster_index_reloid oid	If the table is being scanned using an index, this is the OID of the index being used; otherwise, it is zero.
heap_tuples_scanned bigint	Number of heap tuples scanned. This counter only advances when the phase is seq scanning heap, index scanning heap or writing new heap.
heap_tuples_written bigint	Number of heap tuples written. This counter only advances when the phase is seq scanning heap, index scanning heap or writing new heap.
heap_blks_total bigint	Total number of heap blocks in the table. This number is reported as of the beginning of seq scanning heap.
heap_blks_scanned bigint	Number of heap blocks scanned. This counter only advances when the phase is seq scanning heap.
index_rebuild_count bigint	Number of indexes rebuilt. This counter only advances when the phase is rebuilding index.

**Table 25.39. CLUSTER and VACUUM FULL Phases**

Phase	Description
initializing	The command is preparing to begin scanning the heap. This phase is expected to be very brief.
seq scanning heap	The command is currently scanning the table using a sequential scan.
index scanning heap	CLUSTER is currently scanning the table using an index scan.
sorting tuples	CLUSTER is currently sorting tuples.
writing new heap	CLUSTER is currently writing the new heap.
swapping relation files	The command is currently swapping newly-built files into place.
rebuilding index	The command is currently rebuilding an index.
performing final cleanup	The command is performing final cleanup. When this phase is completed, CLUSTER or VACUUM FULL will end.

## 25.4.5. Base Backup Progress Reporting

Whenever an application like `pg_basebackup` is taking a base backup, the `pg_stat_progress_basebackup` view will contain a row for each WAL sender process that is currently running the `BASE_BACKUP` replication command and streaming the backup. The tables below describe the information that will be reported and provide information about how to interpret it.

**Table 25.40. pg\_stat\_progress\_basebackup View**

Column Type	Description
pid integer	Process ID of a WAL sender process.

Column Type	Description
phase text	Current processing phase. See Table 25.41.
backup_total bigint	Total amount of data that will be streamed. This is estimated and reported as of the beginning of <code>streaming database files</code> phase. Note that this is only an approximation since the database may change during <code>streaming database files</code> phase and WAL log may be included in the backup later. This is always the same value as <code>backup_streamed</code> once the amount of data streamed exceeds the estimated total size. If the estimation is disabled in <code>pg_basebackup</code> (i.e., <code>--no-estimate-size</code> option is specified), this is NULL.
backup_streamed bigint	Amount of data streamed. This counter only advances when the phase is <code>streaming database files</code> or <code>transferring wal files</code> .
tablespaces_total bigint	Total number of tablespaces that will be streamed.
tablespaces_streamed bigint	Number of tablespaces streamed. This counter only advances when the phase is <code>streaming database files</code> .

**Table 25.41. Base Backup Phases**

Phase	Description
initializing	The WAL sender process is preparing to begin the backup. This phase is expected to be very brief.
waiting for checkpoint to finish	The WAL sender process is currently performing <code>pg_start_backup</code> to prepare to take a base backup, and waiting for the start-of-backup checkpoint to finish.
estimating backup size	The WAL sender process is currently estimating the total amount of database files that will be streamed as a base backup.
streaming database files	The WAL sender process is currently streaming database files as a base backup.
waiting for wal archiving to finish	The WAL sender process is currently performing <code>pg_stop_backup</code> to finish the backup, and waiting for all the WAL files required for the base backup to be successfully archived. If either <code>--wal-method=none</code> or <code>--wal-method=stream</code> is specified in <code>pg_basebackup</code> , the backup will end when this phase is completed.
transferring wal files	The WAL sender process is currently transferring all WAL logs generated during the backup. This phase occurs after <code>waiting for wal archiving to finish</code> phase if <code>--wal-method=fetch</code> is specified in <code>pg_basebackup</code> . The backup will end when this phase is completed.

## 25.5. Dynamic Tracing

LightDB provides facilities to support dynamic tracing of the database server. This allows an external utility to be called at specific points in the code and thereby trace execution.

A number of probes or trace points are already inserted into the source code. These probes are intended to be used by database developers and administrators. By default the probes are not compiled into LightDB; the user needs to explicitly tell the configure script to make the probes available.

Currently, the DTrace<sup>1</sup> utility is supported, which, at the time of this writing, is available on Solaris, macOS, FreeBSD, NetBSD, and Oracle Linux. The SystemTap<sup>2</sup> project for Linux provides a DTrace equivalent and can also be used. Supporting other dynamic tracing utilities is theoretically possible by changing the definitions for the macros in `src/include/utills/probes.h`.

## 25.5.1. Compiling for Dynamic Tracing

By default, probes are not available, so you will need to explicitly tell the configure script to make the probes available in LightDB. To include DTrace support specify `--enable-dtrace` to configure.

## 25.5.2. Built-in Probes

A number of standard probes are provided in the source code, as shown in Table 25.42; Table 25.43 shows the types used in the probes. More probes can certainly be added to enhance LightDB's observability.

**Table 25.42. Built-in DTrace Probes**

Name	Parameters	Description
<code>transaction-start</code>	<code>(LocalTransactionId)</code>	Probe that fires at the start of a new transaction. <code>arg0</code> is the transaction ID.
<code>transaction-commit</code>	<code>(LocalTransactionId)</code>	Probe that fires when a transaction completes successfully. <code>arg0</code> is the transaction ID.
<code>transaction-abort</code>	<code>(LocalTransactionId)</code>	Probe that fires when a transaction completes unsuccessfully. <code>arg0</code> is the transaction ID.
<code>query-start</code>	<code>(const char *)</code>	Probe that fires when the processing of a query is started. <code>arg0</code> is the query string.
<code>query-done</code>	<code>(const char *)</code>	Probe that fires when the processing of a query is complete. <code>arg0</code> is the query string.
<code>query-parse-start</code>	<code>(const char *)</code>	Probe that fires when the parsing of a query is started. <code>arg0</code> is the query string.
<code>query-parse-done</code>	<code>(const char *)</code>	Probe that fires when the parsing of a query is complete. <code>arg0</code> is the query string.
<code>query-rewrite-start</code>	<code>(const char *)</code>	Probe that fires when the rewriting of a query is started. <code>arg0</code> is the query string.
<code>query-rewrite-done</code>	<code>(const char *)</code>	Probe that fires when the rewriting of a query is complete. <code>arg0</code> is the query string.
<code>query-plan-start</code>	<code>()</code>	Probe that fires when the planning of a query is started.
<code>query-plan-done</code>	<code>()</code>	Probe that fires when the planning of a query is complete.

<sup>1</sup> <https://en.wikipedia.org/wiki/DTrace>

<sup>2</sup> <https://sourceware.org/systemtap/>

Name	Parameters	Description
query-execute-start	( )	Probe that fires when the execution of a query is started.
query-execute-done	( )	Probe that fires when the execution of a query is complete.
statement-status	(const char *)	Probe that fires anytime the server process updates its <code>pg_stat_activity.status</code> . <code>arg0</code> is the new status string.
checkpoint-start	(int)	Probe that fires when a checkpoint is started. <code>arg0</code> holds the bitwise flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
checkpoint-done	(int, int, int, int, int)	Probe that fires when a checkpoint is complete. (The probes listed next fire in sequence during checkpoint processing.) <code>arg0</code> is the number of buffers written. <code>arg1</code> is the total number of buffers. <code>arg2</code> , <code>arg3</code> and <code>arg4</code> contain the number of WAL files added, removed and recycled respectively.
clog-checkpoint-start	(bool)	Probe that fires when the CLOG portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
clog-checkpoint-done	(bool)	Probe that fires when the CLOG portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>clog-checkpoint-start</code> .
subtrans-checkpoint-start	(bool)	Probe that fires when the SUBTRANS portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
subtrans-checkpoint-done	(bool)	Probe that fires when the SUBTRANS portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>subtrans-checkpoint-start</code> .
multixact-checkpoint-start	(bool)	Probe that fires when the MultiXact portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
multixact-checkpoint-done	(bool)	Probe that fires when the MultiXact portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>multixact-checkpoint-start</code> .
buffer-checkpoint-start	(int)	Probe that fires when the buffer-writing portion of a checkpoint is started. <code>arg0</code> holds the bitwise

Name	Parameters	Description
		flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
buffer-sync-start	(int, int)	Probe that fires when we begin to write dirty buffers during checkpoint (after identifying which buffers must be written). arg0 is the total number of buffers. arg1 is the number that are currently dirty and need to be written.
buffer-sync-written	(int)	Probe that fires after each buffer is written during checkpoint. arg0 is the ID number of the buffer.
buffer-sync-done	(int, int, int)	Probe that fires when all dirty buffers have been written. arg0 is the total number of buffers. arg1 is the number of buffers actually written by the checkpoint process. arg2 is the number that were expected to be written (arg1 of buffer-sync-start); any difference reflects other processes flushing buffers during the checkpoint.
buffer-checkpoint-sync-start	()	Probe that fires after dirty buffers have been written to the kernel, and before starting to issue fsync requests.
buffer-checkpoint-done	()	Probe that fires when syncing of buffers to disk is complete.
twophase-checkpoint-start	()	Probe that fires when the two-phase portion of a checkpoint is started.
twophase-checkpoint-done	()	Probe that fires when the two-phase portion of a checkpoint is complete.
buffer-read-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, bool)	Probe that fires when a buffer read is started. arg0 and arg1 contain the fork and block numbers of the page (but arg1 will be -1 if this is a relation extension request). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read.
buffer-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, bool, bool)	Probe that fires when a buffer read is complete. arg0 and arg1 contain the fork and block numbers of the page (if this is a relation extension



Name	Parameters	Description
		request, arg1 now contains the block number of the newly added block). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read. arg7 is true if the buffer was found in the pool, false if not.
buffer-flush-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires before issuing any write request for a shared buffer. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.
buffer-flush-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a write request is complete. (Note that this just reflects the time to pass the data to the kernel; it's typically not actually been written to disk yet.) The arguments are the same as for buffer-flush-start.
buffer-write-dirty-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a server process begins to write a dirty buffer. (If this happens often, it implies that shared_buffers is too small or the background writer control parameters need adjustment.) arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.
buffer-write-dirty-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a dirty-buffer write is complete. The arguments are the same as for buffer-write-dirty-start.
wal-buffer-write-dirty-start	()	Probe that fires when a server process begins to write a dirty WAL buffer because no more WAL buffer space is available. (If this happens often, it implies that wal_buffers is too small.)
wal-buffer-write-dirty-done	()	Probe that fires when a dirty WAL buffer write is complete.
wal-insert	(unsigned char, unsigned char)	Probe that fires when a WAL record is inserted. arg0 is the resource

Name	Parameters	Description
		manager (rmid) for the record. arg1 contains the info flags.
wal-switch	( )	Probe that fires when a WAL segment switch is requested.
smgr-md-read-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to read a block from a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.
smgr-md-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block read is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually read, while arg7 is the number requested (if these are different it indicates trouble).
smgr-md-write-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to write a block to a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.
smgr-md-write-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block write is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually written, while arg7 is the number requested (if these are different it indicates trouble).

Name	Parameters	Description
sort-start	(int, bool, int, int, bool, int)	Probe that fires when a sort operation is started. arg0 indicates heap, index or datum sort. arg1 is true for unique-value enforcement. arg2 is the number of key columns. arg3 is the number of kilobytes of work memory allowed. arg4 is true if random access to the sort result is required. arg5 indicates serial when 0, parallel worker when 1, or parallel leader when 2.
sort-done	(bool, long)	Probe that fires when a sort is complete. arg0 is true for external sort, false for internal sort. arg1 is the number of disk blocks used for an external sort, or kilobytes of memory used for an internal sort.
lwlock-acquire	(char *, LWLockMode)	Probe that fires when an LWLock has been acquired. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-release	(char *)	Probe that fires when an LWLock has been released (but note that any released waiters have not yet been awakened). arg0 is the LWLock's tranche.
lwlock-wait-start	(char *, LWLockMode)	Probe that fires when an LWLock was not immediately available and a server process has begun to wait for the lock to become available. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-wait-done	(char *, LWLockMode)	Probe that fires when a server process has been released from its wait for an LWLock (it does not actually have the lock yet). arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-condacquire	(char *, LWLockMode)	Probe that fires when an LWLock was successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-condacquire-fail	(char *, LWLockMode)	Probe that fires when an LWLock was not successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.

Name	Parameters	Description
lock-wait-start	(unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has begun to wait because the lock is not available. arg0 through arg3 are the tag fields identifying the object being locked. arg4 indicates the type of object being locked. arg5 indicates the lock type being requested.
lock-wait-done	(unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has finished waiting (i.e., has acquired the lock). The arguments are the same as for lock-wait-start.
deadlock-found	()	Probe that fires when a deadlock is found by the deadlock detector.

**Table 25.43. Defined Types Used in Probe Parameters**

Type	Definition
LocalTransactionId	unsigned int
LWLockMode	int
LOCKMODE	int
BlockNumber	unsigned int
Oid	unsigned int
ForkNumber	int
bool	unsigned char

### 25.5.3. Using Probes

The example below shows a DTrace script for analyzing transaction counts in the system, as an alternative to snapshotting `pg_stat_database` before and after a performance test:

```
#!/usr/sbin/dtrace -qs

postgresql$1:::transaction-start
{
    @start["Start"] = count();
    self->ts = timestamp;
}

postgresql$1:::transaction-abort
{
    @abort["Abort"] = count();
}

postgresql$1:::transaction-commit
/self->ts/
{
    @commit["Commit"] = count();
    @time["Total time (ns)"] = sum(timestamp - self->ts);
    self->ts=0;
}
```

```
}
```

When executed, the example D script gives output such as:

```
# ./txn_count.d `pgrep -n lightdb` or ./txn_count.d <PID>
^C

Start                71
Commit               70
Total time (ns)      2312105013
```

### Note

SystemTap uses a different notation for trace scripts than DTrace does, even though the underlying trace points are compatible. One point worth noting is that at this writing, SystemTap scripts must reference probe names using double underscores in place of hyphens. This is expected to be fixed in future SystemTap releases.

You should remember that DTrace scripts need to be carefully written and debugged, otherwise the trace information collected might be meaningless. In most cases where problems are found it is the instrumentation that is at fault, not the underlying system. When discussing information found using dynamic tracing, be sure to enclose the script used to allow that too to be checked and discussed.

## 25.5.4. Defining New Probes

New probes can be defined within the code wherever the developer desires, though this will require a recompilation. Below are the steps for inserting new probes:

1. Decide on probe names and data to be made available through the probes
2. Add the probe definitions to `src/backend/utils/probes.d`
3. Include `pg_trace.h` if it is not already present in the module(s) containing the probe points, and insert `TRACE_POSTGRESQL` probe macros at the desired locations in the source code
4. Recompile and verify that the new probes are available

**Example:** Here is an example of how you would add a probe to trace all new transactions by transaction ID.

1. Decide that the probe will be named `transaction_start` and requires a parameter of type `LocalTransactionId`
2. Add the probe definition to `src/backend/utils/probes.d`:

```
probe transaction__start(LocalTransactionId);
```

Note the use of the double underline in the probe name. In a DTrace script using the probe, the double underline needs to be replaced with a hyphen, so `transaction-start` is the name to document for users.

3. At compile time, `transaction__start` is converted to a macro called `TRACE_POSTGRESQL_TRANSACTION_START` (notice the underscores are single here), which is available by including `pg_trace.h`. Add the macro call to the appropriate location in the source code. In this case, it looks like the following:

```
TRACE_POSTGRESQL_TRANSACTION_START(vxid.localTransactionId);
```

4. After recompiling and running the new binary, check that your newly added probe is available by executing the following DTrace command. You should see similar output:

```
# dtrace -ln transaction-start
   ID   PROVIDER      MODULE      FUNCTION NAME
18705 postgresql49878 postgres  StartTransactionCommand
transaction-start
18755 postgresql49877 postgres  StartTransactionCommand
transaction-start
18805 postgresql49876 postgres  StartTransactionCommand
transaction-start
18855 postgresql49875 postgres  StartTransactionCommand
transaction-start
18986 postgresql49873 postgres  StartTransactionCommand
transaction-start
```

There are a few things to be careful about when adding trace macros to the C code:

- You should take care that the data types specified for a probe's parameters match the data types of the variables used in the macro. Otherwise, you will get compilation errors.
- On most platforms, if LightDB is built with `--enable-dtrace`, the arguments to a trace macro will be evaluated whenever control passes through the macro, *even if no tracing is being done*. This is usually not worth worrying about if you are just reporting the values of a few local variables. But beware of putting expensive function calls into the arguments. If you need to do that, consider protecting the macro with a check to see if the trace is actually enabled:

```
if (TRACE_POSTGRESQL_TRANSACTION_START_ENABLED())
    TRACE_POSTGRESQL_TRANSACTION_START(some_function(...));
```

Each trace macro has a corresponding ENABLED macro.

---

# Chapter 26. Monitoring Disk Usage

This chapter discusses how to monitor the disk usage of a LightDB database system.

## 26.1. Determining Disk Usage

Each table has a primary heap disk file where most of the data is stored. If the table has any columns with potentially-wide values, there also might be a TOAST file associated with the table, which is used to store values too wide to fit comfortably in the main table (see Section 64.2). There will be one valid index on the TOAST table, if present. There also might be indexes associated with the base table. Each table and index is stored in a separate disk file — possibly more than one file, if the file would exceed one gigabyte. Naming conventions for these files are described in Section 64.1.

You can monitor disk space in three ways: using the SQL functions listed in Table 9.91, using the `oid2name` module, or using manual inspection of the system catalogs. The SQL functions are the easiest to use and are generally recommended. The remainder of this section shows how to do it by inspection of the system catalogs.

Using `ltsql` on a recently vacuumed or analyzed database, you can issue queries to see the disk usage of any table:

```
SELECT pg_relation_filepath(oid), relpages FROM pg_class WHERE
       relname = 'customer';
```

```
pg_relation_filepath | relpages
-----+-----
base/16384/16806    |         60
(1 row)
```

Each page is typically 8 kilobytes. (Remember, `relpages` is only updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.) The file path name is of interest if you want to examine the table's disk file directly.

To show the space used by TOAST tables, use a query like the following:

```
SELECT relname, relpages
FROM pg_class,
     (SELECT reltoastrelid
      FROM pg_class
      WHERE relname = 'customer') AS ss
WHERE oid = ss.reltoastrelid OR
       oid = (SELECT indexrelid
              FROM pg_index
              WHERE indrelid = ss.reltoastrelid)
ORDER BY relname;
```

```
relname          | relpages
-----+-----
pg_toast_16806   |         0
pg_toast_16806_index |         1
```

You can easily display index sizes, too:

```
SELECT c2.relname, c2.relpages
```

```
FROM pg_class c, pg_class c2, pg_index i
WHERE c.relname = 'customer' AND
      c.oid = i.indrelid AND
      c2.oid = i.indexrelid
ORDER BY c2.relname;
```

relname	relpages
customer_id_index	26

It is easy to find your largest tables and indexes using this information:

```
SELECT relname, relpages
FROM pg_class
ORDER BY relpages DESC;
```

relname	relpages
bigtable	3290
customer	3144

## 26.2. Disk Full Failure

The most important disk monitoring task of a database administrator is to make sure the disk doesn't become full. A filled data disk will not result in data corruption, but it might prevent useful activity from occurring. If the disk holding the WAL files grows full, database server panic and consequent shutdown might occur.

If you cannot free up additional space on the disk by deleting other things, you can move some of the database files to other file systems by making use of tablespaces. See Section 20.6 for more information about that.

### Tip

Some file systems perform badly when they are almost full, so do not wait until the disk is completely full to take action.

If your system supports per-user disk quotas, then the database will naturally be subject to whatever quota is placed on the user the server runs as. Exceeding the quota will have the same bad effects as running out of disk space entirely.



---

# Chapter 27. Reliability and the Write-Ahead Log

This chapter explains how the Write-Ahead Log is used to obtain efficient, reliable operation.

## 27.1. Reliability

Reliability is an important property of any serious database system, and LightDB does everything possible to guarantee reliable operation. One aspect of reliable operation is that all data recorded by a committed transaction should be stored in a nonvolatile area that is safe from power loss, operating system failure, and hardware failure (except failure of the nonvolatile area itself, of course). Successfully writing the data to the computer's permanent storage (disk drive or equivalent) ordinarily meets this requirement. In fact, even if a computer is fatally damaged, if the disk drives survive they can be moved to another computer with similar hardware and all committed transactions will remain intact.

While forcing data to the disk platters periodically might seem like a simple operation, it is not. Because disk drives are dramatically slower than main memory and CPUs, several layers of caching exist between the computer's main memory and the disk platters. First, there is the operating system's buffer cache, which caches frequently requested disk blocks and combines disk writes. Fortunately, all operating systems give applications a way to force writes from the buffer cache to disk, and LightDB uses those features. (See the `wal_sync_method` parameter to adjust how this is done.)

Next, there might be a cache in the disk drive controller; this is particularly common on RAID controller cards. Some of these caches are *write-through*, meaning writes are sent to the drive as soon as they arrive. Others are *write-back*, meaning data is sent to the drive at some later time. Such caches can be a reliability hazard because the memory in the disk controller cache is volatile, and will lose its contents in a power failure. Better controller cards have *battery-backup units* (BBUs), meaning the card has a battery that maintains power to the cache in case of system power loss. After power is restored the data will be written to the disk drives.

And finally, most disk drives have caches. Some are write-through while some are write-back, and the same concerns about data loss exist for write-back drive caches as for disk controller caches. Consumer-grade IDE and SATA drives are particularly likely to have write-back caches that will not survive a power failure. Many solid-state drives (SSD) also have volatile write-back caches.

These caches can typically be disabled; however, the method for doing this varies by operating system and drive type:

- On Linux, IDE and SATA drives can be queried using `hdparm -I`; write caching is enabled if there is a `*` next to `Write cache`. `hdparm -W 0` can be used to turn off write caching. SCSI drives can be queried using `sdparm`<sup>1</sup>. Use `sdparm --get=WCE` to check whether the write cache is enabled and `sdparm --clear=WCE` to disable it.
- On FreeBSD, IDE drives can be queried using `atacontrol` and write caching turned off using `hw.ata.wc=0` in `/boot/loader.conf`; SCSI drives can be queried using `camcontrol identify`, and the write cache both queried and changed using `sdparm` when available.
- On Solaris, the disk write cache is controlled by `format -e`. (The Solaris ZFS file system is safe with disk write-cache enabled because it issues its own disk cache flush commands.)
- On Windows, if `wal_sync_method` is `open_datasync` (the default), write caching can be disabled by unchecking `My Computer\Open\disk drive\Properties\Hardware\Properties\Policies\Enable write caching on the disk`. Alternatively, set `wal_sync_method` to `fsync` or `fsync_writethrough`, which prevent write caching.

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<sup>1</sup> <http://sg.danny.cz/sg/sdparm.html>

- On macOS, write caching can be prevented by setting `wal_sync_method` to `fsync_writethrough`.

Recent SATA drives (those following ATAPI-6 or later) offer a drive cache flush command (`FLUSH CACHE EXT`), while SCSI drives have long supported a similar command `SYNCHRONIZE CACHE`. These commands are not directly accessible to LightDB, but some file systems (e.g., ZFS, ext4) can use them to flush data to the platters on write-back-enabled drives. Unfortunately, such file systems behave suboptimally when combined with battery-backup unit (BBU) disk controllers. In such setups, the synchronize command forces all data from the controller cache to the disks, eliminating much of the benefit of the BBU. You can run the `lt_test_fsync` program to see if you are affected. If you are affected, the performance benefits of the BBU can be regained by turning off write barriers in the file system or reconfiguring the disk controller, if that is an option. If write barriers are turned off, make sure the battery remains functional; a faulty battery can potentially lead to data loss. Hopefully file system and disk controller designers will eventually address this suboptimal behavior.

When the operating system sends a write request to the storage hardware, there is little it can do to make sure the data has arrived at a truly non-volatile storage area. Rather, it is the administrator's responsibility to make certain that all storage components ensure integrity for both data and file-system metadata. Avoid disk controllers that have non-battery-backed write caches. At the drive level, disable write-back caching if the drive cannot guarantee the data will be written before shutdown. If you use SSDs, be aware that many of these do not honor cache flush commands by default. You can test for reliable I/O subsystem behavior using `diskchecker.pl`<sup>2</sup>.

Another risk of data loss is posed by the disk platter write operations themselves. Disk platters are divided into sectors, commonly 512 bytes each. Every physical read or write operation processes a whole sector. When a write request arrives at the drive, it might be for some multiple of 512 bytes (LightDB typically writes 8192 bytes, or 16 sectors, at a time), and the process of writing could fail due to power loss at any time, meaning some of the 512-byte sectors were written while others were not. To guard against such failures, LightDB periodically writes full page images to permanent WAL storage *before* modifying the actual page on disk. By doing this, during crash recovery LightDB can restore partially-written pages from WAL. If you have file-system software that prevents partial page writes (e.g., ZFS), you can turn off this page imaging by turning off the `full_page_writes` parameter. Battery-Backed Unit (BBU) disk controllers do not prevent partial page writes unless they guarantee that data is written to the BBU as full (8kB) pages.

LightDB also protects against some kinds of data corruption on storage devices that may occur because of hardware errors or media failure over time, such as reading/writing garbage data.

- Each individual record in a WAL file is protected by a CRC-32 (32-bit) check that allows us to tell if record contents are correct. The CRC value is set when we write each WAL record and checked during crash recovery, archive recovery and replication.
- Data pages are not currently checksummed by default, though full page images recorded in WAL records will be protected; see `initdb` for details about enabling data page checksums.
- Internal data structures such as `lt_xact`, `lt_subtrans`, `lt_multixact`, `lt_serial`, `lt_notify`, `lt_stat`, `lt_snapshots` are not directly checksummed, nor are pages protected by full page writes. However, where such data structures are persistent, WAL records are written that allow recent changes to be accurately rebuilt at crash recovery and those WAL records are protected as discussed above.
- Individual state files in `lt_twophase` are protected by CRC-32.
- Temporary data files used in larger SQL queries for sorts, materializations and intermediate results are not currently checksummed, nor will WAL records be written for changes to those files.

LightDB does not protect against correctable memory errors and it is assumed you will operate using RAM that uses industry standard Error Correcting Codes (ECC) or better protection.

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<sup>2</sup> <https://brad.livejournal.com/2116715.html>

## 27.2. Write-Ahead Logging (WAL)

*Write-Ahead Logging* (WAL) is a standard method for ensuring data integrity. A detailed description can be found in most (if not all) books about transaction processing. Briefly, WAL's central concept is that changes to data files (where tables and indexes reside) must be written only after those changes have been logged, that is, after log records describing the changes have been flushed to permanent storage. If we follow this procedure, we do not need to flush data pages to disk on every transaction commit, because we know that in the event of a crash we will be able to recover the database using the log: any changes that have not been applied to the data pages can be redone from the log records. (This is roll-forward recovery, also known as REDO.)

### Tip

Because WAL restores database file contents after a crash, journaled file systems are not necessary for reliable storage of the data files or WAL files. In fact, journaling overhead can reduce performance, especially if journaling causes file system *data* to be flushed to disk. Fortunately, data flushing during journaling can often be disabled with a file system mount option, e.g., `data=writeback` on a Linux ext3 file system. Journaled file systems do improve boot speed after a crash.

Using WAL results in a significantly reduced number of disk writes, because only the log file needs to be flushed to disk to guarantee that a transaction is committed, rather than every data file changed by the transaction. The log file is written sequentially, and so the cost of syncing the log is much less than the cost of flushing the data pages. This is especially true for servers handling many small transactions touching different parts of the data store. Furthermore, when the server is processing many small concurrent transactions, one `fsync` of the log file may suffice to commit many transactions.

WAL also makes it possible to support on-line backup and point-in-time recovery, as described in Section 23.3. By archiving the WAL data we can support reverting to any time instant covered by the available WAL data: we simply install a prior physical backup of the database, and replay the WAL log just as far as the desired time. What's more, the physical backup doesn't have to be an instantaneous snapshot of the database state — if it is made over some period of time, then replaying the WAL log for that period will fix any internal inconsistencies.

## 27.3. Asynchronous Commit

*Asynchronous commit* is an option that allows transactions to complete more quickly, at the cost that the most recent transactions may be lost if the database should crash. In many applications this is an acceptable trade-off.

As described in the previous section, transaction commit is normally *synchronous*: the server waits for the transaction's WAL records to be flushed to permanent storage before returning a success indication to the client. The client is therefore guaranteed that a transaction reported to be committed will be preserved, even in the event of a server crash immediately after. However, for short transactions this delay is a major component of the total transaction time. Selecting asynchronous commit mode means that the server returns success as soon as the transaction is logically completed, before the WAL records it generated have actually made their way to disk. This can provide a significant boost in throughput for small transactions.

Asynchronous commit introduces the risk of data loss. There is a short time window between the report of transaction completion to the client and the time that the transaction is truly committed (that is, it is guaranteed not to be lost if the server crashes). Thus asynchronous commit should not be used if the client will take external actions relying on the assumption that the transaction will be remembered. As an example, a bank would certainly not use asynchronous commit for a transaction recording an ATM's dispensing of cash. But in many scenarios, such as event logging, there is no need for a strong guarantee of this kind.

The risk that is taken by using asynchronous commit is of data loss, not data corruption. If the database should crash, it will recover by replaying WAL up to the last record that was flushed. The database will therefore be restored to a self-consistent state, but any transactions that were not yet flushed to disk will not be reflected in that state. The net effect is therefore loss of the last few transactions. Because the transactions are replayed in commit order, no inconsistency can be introduced — for example, if transaction B made changes relying on the effects of a previous transaction A, it is not possible for A's effects to be lost while B's effects are preserved.

The user can select the commit mode of each transaction, so that it is possible to have both synchronous and asynchronous commit transactions running concurrently. This allows flexible trade-offs between performance and certainty of transaction durability. The commit mode is controlled by the user-settable parameter `synchronous_commit`, which can be changed in any of the ways that a configuration parameter can be set. The mode used for any one transaction depends on the value of `synchronous_commit` when transaction commit begins.

Certain utility commands, for instance `DROP TABLE`, are forced to commit synchronously regardless of the setting of `synchronous_commit`. This is to ensure consistency between the server's file system and the logical state of the database. The commands supporting two-phase commit, such as `PREPARE TRANSACTION`, are also always synchronous.

If the database crashes during the risk window between an asynchronous commit and the writing of the transaction's WAL records, then changes made during that transaction *will* be lost. The duration of the risk window is limited because a background process (the “WAL writer”) flushes unwritten WAL records to disk every `wal_writer_delay` milliseconds. The actual maximum duration of the risk window is three times `wal_writer_delay` because the WAL writer is designed to favor writing whole pages at a time during busy periods.

### Caution

An immediate-mode shutdown is equivalent to a server crash, and will therefore cause loss of any unflushed asynchronous commits.

Asynchronous commit provides behavior different from setting `fsync = off`. `fsync` is a server-wide setting that will alter the behavior of all transactions. It disables all logic within LightDB that attempts to synchronize writes to different portions of the database, and therefore a system crash (that is, a hardware or operating system crash, not a failure of LightDB itself) could result in arbitrarily bad corruption of the database state. In many scenarios, asynchronous commit provides most of the performance improvement that could be obtained by turning off `fsync`, but without the risk of data corruption.

`commit_delay` also sounds very similar to asynchronous commit, but it is actually a synchronous commit method (in fact, `commit_delay` is ignored during an asynchronous commit). `commit_delay` causes a delay just before a transaction flushes WAL to disk, in the hope that a single flush executed by one such transaction can also serve other transactions committing at about the same time. The setting can be thought of as a way of increasing the time window in which transactions can join a group about to participate in a single flush, to amortize the cost of the flush among multiple transactions.

## 27.4. WAL Configuration

There are several WAL-related configuration parameters that affect database performance. This section explains their use. Consult Chapter 17 for general information about setting server configuration parameters.

*Checkpoints* are points in the sequence of transactions at which it is guaranteed that the heap and index data files have been updated with all information written before that checkpoint. At checkpoint time, all dirty data pages are flushed to disk and a special checkpoint record is written to the log file. (The

change records were previously flushed to the WAL files.) In the event of a crash, the crash recovery procedure looks at the latest checkpoint record to determine the point in the log (known as the redo record) from which it should start the REDO operation. Any changes made to data files before that point are guaranteed to be already on disk. Hence, after a checkpoint, log segments preceding the one containing the redo record are no longer needed and can be recycled or removed. (When WAL archiving is being done, the log segments must be archived before being recycled or removed.)

The checkpoint requirement of flushing all dirty data pages to disk can cause a significant I/O load. For this reason, checkpoint activity is throttled so that I/O begins at checkpoint start and completes before the next checkpoint is due to start; this minimizes performance degradation during checkpoints.

The server's checkpointer process automatically performs a checkpoint every so often. A checkpoint is begun every `checkpoint_timeout` seconds, or if `max_wal_size` is about to be exceeded, whichever comes first. The default settings are 5 minutes and 1 GB, respectively. If no WAL has been written since the previous checkpoint, new checkpoints will be skipped even if `checkpoint_timeout` has passed. (If WAL archiving is being used and you want to put a lower limit on how often files are archived in order to bound potential data loss, you should adjust the `archive_timeout` parameter rather than the checkpoint parameters.) It is also possible to force a checkpoint by using the SQL command `CHECKPOINT`.

Reducing `checkpoint_timeout` and/or `max_wal_size` causes checkpoints to occur more often. This allows faster after-crash recovery, since less work will need to be redone. However, one must balance this against the increased cost of flushing dirty data pages more often. If `full_page_writes` is set (as is the default), there is another factor to consider. To ensure data page consistency, the first modification of a data page after each checkpoint results in logging the entire page content. In that case, a smaller checkpoint interval increases the volume of output to the WAL log, partially negating the goal of using a smaller interval, and in any case causing more disk I/O.

Checkpoints are fairly expensive, first because they require writing out all currently dirty buffers, and second because they result in extra subsequent WAL traffic as discussed above. It is therefore wise to set the checkpointing parameters high enough so that checkpoints don't happen too often. As a simple sanity check on your checkpointing parameters, you can set the `checkpoint_warning` parameter. If checkpoints happen closer together than `checkpoint_warning` seconds, a message will be output to the server log recommending increasing `max_wal_size`. Occasional appearance of such a message is not cause for alarm, but if it appears often then the checkpoint control parameters should be increased. Bulk operations such as large COPY transfers might cause a number of such warnings to appear if you have not set `max_wal_size` high enough.

To avoid flooding the I/O system with a burst of page writes, writing dirty buffers during a checkpoint is spread over a period of time. That period is controlled by `checkpoint_completion_target`, which is given as a fraction of the checkpoint interval. The I/O rate is adjusted so that the checkpoint finishes when the given fraction of `checkpoint_timeout` seconds have elapsed, or before `max_wal_size` is exceeded, whichever is sooner. With the default value of 0.5, LightDB can be expected to complete each checkpoint in about half the time before the next checkpoint starts. On a system that's very close to maximum I/O throughput during normal operation, you might want to increase `checkpoint_completion_target` to reduce the I/O load from checkpoints. The disadvantage of this is that prolonging checkpoints affects recovery time, because more WAL segments will need to be kept around for possible use in recovery. Although `checkpoint_completion_target` can be set as high as 1.0, it is best to keep it less than that (perhaps 0.9 at most) since checkpoints include some other activities besides writing dirty buffers. A setting of 1.0 is quite likely to result in checkpoints not being completed on time, which would result in performance loss due to unexpected variation in the number of WAL segments needed.

On Linux and POSIX platforms `checkpoint_flush_after` allows to force the OS that pages written by the checkpoint should be flushed to disk after a configurable number of bytes. Otherwise, these pages may be kept in the OS's page cache, inducing a stall when `fsync` is issued at the end of a checkpoint. This setting will often help to reduce transaction latency, but it also can have an adverse effect on performance; particularly for workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache.

The number of WAL segment files in `lt_wal` directory depends on `min_wal_size`, `max_wal_size` and the amount of WAL generated in previous checkpoint cycles. When old log segment files are no longer needed, they are removed or recycled (that is, renamed to become future segments in the numbered sequence). If, due to a short-term peak of log output rate, `max_wal_size` is exceeded, the unneeded segment files will be removed until the system gets back under this limit. Below that limit, the system recycles enough WAL files to cover the estimated need until the next checkpoint, and removes the rest. The estimate is based on a moving average of the number of WAL files used in previous checkpoint cycles. The moving average is increased immediately if the actual usage exceeds the estimate, so it accommodates peak usage rather than average usage to some extent. `min_wal_size` puts a minimum on the amount of WAL files recycled for future usage; that much WAL is always recycled for future use, even if the system is idle and the WAL usage estimate suggests that little WAL is needed.

Independently of `max_wal_size`, the most recent `wal_keep_size` megabytes of WAL files plus one additional WAL file are kept at all times. Also, if WAL archiving is used, old segments cannot be removed or recycled until they are archived. If WAL archiving cannot keep up with the pace that WAL is generated, or if `archive_command` fails repeatedly, old WAL files will accumulate in `lt_wal` until the situation is resolved. A slow or failed standby server that uses a replication slot will have the same effect (see Section 24.2.6).

In archive recovery or standby mode, the server periodically performs *restartpoints*, which are similar to checkpoints in normal operation: the server forces all its state to disk, updates the `lt_control` file to indicate that the already-processed WAL data need not be scanned again, and then recycles any old log segment files in the `lt_wal` directory. Restartpoints can't be performed more frequently than checkpoints in the master because restartpoints can only be performed at checkpoint records. A restartpoint is triggered when a checkpoint record is reached if at least `checkpoint_timeout` seconds have passed since the last restartpoint, or if WAL size is about to exceed `max_wal_size`. However, because of limitations on when a restartpoint can be performed, `max_wal_size` is often exceeded during recovery, by up to one checkpoint cycle's worth of WAL. (`max_wal_size` is never a hard limit anyway, so you should always leave plenty of headroom to avoid running out of disk space.)

There are two commonly used internal WAL functions: `XLogInsertRecord` and `XLogFlush`. `XLogInsertRecord` is used to place a new record into the WAL buffers in shared memory. If there is no space for the new record, `XLogInsertRecord` will have to write (move to kernel cache) a few filled WAL buffers. This is undesirable because `XLogInsertRecord` is used on every database low level modification (for example, row insertion) at a time when an exclusive lock is held on affected data pages, so the operation needs to be as fast as possible. What is worse, writing WAL buffers might also force the creation of a new log segment, which takes even more time. Normally, WAL buffers should be written and flushed by an `XLogFlush` request, which is made, for the most part, at transaction commit time to ensure that transaction records are flushed to permanent storage. On systems with high log output, `XLogFlush` requests might not occur often enough to prevent `XLogInsertRecord` from having to do writes. On such systems one should increase the number of WAL buffers by modifying the `wal_buffers` parameter. When `full_page_writes` is set and the system is very busy, setting `wal_buffers` higher will help smooth response times during the period immediately following each checkpoint.

The `commit_delay` parameter defines for how many microseconds a group commit leader process will sleep after acquiring a lock within `XLogFlush`, while group commit followers queue up behind the leader. This delay allows other server processes to add their commit records to the WAL buffers so that all of them will be flushed by the leader's eventual sync operation. No sleep will occur if `fsync` is not enabled, or if fewer than `commit_siblings` other sessions are currently in active transactions; this avoids sleeping when it's unlikely that any other session will commit soon. Note that on some platforms, the resolution of a sleep request is ten milliseconds, so that any nonzero `commit_delay` setting between 1 and 10000 microseconds would have the same effect. Note also that on some platforms, sleep operations may take slightly longer than requested by the parameter.

Since the purpose of `commit_delay` is to allow the cost of each flush operation to be amortized across concurrently committing transactions (potentially at the expense of transaction latency), it is

necessary to quantify that cost before the setting can be chosen intelligently. The higher that cost is, the more effective `commit_delay` is expected to be in increasing transaction throughput, up to a point. The `lt_test_fsync` program can be used to measure the average time in microseconds that a single WAL flush operation takes. A value of half of the average time the program reports it takes to flush after a single 8kB write operation is often the most effective setting for `commit_delay`, so this value is recommended as the starting point to use when optimizing for a particular workload. While tuning `commit_delay` is particularly useful when the WAL log is stored on high-latency rotating disks, benefits can be significant even on storage media with very fast sync times, such as solid-state drives or RAID arrays with a battery-backed write cache; but this should definitely be tested against a representative workload. Higher values of `commit_siblings` should be used in such cases, whereas smaller `commit_siblings` values are often helpful on higher latency media. Note that it is quite possible that a setting of `commit_delay` that is too high can increase transaction latency by so much that total transaction throughput suffers.

When `commit_delay` is set to zero (the default), it is still possible for a form of group commit to occur, but each group will consist only of sessions that reach the point where they need to flush their commit records during the window in which the previous flush operation (if any) is occurring. At higher client counts a “gangway effect” tends to occur, so that the effects of group commit become significant even when `commit_delay` is zero, and thus explicitly setting `commit_delay` tends to help less. Setting `commit_delay` can only help when (1) there are some concurrently committing transactions, and (2) throughput is limited to some degree by commit rate; but with high rotational latency this setting can be effective in increasing transaction throughput with as few as two clients (that is, a single committing client with one sibling transaction).

The `wal_sync_method` parameter determines how LightDB will ask the kernel to force WAL updates out to disk. All the options should be the same in terms of reliability, with the exception of `fsync_writethrough`, which can sometimes force a flush of the disk cache even when other options do not do so. However, it's quite platform-specific which one will be the fastest. You can test the speeds of different options using the `lt_test_fsync` program. Note that this parameter is irrelevant if `fsync` has been turned off.

Enabling the `wal_debug` configuration parameter (provided that LightDB has been compiled with support for it) will result in each `XLogInsertRecord` and `XLogFlush` WAL call being logged to the server log. This option might be replaced by a more general mechanism in the future.

## 27.5. WAL Internals

WAL is automatically enabled; no action is required from the administrator except ensuring that the disk-space requirements for the WAL logs are met, and that any necessary tuning is done (see Section 27.4).

WAL records are appended to the WAL logs as each new record is written. The insert position is described by a Log Sequence Number (LSN) that is a byte offset into the logs, increasing monotonically with each new record. LSN values are returned as the datatype `pg_lsn`. Values can be compared to calculate the volume of WAL data that separates them, so they are used to measure the progress of replication and recovery.

WAL logs are stored in the directory `lt_wal` under the data directory, as a set of segment files, normally each 16 MB in size (but the size can be changed by altering the `--wal-segsize` `initdb` option). Each segment is divided into pages, normally 8 kB each (this size can be changed via the `--with-wal-blocksize` `configure` option). The log record headers are described in `access/xlogrecord.h`; the record content is dependent on the type of event that is being logged. Segment files are given ever-increasing numbers as names, starting at `000000010000000000000001`. The numbers do not wrap, but it will take a very, very long time to exhaust the available stock of numbers.

It is advantageous if the log is located on a different disk from the main database files. This can be achieved by moving the `lt_wal` directory to another location (while the server is shut down, of course) and creating a symbolic link from the original location in the main data directory to the new location.

The aim of WAL is to ensure that the log is written before database records are altered, but this can be subverted by disk drives that falsely report a successful write to the kernel, when in fact they have only cached the data and not yet stored it on the disk. A power failure in such a situation might lead to irrecoverable data corruption. Administrators should try to ensure that disks holding LightDB's WAL log files do not make such false reports. (See Section 27.1.)

After a checkpoint has been made and the log flushed, the checkpoint's position is saved in the file `lt_control`. Therefore, at the start of recovery, the server first reads `lt_control` and then the checkpoint record; then it performs the REDO operation by scanning forward from the log location indicated in the checkpoint record. Because the entire content of data pages is saved in the log on the first page modification after a checkpoint (assuming `full_page_writes` is not disabled), all pages changed since the checkpoint will be restored to a consistent state.

To deal with the case where `lt_control` is corrupt, we should support the possibility of scanning existing log segments in reverse order — newest to oldest — in order to find the latest checkpoint. This has not been implemented yet. `lt_control` is small enough (less than one disk page) that it is not subject to partial-write problems, and as of this writing there have been no reports of database failures due solely to the inability to read `lt_control` itself. So while it is theoretically a weak spot, `lt_control` does not seem to be a problem in practice.



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# Chapter 28. Logical Replication

Logical replication is a method of replicating data objects and their changes, based upon their replication identity (usually a primary key). We use the term logical in contrast to physical replication, which uses exact block addresses and byte-by-byte replication. LightDB supports both mechanisms concurrently, see Chapter 24. Logical replication allows fine-grained control over both data replication and security.

Logical replication uses a *publish* and *subscribe* model with one or more *subscribers* subscribing to one or more *publications* on a *publisher* node. Subscribers pull data from the publications they subscribe to and may subsequently re-publish data to allow cascading replication or more complex configurations.

Logical replication of a table typically starts with taking a snapshot of the data on the publisher database and copying that to the subscriber. Once that is done, the changes on the publisher are sent to the subscriber as they occur in real-time. The subscriber applies the data in the same order as the publisher so that transactional consistency is guaranteed for publications within a single subscription. This method of data replication is sometimes referred to as transactional replication.

The typical use-cases for logical replication are:

- Sending incremental changes in a single database or a subset of a database to subscribers as they occur.
- Firing triggers for individual changes as they arrive on the subscriber.
- Consolidating multiple databases into a single one (for example for analytical purposes).
- Replicating between different major versions of LightDB.
- Replicating between LightDB instances on different platforms (for example Linux to Windows)
- Giving access to replicated data to different groups of users.
- Sharing a subset of the database between multiple databases.

The subscriber database behaves in the same way as any other LightDB instance and can be used as a publisher for other databases by defining its own publications. When the subscriber is treated as read-only by application, there will be no conflicts from a single subscription. On the other hand, if there are other writes done either by an application or by other subscribers to the same set of tables, conflicts can arise.

## 28.1. Publication

A *publication* can be defined on any physical replication master. The node where a publication is defined is referred to as *publisher*. A publication is a set of changes generated from a table or a group of tables, and might also be described as a change set or replication set. Each publication exists in only one database.

Publications are different from schemas and do not affect how the table is accessed. Each table can be added to multiple publications if needed. Publications may currently only contain tables. Objects must be added explicitly, except when a publication is created for `ALL TABLES`.

Publications can choose to limit the changes they produce to any combination of `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE`, similar to how triggers are fired by particular event types. By default, all operation types are replicated.

A published table must have a “replica identity” configured in order to be able to replicate `UPDATE` and `DELETE` operations, so that appropriate rows to update or delete can be identified on the subscriber

side. By default, this is the primary key, if there is one. Another unique index (with certain additional requirements) can also be set to be the replica identity. If the table does not have any suitable key, then it can be set to replica identity “full”, which means the entire row becomes the key. This, however, is very inefficient and should only be used as a fallback if no other solution is possible. If a replica identity other than “full” is set on the publisher side, a replica identity comprising the same or fewer columns must also be set on the subscriber side. See `REPLICA IDENTITY` for details on how to set the replica identity. If a table without a replica identity is added to a publication that replicates `UPDATE` or `DELETE` operations then subsequent `UPDATE` or `DELETE` operations will cause an error on the publisher. `INSERT` operations can proceed regardless of any replica identity.

Every publication can have multiple subscribers.

A publication is created using the `CREATE PUBLICATION` command and may later be altered or dropped using corresponding commands.

The individual tables can be added and removed dynamically using `ALTER PUBLICATION`. Both the `ADD TABLE` and `DROP TABLE` operations are transactional; so the table will start or stop replicating at the correct snapshot once the transaction has committed.

## 28.2. Subscription

A *subscription* is the downstream side of logical replication. The node where a subscription is defined is referred to as the *subscriber*. A subscription defines the connection to another database and set of publications (one or more) to which it wants to subscribe.

The subscriber database behaves in the same way as any other LightDB instance and can be used as a publisher for other databases by defining its own publications.

A subscriber node may have multiple subscriptions if desired. It is possible to define multiple subscriptions between a single publisher-subscriber pair, in which case care must be taken to ensure that the subscribed publication objects don't overlap.

Each subscription will receive changes via one replication slot (see Section 24.2.6). Additional temporary replication slots may be required for the initial data synchronization of pre-existing table data.

A logical replication subscription can be a standby for synchronous replication (see Section 24.2.8). The standby name is by default the subscription name. An alternative name can be specified as `application_name` in the connection information of the subscription.

Subscriptions are dumped by `lt_dump` if the current user is a superuser. Otherwise a warning is written and subscriptions are skipped, because non-superusers cannot read all subscription information from the `pg_subscription` catalog.

The subscription is added using `CREATE SUBSCRIPTION` and can be stopped/resumed at any time using the `ALTER SUBSCRIPTION` command and removed using `DROP SUBSCRIPTION`.

When a subscription is dropped and recreated, the synchronization information is lost. This means that the data has to be resynchronized afterwards.

The schema definitions are not replicated, and the published tables must exist on the subscriber. Only regular tables may be the target of replication. For example, you can't replicate to a view.

The tables are matched between the publisher and the subscriber using the fully qualified table name. Replication to differently-named tables on the subscriber is not supported.

Columns of a table are also matched by name. The order of columns in the subscriber table does not need to match that of the publisher. The data types of the columns do not need to match, as long as the text representation of the data can be converted to the target type. For example, you can replicate from a column of type `integer` to a column of type `bigint`. The target table can also have additional

columns not provided by the published table. Any such columns will be filled with the default value as specified in the definition of the target table.

## 28.2.1. Replication Slot Management

As mentioned earlier, each (active) subscription receives changes from a replication slot on the remote (publishing) side. Normally, the remote replication slot is created automatically when the subscription is created using `CREATE SUBSCRIPTION` and it is dropped automatically when the subscription is dropped using `DROP SUBSCRIPTION`. In some situations, however, it can be useful or necessary to manipulate the subscription and the underlying replication slot separately. Here are some scenarios:

- When creating a subscription, the replication slot already exists. In that case, the subscription can be created using the `create_slot = false` option to associate with the existing slot.
- When creating a subscription, the remote host is not reachable or in an unclear state. In that case, the subscription can be created using the `connect = false` option. The remote host will then not be contacted at all. This is what `lt_dump` uses. The remote replication slot will then have to be created manually before the subscription can be activated.
- When dropping a subscription, the replication slot should be kept. This could be useful when the subscriber database is being moved to a different host and will be activated from there. In that case, disassociate the slot from the subscription using `ALTER SUBSCRIPTION` before attempting to drop the subscription.
- When dropping a subscription, the remote host is not reachable. In that case, disassociate the slot from the subscription using `ALTER SUBSCRIPTION` before attempting to drop the subscription. If the remote database instance no longer exists, no further action is then necessary. If, however, the remote database instance is just unreachable, the replication slot should then be dropped manually; otherwise it would continue to reserve WAL and might eventually cause the disk to fill up. Such cases should be carefully investigated.

## 28.3. Conflicts

Logical replication behaves similarly to normal DML operations in that the data will be updated even if it was changed locally on the subscriber node. If incoming data violates any constraints the replication will stop. This is referred to as a *conflict*. When replicating `UPDATE` or `DELETE` operations, missing data will not produce a conflict and such operations will simply be skipped.

A conflict will produce an error and will stop the replication; it must be resolved manually by the user. Details about the conflict can be found in the subscriber's server log.

The resolution can be done either by changing data on the subscriber so that it does not conflict with the incoming change or by skipping the transaction that conflicts with the existing data. The transaction can be skipped by calling the `pg_replication_origin_advance()` function with a `node_name` corresponding to the subscription name, and a position. The current position of origins can be seen in the `pg_replication_origin_status` system view.

## 28.4. Restrictions

Logical replication currently has the following restrictions or missing functionality. These might be addressed in future releases.

- The database schema and DDL commands are not replicated. The initial schema can be copied by hand using `lt_dump --schema-only`. Subsequent schema changes would need to be kept in sync manually. (Note, however, that there is no need for the schemas to be absolutely the same on both sides.) Logical replication is robust when schema definitions change in a live database: When the schema is changed on the publisher and replicated data starts arriving at the subscriber but

does not fit into the table schema, replication will error until the schema is updated. In many cases, intermittent errors can be avoided by applying additive schema changes to the subscriber first.

- Sequence data is not replicated. The data in serial or identity columns backed by sequences will of course be replicated as part of the table, but the sequence itself would still show the start value on the subscriber. If the subscriber is used as a read-only database, then this should typically not be a problem. If, however, some kind of switchover or failover to the subscriber database is intended, then the sequences would need to be updated to the latest values, either by copying the current data from the publisher (perhaps using `lt_dump`) or by determining a sufficiently high value from the tables themselves.
- Replication of `TRUNCATE` commands is supported, but some care must be taken when truncating groups of tables connected by foreign keys. When replicating a truncate action, the subscriber will truncate the same group of tables that was truncated on the publisher, either explicitly specified or implicitly collected via `CASCADE`, minus tables that are not part of the subscription. This will work correctly if all affected tables are part of the same subscription. But if some tables to be truncated on the subscriber have foreign-key links to tables that are not part of the same (or any) subscription, then the application of the truncate action on the subscriber will fail.
- Large objects (see Chapter 33) are not replicated. There is no workaround for that, other than storing data in normal tables.
- Replication is only supported by tables, including partitioned tables. Attempts to replicate other types of relations, such as views, materialized views, or foreign tables, will result in an error.
- When replicating between partitioned tables, the actual replication originates, by default, from the leaf partitions on the publisher, so partitions on the publisher must also exist on the subscriber as valid target tables. (They could either be leaf partitions themselves, or they could be further subpartitioned, or they could even be independent tables.) Publications can also specify that changes are to be replicated using the identity and schema of the partitioned root table instead of that of the individual leaf partitions in which the changes actually originate (see `CREATE PUBLICATION`).

## 28.5. Architecture

Logical replication starts by copying a snapshot of the data on the publisher database. Once that is done, changes on the publisher are sent to the subscriber as they occur in real time. The subscriber applies data in the order in which commits were made on the publisher so that transactional consistency is guaranteed for the publications within any single subscription.

Logical replication is built with an architecture similar to physical streaming replication (see Section 24.2.5). It is implemented by “walsender” and “apply” processes. The walsender process starts logical decoding (described in Chapter 45) of the WAL and loads the standard logical decoding plugin (`ltoutput`). The plugin transforms the changes read from WAL to the logical replication protocol (see Section 49.5) and filters the data according to the publication specification. The data is then continuously transferred using the streaming replication protocol to the apply worker, which maps the data to local tables and applies the individual changes as they are received, in correct transactional order.

The apply process on the subscriber database always runs with `session_replication_role` set to `replica`, which produces the usual effects on triggers and constraints.

The logical replication apply process currently only fires row triggers, not statement triggers. The initial table synchronization, however, is implemented like a `COPY` command and thus fires both row and statement triggers for `INSERT`.

### 28.5.1. Initial Snapshot

The initial data in existing subscribed tables are snapshotted and copied in a parallel instance of a special kind of apply process. This process will create its own temporary replication slot and copy the

existing data. Once existing data is copied, the worker enters synchronization mode, which ensures that the table is brought up to a synchronized state with the main apply process by streaming any changes that happened during the initial data copy using standard logical replication. Once the synchronization is done, the control of the replication of the table is given back to the main apply process where the replication continues as normal.

## 28.6. Monitoring

Because logical replication is based on a similar architecture as physical streaming replication, the monitoring on a publication node is similar to monitoring of a physical replication master (see Section 24.2.5.2).

The monitoring information about subscription is visible in `pg_stat_subscription`. This view contains one row for every subscription worker. A subscription can have zero or more active subscription workers depending on its state.

Normally, there is a single apply process running for an enabled subscription. A disabled subscription or a crashed subscription will have zero rows in this view. If the initial data synchronization of any table is in progress, there will be additional workers for the tables being synchronized.

## 28.7. Security

A user able to modify the schema of subscriber-side tables can execute arbitrary code as a superuser. Limit ownership and TRIGGER privilege on such tables to roles that superusers trust. Moreover, if untrusted users can create tables, use only publications that list tables explicitly. That is to say, create a subscription FOR ALL TABLES only when superusers trust every user permitted to create a non-temp table on the publisher or the subscriber.

The role used for the replication connection must have the REPLICATION attribute (or be a superuser). If the role lacks SUPERUSER and BYPASSRLS, publisher row security policies can execute. If the role does not trust all table owners, include `options=-row_security=off` in the connection string; if a table owner then adds a row security policy, that setting will cause replication to halt rather than execute the policy. Access for the role must be configured in `lt_hba.conf` and it must have the LOGIN attribute.

In order to be able to copy the initial table data, the role used for the replication connection must have the SELECT privilege on a published table (or be a superuser).

To create a publication, the user must have the CREATE privilege in the database.

To add tables to a publication, the user must have ownership rights on the table. To create a publication that publishes all tables automatically, the user must be a superuser.

To create a subscription, the user must be a superuser.

The subscription apply process will run in the local database with the privileges of a superuser.

Privileges are only checked once at the start of a replication connection. They are not re-checked as each change record is read from the publisher, nor are they re-checked for each change when applied.

## 28.8. Configuration Settings

Logical replication requires several configuration options to be set.

On the publisher side, `wal_level` must be set to `logical`, and `max_replication_slots` must be set to at least the number of subscriptions expected to connect, plus some reserve for table synchronization. And `max_wal_senders` should be set to at least the same as

`max_replication_slots` plus the number of physical replicas that are connected at the same time.

The subscriber also requires the `max_replication_slots` be set to configure how many replication origins can be tracked. In this case it should be set to at least the number of subscriptions that will be added to the subscriber. `max_logical_replication_workers` must be set to at least the number of subscriptions, again plus some reserve for the table synchronization. Additionally the `max_worker_processes` may need to be adjusted to accommodate for replication workers, at least  $(\text{max\_logical\_replication\_workers} + 1)$ . Note that some extensions and parallel queries also take worker slots from `max_worker_processes`.

## 28.9. Quick Setup

First set the configuration options in `lightdb.conf`:

```
wal_level = logical
```

The other required settings have default values that are sufficient for a basic setup.

`lt_hba.conf` needs to be adjusted to allow replication (the values here depend on your actual network configuration and user you want to use for connecting):

```
host      all      repuser      0.0.0.0/0      md5
```

Then on the publisher database:

```
CREATE PUBLICATION mypub FOR TABLE users, departments;
```

And on the subscriber database:

```
CREATE SUBSCRIPTION mysub CONNECTION 'dbname=foo host=bar
user=repuser' PUBLICATION mypub;
```

The above will start the replication process, which synchronizes the initial table contents of the tables `users` and `departments` and then starts replicating incremental changes to those tables.

---

# Chapter 29. Just-in-Time Compilation (JIT)

This chapter explains what just-in-time compilation is, and how it can be configured in LightDB.

## 29.1. What Is JIT compilation?

Just-in-Time (JIT) compilation is the process of turning some form of interpreted program evaluation into a native program, and doing so at run time. For example, instead of using general-purpose code that can evaluate arbitrary SQL expressions to evaluate a particular SQL predicate like `WHERE a.col = 3`, it is possible to generate a function that is specific to that expression and can be natively executed by the CPU, yielding a speedup.

LightDB has builtin support to perform JIT compilation using LLVM<sup>1</sup>.

See `src/backend/jit/README` for further details.

### 29.1.1. JIT Accelerated Operations

Currently LightDB's JIT implementation has support for accelerating expression evaluation and tuple deforming. Several other operations could be accelerated in the future.

Expression evaluation is used to evaluate `WHERE` clauses, target lists, aggregates and projections. It can be accelerated by generating code specific to each case.

Tuple deforming is the process of transforming an on-disk tuple (see Section 64.6.1) into its in-memory representation. It can be accelerated by creating a function specific to the table layout and the number of columns to be extracted.

### 29.1.2. Inlining

LightDB is very extensible and allows new data types, functions, operators and other database objects to be defined; see Chapter 36. In fact the built-in objects are implemented using nearly the same mechanisms. This extensibility implies some overhead, for example due to function calls (see Section 36.3). To reduce that overhead, JIT compilation can inline the bodies of small functions into the expressions using them. That allows a significant percentage of the overhead to be optimized away.

### 29.1.3. Optimization

LLVM has support for optimizing generated code. Some of the optimizations are cheap enough to be performed whenever JIT is used, while others are only beneficial for longer-running queries. See <https://llvm.org/docs/Passes.html#transform-passes> for more details about optimizations.

## 29.2. When to JIT?

JIT compilation is beneficial primarily for long-running CPU-bound queries. Frequently these will be analytical queries. For short queries the added overhead of performing JIT compilation will often be higher than the time it can save.

To determine whether JIT compilation should be used, the total estimated cost of a query (see Chapter 66 and Section 17.7.2) is used. The estimated cost of the query will be compared

---

<sup>1</sup> <https://llvm.org/>

with the setting of `jit_above_cost`. If the cost is higher, JIT compilation will be performed. Two further decisions are then needed. Firstly, if the estimated cost is more than the setting of `jit_inline_above_cost`, short functions and operators used in the query will be inlined. Secondly, if the estimated cost is more than the setting of `jit_optimize_above_cost`, expensive optimizations are applied to improve the generated code. Each of these options increases the JIT compilation overhead, but can reduce query execution time considerably.

These cost-based decisions will be made at plan time, not execution time. This means that when prepared statements are in use, and a generic plan is used (see `PREPARE`), the values of the configuration parameters in effect at prepare time control the decisions, not the settings at execution time.

**Note**

If `jit` is set to `off`, or if no JIT implementation is available (for example because the server was compiled without `--with-llvm`), JIT will not be performed, even if it would be beneficial based on the above criteria. Setting `jit` to `off` has effects at both plan and execution time.

`EXPLAIN` can be used to see whether JIT is used or not. As an example, here is a query that is not using JIT:

```
=# EXPLAIN ANALYZE SELECT SUM(relpages) FROM pg_class;
                                         QUERY PLAN
-----
Aggregate  (cost=16.27..16.29 rows=1 width=8) (actual
time=0.303..0.303 rows=1 loops=1)
  -> Seq Scan on pg_class  (cost=0.00..15.42 rows=342 width=4)
(actual time=0.017..0.111 rows=356 loops=1)
Planning Time: 0.116 ms
Execution Time: 0.365 ms
(4 rows)
```

Given the cost of the plan, it is entirely reasonable that no JIT was used; the cost of JIT would have been bigger than the potential savings. Adjusting the cost limits will lead to JIT use:

```
=# SET jit_above_cost = 10;
SET
=# EXPLAIN ANALYZE SELECT SUM(relpages) FROM pg_class;
                                         QUERY PLAN
-----
Aggregate  (cost=16.27..16.29 rows=1 width=8) (actual
time=6.049..6.049 rows=1 loops=1)
  -> Seq Scan on pg_class  (cost=0.00..15.42 rows=342 width=4)
(actual time=0.019..0.052 rows=356 loops=1)
Planning Time: 0.133 ms
JIT:
  Functions: 3
  Options: Inlining false, Optimization false, Expressions true,
Deforming true
  Timing: Generation 1.259 ms, Inlining 0.000 ms, Optimization
0.797 ms, Emission 5.048 ms, Total 7.104 ms
Execution Time: 7.416 ms
```



As visible here, JIT was used, but inlining and expensive optimization were not. If `jit_inline_above_cost` or `jit_optimize_above_cost` were also lowered, that would change.

## 29.3. Configuration

The configuration variable `jit` determines whether JIT compilation is enabled or disabled. If it is enabled, the configuration variables `jit_above_cost`, `jit_inline_above_cost`, and `jit_optimize_above_cost` determine whether JIT compilation is performed for a query, and how much effort is spent doing so.

`jit_provider` determines which JIT implementation is used. It is rarely required to be changed. See Section 29.4.2.

For development and debugging purposes a few additional configuration parameters exist, as described in Section 17.17.

## 29.4. Extensibility

### 29.4.1. Inlining Support for Extensions

LightDB's JIT implementation can inline the bodies of functions of types `C` and `internal`, as well as operators based on such functions. To do so for functions in extensions, the definitions of those functions need to be made available. When using PGXS to build an extension against a server that has been compiled with LLVM JIT support, the relevant files will be built and installed automatically.

The relevant files have to be installed into `$pkglibdir/bitcode/$extension/` and a summary of them into `$pkglibdir/bitcode/$extension.index.bc`, where `$pkglibdir` is the directory returned by `lt_config --pkglibdir` and `$extension` is the base name of the extension's shared library.

#### Note

For functions built into LightDB itself, the bitcode is installed into `$pkglibdir/bitcode/postgres`.

### 29.4.2. Pluggable JIT Providers

LightDB provides a JIT implementation based on LLVM. The interface to the JIT provider is pluggable and the provider can be changed without recompiling (although currently, the build process only provides inlining support data for LLVM). The active provider is chosen via the setting `jit_provider`.

#### 29.4.2.1. JIT Provider Interface

A JIT provider is loaded by dynamically loading the named shared library. The normal library search path is used to locate the library. To provide the required JIT provider callbacks and to indicate that the library is actually a JIT provider, it needs to provide a C function named `_PG_jit_provider_init`. This function is passed a struct that needs to be filled with the callback function pointers for individual actions:

```
struct JitProviderCallbacks
{
    JitProviderResetAfterErrorCB reset_after_error;
    JitProviderReleaseContextCB release_context;
};
```

```
    JitProviderCompileExprCB compile_expr;  
};  
  
extern void _PG_jit_provider_init(JitProviderCallbacks *cb);
```

---

# Chapter 30. Regression Tests

The regression tests are a comprehensive set of tests for the SQL implementation in LightDB. They test standard SQL operations as well as the extended capabilities of LightDB.

## 30.1. Running the Tests

The regression tests can be run against an already installed and running server, or using a temporary installation within the build tree. Furthermore, there is a “parallel” and a “sequential” mode for running the tests. The sequential method runs each test script alone, while the parallel method starts up multiple server processes to run groups of tests in parallel. Parallel testing adds confidence that interprocess communication and locking are working correctly.

### 30.1.1. Running the Tests Against a Temporary Installation

To run the parallel regression tests after building but before installation, type:

```
make check
```

in the top-level directory. (Or you can change to `src/test/regress` and run the command there.) At the end you should see something like:

```
=====  
All 193 tests passed.  
=====
```

or otherwise a note about which tests failed. See Section 30.2 below before assuming that a “failure” represents a serious problem.

Because this test method runs a temporary server, it will not work if you did the build as the root user, since the server will not start as root. Recommended procedure is not to do the build as root, or else to perform testing after completing the installation.

If you have configured LightDB to install into a location where an older LightDB installation already exists, and you perform `make check` before installing the new version, you might find that the tests fail because the new programs try to use the already-installed shared libraries. (Typical symptoms are complaints about undefined symbols.) If you wish to run the tests before overwriting the old installation, you'll need to build with `configure --disable-rpath`. It is not recommended that you use this option for the final installation, however.

The parallel regression test starts quite a few processes under your user ID. Presently, the maximum concurrency is twenty parallel test scripts, which means forty processes: there's a server process and a `ltsql` process for each test script. So if your system enforces a per-user limit on the number of processes, make sure this limit is at least fifty or so, else you might get random-seeming failures in the parallel test. If you are not in a position to raise the limit, you can cut down the degree of parallelism by setting the `MAX_CONNECTIONS` parameter. For example:

```
make MAX_CONNECTIONS=10 check
```

runs no more than ten tests concurrently.

## 30.1.2. Running the Tests Against an Existing Installation

To run the tests after installation, initialize a data directory and start the server as explained in Chapter 16, then type:

```
make installcheck
```

or for a parallel test:

```
make installcheck-parallel
```

The tests will expect to contact the server at the local host and the default port number, unless directed otherwise by `LTHOST` and `LTPORT` environment variables. The tests will be run in a database named `regression`; any existing database by this name will be dropped.

The tests will also transiently create some cluster-wide objects, such as roles, tablespaces, and subscriptions. These objects will have names beginning with `regress_`. Beware of using `installcheck` mode with an installation that has any actual global objects named that way.

## 30.1.3. Additional Test Suites

The `make check` and `make installcheck` commands run only the “core” regression tests, which test built-in functionality of the LightDB server. The source distribution contains many additional test suites, most of them having to do with add-on functionality such as optional procedural languages.

To run all test suites applicable to the modules that have been selected to be built, including the core tests, type one of these commands at the top of the build tree:

```
make check-world  
make installcheck-world
```

These commands run the tests using temporary servers or an already-installed server, respectively, just as previously explained for `make check` and `make installcheck`. Other considerations are the same as previously explained for each method. Note that `make check-world` builds a separate instance (temporary data directory) for each tested module, so it requires more time and disk space than `make installcheck-world`.

On a modern machine with multiple CPU cores and no tight operating-system limits, you can make things go substantially faster with parallelism. The recipe that most LightDB developers actually use for running all tests is something like

```
make check-world -j8 >/dev/null
```

with a `-j` limit near to or a bit more than the number of available cores. Discarding stdout eliminates chatter that's not interesting when you just want to verify success. (In case of failure, the stderr messages are usually enough to determine where to look closer.)

Alternatively, you can run individual test suites by typing `make check` or `make installcheck` in the appropriate subdirectory of the build tree. Keep in mind that `make installcheck` assumes you've installed the relevant module(s), not only the core server.

The additional tests that can be invoked this way include:

- Regression tests for optional procedural languages. These are located under `src/pl`.

- Regression tests for `contrib` modules, located under `contrib`. Not all `contrib` modules have tests.
- Regression tests for the ECPG interface library, located in `src/interfaces/ecpg/test`.
- Tests for core-supported authentication methods, located in `src/test/authentication`. (See below for additional authentication-related tests.)
- Tests stressing behavior of concurrent sessions, located in `src/test/isolation`.
- Tests for crash recovery and physical replication, located in `src/test/recovery`.
- Tests for logical replication, located in `src/test/subscription`.
- Tests of client programs, located under `src/bin`.

When using `installcheck` mode, these tests will create and destroy test databases whose names include `regression`, for example `pl_regression` or `contrib_regression`. Beware of using `installcheck` mode with an installation that has any non-test databases named that way.

Some of these auxiliary test suites use the TAP infrastructure explained in Section 30.4. The TAP-based tests are run only when LightDB was configured with the option `--enable-tap-tests`. This is recommended for development, but can be omitted if there is no suitable Perl installation.

Some test suites are not run by default, either because they are not secure to run on a multiuser system or because they require special software. You can decide which test suites to run additionally by setting the `make` or environment variable `PG_TEST_EXTRA` to a whitespace-separated list, for example:

```
make check-world PG_TEST_EXTRA='kerberos ldap ssl'
```

The following values are currently supported:

`kerberos`

Runs the test suite under `src/test/kerberos`. This requires an MIT Kerberos installation and opens TCP/IP listen sockets.

`ldap`

Runs the test suite under `src/test/ldap`. This requires an OpenLDAP installation and opens TCP/IP listen sockets.

`ssl`

Runs the test suite under `src/test/ssl`. This opens TCP/IP listen sockets.

Tests for features that are not supported by the current build configuration are not run even if they are mentioned in `PG_TEST_EXTRA`.

In addition, there are tests in `src/test/modules` which will be run by `make check-world` but not by `make installcheck-world`. This is because they install non-production extensions or have other side-effects that are considered undesirable for a production installation. You can use `make install` and `make installcheck` in one of those subdirectories if you wish, but it's not recommended to do so with a non-test server.

## 30.1.4. Locale and Encoding

By default, tests using a temporary installation use the locale defined in the current environment and the corresponding database encoding as determined by `initdb`. It can be useful to test different locales by setting the appropriate environment variables, for example:

```
make check LANG=C
make check LC_COLLATE=en_US.utf8 LC_CTYPE=fr_CA.utf8
```

For implementation reasons, setting `LC_ALL` does not work for this purpose; all the other locale-related environment variables do work.

When testing against an existing installation, the locale is determined by the existing database cluster and cannot be set separately for the test run.

You can also choose the database encoding explicitly by setting the variable `ENCODING`, for example:

```
make check LANG=C ENCODING=EUC_JP
```

Setting the database encoding this way typically only makes sense if the locale is `C`; otherwise the encoding is chosen automatically from the locale, and specifying an encoding that does not match the locale will result in an error.

The database encoding can be set for tests against either a temporary or an existing installation, though in the latter case it must be compatible with the installation's locale.

### 30.1.5. Extra Tests

The core regression test suite contains a few test files that are not run by default, because they might be platform-dependent or take a very long time to run. You can run these or other extra test files by setting the variable `EXTRA_TESTS`. For example, to run the `numeric_big` test:

```
make check EXTRA_TESTS=numeric_big
```

### 30.1.6. Testing Hot Standby

The source distribution also contains regression tests for the static behavior of Hot Standby. These tests require a running primary server and a running standby server that is accepting new WAL changes from the primary (using either file-based log shipping or streaming replication). Those servers are not automatically created for you, nor is replication setup documented here. Please check the various sections of the documentation devoted to the required commands and related issues.

To run the Hot Standby tests, first create a database called `regression` on the primary:

```
ltsql -h primary -c "CREATE DATABASE regression"
```

Next, run the preparatory script `src/test/regress/sql/hs_primary_setup.sql` on the primary in the regression database, for example:

```
ltsql -h primary -f src/test/regress/sql/hs_primary_setup.sql
regression
```

Allow these changes to propagate to the standby.

Now arrange for the default database connection to be to the standby server under test (for example, by setting the `LTHOST` and `LTPORT` environment variables). Finally, run `make standbycheck` in the regression directory:

```
cd src/test/regress
```

```
make standbycheck
```

Some extreme behaviors can also be generated on the primary using the script `src/test/regress/sql/hs_primary_extremes.sql` to allow the behavior of the standby to be tested.

## 30.2. Test Evaluation

Some properly installed and fully functional LightDB installations can “fail” some of these regression tests due to platform-specific artifacts such as varying floating-point representation and message wording. The tests are currently evaluated using a simple `diff` comparison against the outputs generated on a reference system, so the results are sensitive to small system differences. When a test is reported as “failed”, always examine the differences between expected and actual results; you might find that the differences are not significant. Nonetheless, we still strive to maintain accurate reference files across all supported platforms, so it can be expected that all tests pass.

The actual outputs of the regression tests are in files in the `src/test/regress/results` directory. The test script uses `diff` to compare each output file against the reference outputs stored in the `src/test/regress/expected` directory. Any differences are saved for your inspection in `src/test/regress/regression.diffs`. (When running a test suite other than the core tests, these files of course appear in the relevant subdirectory, not `src/test/regress`.)

If you don't like the `diff` options that are used by default, set the environment variable `LT_REGRESS_DIFF_OPTS`, for instance `PG_REGRESS_DIFF_OPTS='-c'`. (Or you can run `diff` yourself, if you prefer.)

If for some reason a particular platform generates a “failure” for a given test, but inspection of the output convinces you that the result is valid, you can add a new comparison file to silence the failure report in future test runs. See Section 30.3 for details.

### 30.2.1. Error Message Differences

Some of the regression tests involve intentional invalid input values. Error messages can come from either the LightDB code or from the host platform system routines. In the latter case, the messages can vary between platforms, but should reflect similar information. These differences in messages will result in a “failed” regression test that can be validated by inspection.

### 30.2.2. Locale Differences

If you run the tests against a server that was initialized with a collation-order locale other than `C`, then there might be differences due to sort order and subsequent failures. The regression test suite is set up to handle this problem by providing alternate result files that together are known to handle a large number of locales.

To run the tests in a different locale when using the temporary-installation method, pass the appropriate locale-related environment variables on the `make` command line, for example:

```
make check LANG=de_DE.utf8
```

(The regression test driver unsets `LC_ALL`, so it does not work to choose the locale using that variable.) To use no locale, either unset all locale-related environment variables (or set them to `C`) or use the following special invocation:

```
make check NO_LOCALE=1
```

When running the tests against an existing installation, the locale setup is determined by the existing installation. To change it, initialize the database cluster with a different locale by passing the appropriate options to `initdb`.

In general, it is advisable to try to run the regression tests in the locale setup that is wanted for production use, as this will exercise the locale- and encoding-related code portions that will actually be used in production. Depending on the operating system environment, you might get failures, but then you will at least know what locale-specific behaviors to expect when running real applications.

### 30.2.3. Date and Time Differences

Most of the date and time results are dependent on the time zone environment. The reference files are generated for time zone PST8PDT (Berkeley, California), and there will be apparent failures if the tests are not run with that time zone setting. The regression test driver sets environment variable LTTZ to PST8PDT, which normally ensures proper results.

### 30.2.4. Floating-Point Differences

Some of the tests involve computing 64-bit floating-point numbers (`double precision`) from table columns. Differences in results involving mathematical functions of `double precision` columns have been observed. The `float8` and `geometry` tests are particularly prone to small differences across platforms, or even with different compiler optimization settings. Human eyeball comparison is needed to determine the real significance of these differences which are usually 10 places to the right of the decimal point.

Some systems display minus zero as `-0`, while others just show `0`.

Some systems signal errors from `pow()` and `exp()` differently from the mechanism expected by the current LightDB code.

### 30.2.5. Row Ordering Differences

You might see differences in which the same rows are output in a different order than what appears in the expected file. In most cases this is not, strictly speaking, a bug. Most of the regression test scripts are not so pedantic as to use an `ORDER BY` for every single `SELECT`, and so their result row orderings are not well-defined according to the SQL specification. In practice, since we are looking at the same queries being executed on the same data by the same software, we usually get the same result ordering on all platforms, so the lack of `ORDER BY` is not a problem. Some queries do exhibit cross-platform ordering differences, however. When testing against an already-installed server, ordering differences can also be caused by non-C locale settings or non-default parameter settings, such as custom values of `work_mem` or the planner cost parameters.

Therefore, if you see an ordering difference, it's not something to worry about, unless the query does have an `ORDER BY` that your result is violating. However, please report it anyway, so that we can add an `ORDER BY` to that particular query to eliminate the bogus "failure" in future releases.

You might wonder why we don't order all the regression test queries explicitly to get rid of this issue once and for all. The reason is that that would make the regression tests less useful, not more, since they'd tend to exercise query plan types that produce ordered results to the exclusion of those that don't.

### 30.2.6. Insufficient Stack Depth

If the `errors` test results in a server crash at the `select infinite_recurse()` command, it means that the platform's limit on process stack size is smaller than the `max_stack_depth` parameter indicates. This can be fixed by running the server under a higher stack size limit (4MB is recommended with the default value of `max_stack_depth`). If you are unable to do that, an alternative is to reduce the value of `max_stack_depth`.

On platforms supporting `getrlimit()`, the server should automatically choose a safe value of `max_stack_depth`; so unless you've manually overridden this setting, a failure of this kind is a reportable bug.



## 30.2.7. The “random” Test

The random test script is intended to produce random results. In very rare cases, this causes that regression test to fail. Typing:

```
diff results/random.out expected/random.out
```

should produce only one or a few lines of differences. You need not worry unless the random test fails repeatedly.

## 30.2.8. Configuration Parameters

When running the tests against an existing installation, some non-default parameter settings could cause the tests to fail. For example, changing parameters such as `enable_seqscan` or `enable_indexscan` could cause plan changes that would affect the results of tests that use `EXPLAIN`.

## 30.3. Variant Comparison Files

Since some of the tests inherently produce environment-dependent results, we have provided ways to specify alternate “expected” result files. Each regression test can have several comparison files showing possible results on different platforms. There are two independent mechanisms for determining which comparison file is used for each test.

The first mechanism allows comparison files to be selected for specific platforms. There is a mapping file, `src/test/regress/resultmap`, that defines which comparison file to use for each platform. To eliminate bogus test “failures” for a particular platform, you first choose or make a variant result file, and then add a line to the `resultmap` file.

Each line in the mapping file is of the form

```
testname:output:platformpattern=comparisonfilename
```

The test name is just the name of the particular regression test module. The output value indicates which output file to check. For the standard regression tests, this is always `out`. The value corresponds to the file extension of the output file. The platform pattern is a pattern in the style of the Unix tool `expr` (that is, a regular expression with an implicit `^` anchor at the start). It is matched against the platform name as printed by `config.guess`. The comparison file name is the base name of the substitute result comparison file.

For example: some systems lack a working `strtof` function, for which our workaround causes rounding errors in the `float4` regression test. Therefore, we provide a variant comparison file, `float4-misrounded-input.out`, which includes the results to be expected on these systems. To silence the bogus “failure” message on HP-UX 10 platforms, `resultmap` includes:

```
float4:out:hppa.*-hp-hpux10.*=float4-misrounded-input.out
```

which will trigger on any machine where the output of `config.guess` matches `hppa.*-hp-hpux10.*`. Other lines in `resultmap` select the variant comparison file for other platforms where it's appropriate.

The second selection mechanism for variant comparison files is much more automatic: it simply uses the “best match” among several supplied comparison files. The regression test driver script considers both the standard comparison file for a test, `testname.out`, and variant files named `testname_digit.out` (where the `digit` is any single digit 0-9). If any such file is an exact

match, the test is considered to pass; otherwise, the one that generates the shortest diff is used to create the failure report. (If `resultmap` includes an entry for the particular test, then the base `testname` is the substitute name given in `resultmap`.)

For example, for the `char` test, the comparison file `char.out` contains results that are expected in the `C` and `POSIX` locales, while the file `char_1.out` contains results sorted as they appear in many other locales.

The best-match mechanism was devised to cope with locale-dependent results, but it can be used in any situation where the test results cannot be predicted easily from the platform name alone. A limitation of this mechanism is that the test driver cannot tell which variant is actually “correct” for the current environment; it will just pick the variant that seems to work best. Therefore it is safest to use this mechanism only for variant results that you are willing to consider equally valid in all contexts.

## 30.4. TAP Tests

Various tests, particularly the client program tests under `src/bin`, use the Perl TAP tools and are run using the Perl testing program `prove`. You can pass command-line options to `prove` by setting the make variable `PROVE_FLAGS`, for example:

```
make -C src/bin check PROVE_FLAGS='--timer'
```

See the manual page of `prove` for more information.

The make variable `PROVE_TESTS` can be used to define a whitespace-separated list of paths relative to the `Makefile` invoking `prove` to run the specified subset of tests instead of the default `t/* .pl`. For example:

```
make check PROVE_TESTS='t/001_test1.pl t/003_test3.pl'
```

The TAP tests require the Perl module `IPC::Run`. This module is available from CPAN or an operating system package. They also require `LightDB` to be configured with the option `--enable-tap-tests`.

Generically speaking, the TAP tests will test the executables in a previously-installed installation tree if you say `make installcheck`, or will build a new local installation tree from current sources if you say `make check`. In either case they will initialize a local instance (data directory) and transiently run a server in it. Some of these tests run more than one server. Thus, these tests can be fairly resource-intensive.

It's important to realize that the TAP tests will start test server(s) even when you say `make installcheck`; this is unlike the traditional non-TAP testing infrastructure, which expects to use an already-running test server in that case. Some `LightDB` subdirectories contain both traditional-style and TAP-style tests, meaning that `make installcheck` will produce a mix of results from temporary servers and the already-running test server.

## 30.5. Test Coverage Examination

The `LightDB` source code can be compiled with coverage testing instrumentation, so that it becomes possible to examine which parts of the code are covered by the regression tests or any other test suite that is run with the code. This is currently supported when compiling with `GCC` and requires the `gcov` and `lcov` programs.

A typical workflow would look like this:

```
./configure --enable-coverage ... OTHER OPTIONS ...
```

```
make
make check # or other test suite
make coverage-html
```

Then point your HTML browser to `coverage/index.html`. The make commands also work in subdirectories.

If you don't have `lcov` or prefer text output over an HTML report, you can also run

```
make coverage
```

instead of `make coverage-html`, which will produce `.gcov` output files for each source file relevant to the test. (`make coverage` and `make coverage-html` will overwrite each other's files, so mixing them might be confusing.)

To reset the execution counts between test runs, run:

```
make coverage-clean
```

---

# Chapter 31. Transparent Data Encryption

TDE(Transparent Data Encryption) is to store all files constituting the database cluster securely on the disk in an encrypted format (static data encryption), and then decrypt them when reading blocks from the disk. Data is unencrypted in memory.

TDE has the following characteristics:

- The encryption is transparent from the application's point of view.
- It uses a single key to encrypt the whole cluster.

During startup, the server can access the key of the initialization database and provide the encryption key through a special configuration parameter, which specifies a custom key setting command for realizing special security requirements. TDE internally uses the industry standard 128 bit aes-ctr encryption algorithm to encrypt / decrypt data blocks on the disk.

Use `lt_initdb` passes in the TDE key through the `-K` option. Before creating a database instance, you must write some code to ensure that the database can read the key during startup and instance creation. Note that this key is never visible to anybody but the database server. The key must be a 32 byte hexadecimal string, or an error will be reported when initializing the instance:

```
fatal: encryption key is too short, should be a 32 character
hex key
```

Here is an example:

```
cat /somewhere/provide_key.sh
#!/bin/sh
echo 882fb7c12e80280fd664c69d2d636913
```

All you need is a program that prints the key to stdout, and make sure that LightDB is able to execute this program:

```
chmod +x /somewhere/provide_key.sh
```

Create a database instance:

```
lt_initdb -p 5432 -D ./data -K /somewhere/provide_key.sh
```

You can use `lt_controldata` to determine whether the current instance has used transparent encryption. At the end of the listing, you can find the encryption details.

The GUC parameter of `lightdb_encryption_key_command` will exist in the `lightdb.conf` configuration file, which ensures that the TDE key will be read again after each restart of the data.

Note that we don't currently support in-place encryption of existing clusters. You will need to perform a dump and reload to an encrypted instance, or use logical replication to perform the migration online.

---

# Part IV. Client Interfaces

This part describes the client programming interfaces distributed with LightDB. Each of these chapters can be read independently. Note that there are many other programming interfaces for client programs that are distributed separately and contain their own documentation (Appendix H lists some of the more popular ones). Readers of this part should be familiar with using SQL commands to manipulate and query the database (see Part II) and of course with the programming language that the interface uses.

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# Chapter 32. libpq — C Library

libpq is the C application programmer's interface to LightDB. libpq is a set of library functions that allow client programs to pass queries to the LightDB backend server and to receive the results of these queries.

libpq is also the underlying engine for several other LightDB application interfaces, including those written for C++, Perl, Python, Tcl and ECPG. So some aspects of libpq's behavior will be important to you if you use one of those packages. In particular, Section 32.14, Section 32.15 and Section 32.18 describe behavior that is visible to the user of any application that uses libpq.

Some short programs are included at the end of this chapter (Section 32.21) to show how to write programs that use libpq. There are also several complete examples of libpq applications in the directory `src/test/examples` in the source code distribution.

Client programs that use libpq must include the header file `libpq-fe.h` and must link with the libpq library.

## 32.1. Database Connection Control Functions

The following functions deal with making a connection to a LightDB backend server. An application program can have several backend connections open at one time. (One reason to do that is to access more than one database.) Each connection is represented by a `PGconn` object, which is obtained from the function `PQconnectdb`, `PQconnectdbParams`, or `PQsetdbLogin`. Note that these functions will always return a non-null object pointer, unless perhaps there is too little memory even to allocate the `PGconn` object. The `PQstatus` function should be called to check the return value for a successful connection before queries are sent via the connection object.

### Warning

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from `search_path`. One can set parameter key word `options` to value `-csearch_path=`. Alternately, one can issue `PQexec(conn, "SELECT pg_catalog.set_config('search_path', '', false)")` after connecting. This consideration is not specific to libpq; it applies to every interface for executing arbitrary SQL commands.

### Warning

On Unix, forking a process with open libpq connections can lead to unpredictable results because the parent and child processes share the same sockets and operating system resources. For this reason, such usage is not recommended, though doing an `exec` from the child process to load a new executable is safe.

`PQconnectdbParams`

Makes a new connection to the database server.

```
PGconn *PQconnectdbParams(const char * const *keywords,
                          const char * const *values,
                          int expand_dbname);
```

This function opens a new database connection using the parameters taken from two NULL-terminated arrays. The first, `keywords`, is defined as an array of strings, each one being a key word. The second, `values`, gives the value for each key word. Unlike `PQsetdbLogin` below, the parameter set can be extended without changing the function signature, so use of this function (or its nonblocking analogs `PQconnectStartParams` and `PQconnectPoll`) is preferred for new application programming.

The currently recognized parameter key words are listed in Section 32.1.2.

The passed arrays can be empty to use all default parameters, or can contain one or more parameter settings. They must be matched in length. Processing will stop at the first NULL entry in the `keywords` array. Also, if the `values` entry associated with a non-NULL `keywords` entry is NULL or an empty string, that entry is ignored and processing continues with the next pair of array entries.

When `expand_dbname` is non-zero, the value for the first `dbname` key word is checked to see if it is a *connection string*. If so, it is “expanded” into the individual connection parameters extracted from the string. The value is considered to be a connection string, rather than just a database name, if it contains an equal sign (=) or it begins with a URI scheme designator. (More details on connection string formats appear in Section 32.1.1.) Only the first occurrence of `dbname` is treated in this way; any subsequent `dbname` parameter is processed as a plain database name.

In general the parameter arrays are processed from start to end. If any key word is repeated, the last value (that is not NULL or empty) is used. This rule applies in particular when a key word found in a connection string conflicts with one appearing in the `keywords` array. Thus, the programmer may determine whether array entries can override or be overridden by values taken from a connection string. Array entries appearing before an expanded `dbname` entry can be overridden by fields of the connection string, and in turn those fields are overridden by array entries appearing after `dbname` (but, again, only if those entries supply non-empty values).

After processing all the array entries and any expanded connection string, any connection parameters that remain unset are filled with default values. If an unset parameter's corresponding environment variable (see Section 32.14) is set, its value is used. If the environment variable is not set either, then the parameter's built-in default value is used.

#### `PQconnectdb`

Makes a new connection to the database server.

```
PGconn *PQconnectdb(const char *conninfo);
```

This function opens a new database connection using the parameters taken from the string `conninfo`.

The passed string can be empty to use all default parameters, or it can contain one or more parameter settings separated by whitespace, or it can contain a URI. See Section 32.1.1 for details.

#### `PQsetdbLogin`

Makes a new connection to the database server.

```
PGconn *PQsetdbLogin(const char *pghost,
                    const char *pgport,
                    const char *pgoptions,
                    const char *pgtty,
                    const char *dbName,
                    const char *login,
                    const char *pwd);
```

This is the predecessor of `PQconnectdb` with a fixed set of parameters. It has the same functionality except that the missing parameters will always take on default values. Write `NULL` or an empty string for any one of the fixed parameters that is to be defaulted.

If the *dbName* contains an `=` sign or has a valid connection URI prefix, it is taken as a *conninfo* string in exactly the same way as if it had been passed to `PQconnectdb`, and the remaining parameters are then applied as specified for `PQconnectdbParams`.

### `PQsetdb`

Makes a new connection to the database server.

```
PGconn *PQsetdb(char *pghost,
                char *pgport,
                char *pgoptions,
                char *pgtty,
                char *dbName);
```

This is a macro that calls `PQsetdbLogin` with null pointers for the *login* and *pwd* parameters. It is provided for backward compatibility with very old programs.

### `PQconnectStartParams`

### `PQconnectStart`

### `PQconnectPoll`

Make a connection to the database server in a nonblocking manner.

```
PGconn *PQconnectStartParams(const char * const *keywords,
                             const char * const *values,
                             int expand_dbname);
```

```
PGconn *PQconnectStart(const char *conninfo);
```

```
PostgresPollingStatusType PQconnectPoll(PGconn *conn);
```

These three functions are used to open a connection to a database server such that your application's thread of execution is not blocked on remote I/O whilst doing so. The point of this approach is that the waits for I/O to complete can occur in the application's main loop, rather than down inside `PQconnectdbParams` or `PQconnectdb`, and so the application can manage this operation in parallel with other activities.

With `PQconnectStartParams`, the database connection is made using the parameters taken from the *keywords* and *values* arrays, and controlled by *expand\_dbname*, as described above for `PQconnectdbParams`.

With `PQconnectStart`, the database connection is made using the parameters taken from the string *conninfo* as described above for `PQconnectdb`.

Neither `PQconnectStartParams` nor `PQconnectStart` nor `PQconnectPoll` will block, so long as a number of restrictions are met:

- The *hostaddr* parameter must be used appropriately to prevent DNS queries from being made. See the documentation of this parameter in Section 32.1.2 for details.
- If you call `PQtrace`, ensure that the stream object into which you trace will not block.
- You must ensure that the socket is in the appropriate state before calling `PQconnectPoll`, as described below.

To begin a nonblocking connection request, call `PQconnectStart` or `PQconnectStartParams`. If the result is null, then libpq has been unable to allocate a new `PGconn` structure. Otherwise, a valid `PGconn` pointer is returned (though not yet representing a valid connection to the database). Next call `PQstatus(conn)`. If the result is `CONNECTION_BAD`, the connection attempt has already failed, typically because of invalid connection parameters.

If `PQconnectStart` or `PQconnectStartParams` succeeds, the next stage is to poll libpq so that it can proceed with the connection sequence. Use `PQsocket(conn)` to obtain the descriptor of the socket underlying the database connection. (Caution: do not assume that the socket remains the same across `PQconnectPoll` calls.) Loop thus: If `PQconnectPoll(conn)` last returned `PGRES_POLLING_READING`, wait until the socket is ready to read (as indicated by `select()`, `poll()`, or similar system function). Then call `PQconnectPoll(conn)` again. Conversely, if `PQconnectPoll(conn)` last returned `PGRES_POLLING_WRITING`, wait until the socket is ready to write, then call `PQconnectPoll(conn)` again. On the first iteration, i.e., if you have yet to call `PQconnectPoll`, behave as if it last returned `PGRES_POLLING_WRITING`. Continue this loop until `PQconnectPoll(conn)` returns `PGRES_POLLING_FAILED`, indicating the connection procedure has failed, or `PGRES_POLLING_OK`, indicating the connection has been successfully made.

At any time during connection, the status of the connection can be checked by calling `PQstatus`. If this call returns `CONNECTION_BAD`, then the connection procedure has failed; if the call returns `CONNECTION_OK`, then the connection is ready. Both of these states are equally detectable from the return value of `PQconnectPoll`, described above. Other states might also occur during (and only during) an asynchronous connection procedure. These indicate the current stage of the connection procedure and might be useful to provide feedback to the user for example. These statuses are:

`CONNECTION_STARTED`

Waiting for connection to be made.

`CONNECTION_MADE`

Connection OK; waiting to send.

`CONNECTION_AWAITING_RESPONSE`

Waiting for a response from the server.

`CONNECTION_AUTH_OK`

Received authentication; waiting for backend start-up to finish.

`CONNECTION_SSL_STARTUP`

Negotiating SSL encryption.

`CONNECTION_SETENV`

Negotiating environment-driven parameter settings.

`CONNECTION_CHECK_WRITABLE`

Checking if connection is able to handle write transactions.

`CONNECTION_CONSUME`

Consuming any remaining response messages on connection.

Note that, although these constants will remain (in order to maintain compatibility), an application should never rely upon these occurring in a particular order, or at all, or on the status always being one of these documented values. An application might do something like this:

```
switch(PQstatus(conn))
{
    case CONNECTION_STARTED:
        feedback = "Connecting...";
        break;

    case CONNECTION_MADE:
        feedback = "Connected to server...";
        break;

    .
    .
    .

    default:
        feedback = "Connecting...";
}

```

The `connect_timeout` connection parameter is ignored when using `PQconnectPoll`; it is the application's responsibility to decide whether an excessive amount of time has elapsed. Otherwise, `PQconnectStart` followed by a `PQconnectPoll` loop is equivalent to `PQconnectdb`.

Note that when `PQconnectStart` or `PQconnectStartParams` returns a non-null pointer, you must call `PQfinish` when you are finished with it, in order to dispose of the structure and any associated memory blocks. This must be done even if the connection attempt fails or is abandoned.

#### PQconndefaults

Returns the default connection options.

```
PQconninfoOption *PQconndefaults(void);

typedef struct
{
    char    *keyword;    /* The keyword of the option */
    char    *envvar;    /* Fallback environment variable name */
    char    *compiled;  /* Fallback compiled in default value */
    char    *val;       /* Option's current value, or NULL */
    char    *label;    /* Label for field in connect dialog */
    char    *dispchar; /* Indicates how to display this field
                        in a connect dialog. Values are:
                        ""      Display entered value as is
                        "*"    Password field - hide value
                        "D"    Debug option - don't show by
                        default */
    int     dispsize;  /* Field size in characters for dialog */
} PQconninfoOption;

```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and their current default values. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null keyword pointer. The null pointer is returned if memory could not be allocated. Note that the current default values (`val` fields) will depend on environment variables and other context. A missing or invalid service file will be silently ignored. Callers must treat the connection options data as read-only.

After processing the options array, free it by passing it to `PQconninfoFree`. If this is not done, a small amount of memory is leaked for each call to `PQconnndefaults`.

### `PQconninfo`

Returns the connection options used by a live connection.

```
PQconninfoOption *PQconninfo(PGconn *conn);
```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and the values that were used to connect to the server. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null keyword pointer. All notes above for `PQconnndefaults` also apply to the result of `PQconninfo`.

### `PQconninfoParse`

Returns parsed connection options from the provided connection string.

```
PQconninfoOption *PQconninfoParse(const char *conninfo, char **errmsg);
```

Parses a connection string and returns the resulting options as an array; or returns `NULL` if there is a problem with the connection string. This function can be used to extract the `PQconnectdb` options in the provided connection string. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null keyword pointer.

All legal options will be present in the result array, but the `PQconninfoOption` for any option not present in the connection string will have `val` set to `NULL`; default values are not inserted.

If `errmsg` is not `NULL`, then `*errmsg` is set to `NULL` on success, else to a malloc'd error string explaining the problem. (It is also possible for `*errmsg` to be set to `NULL` and the function to return `NULL`; this indicates an out-of-memory condition.)

After processing the options array, free it by passing it to `PQconninfoFree`. If this is not done, some memory is leaked for each call to `PQconninfoParse`. Conversely, if an error occurs and `errmsg` is not `NULL`, be sure to free the error string using `PQfreemem`.

### `PQfinish`

Closes the connection to the server. Also frees memory used by the `PGconn` object.

```
void PQfinish(PGconn *conn);
```

Note that even if the server connection attempt fails (as indicated by `PQstatus`), the application should call `PQfinish` to free the memory used by the `PGconn` object. The `PGconn` pointer must not be used again after `PQfinish` has been called.

### `PQreset`

Resets the communication channel to the server.

```
void PQreset(PGconn *conn);
```

This function will close the connection to the server and attempt to establish a new connection, using all the same parameters previously used. This might be useful for error recovery if a working connection is lost.

PQresetStart  
PQresetPoll

Reset the communication channel to the server, in a nonblocking manner.

```
int PQresetStart(PGconn *conn);
```

```
PostgresPollingStatusType PQresetPoll(PGconn *conn);
```

These functions will close the connection to the server and attempt to establish a new connection, using all the same parameters previously used. This can be useful for error recovery if a working connection is lost. They differ from `PQreset` (above) in that they act in a nonblocking manner. These functions suffer from the same restrictions as `PQconnectStartParams`, `PQconnectStart` and `PQconnectPoll`.

To initiate a connection reset, call `PQresetStart`. If it returns 0, the reset has failed. If it returns 1, poll the reset using `PQresetPoll` in exactly the same way as you would create the connection using `PQconnectPoll`.

PQpingParams

`PQpingParams` reports the status of the server. It accepts connection parameters identical to those of `PQconnectdbParams`, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

```
PGPing PQpingParams(const char * const *keywords,  
                   const char * const *values,  
                   int expand_dbname);
```

The function returns one of the following values:

`PQPING_OK`

The server is running and appears to be accepting connections.

`PQPING_REJECT`

The server is running but is in a state that disallows connections (startup, shutdown, or crash recovery).

`PQPING_NO_RESPONSE`

The server could not be contacted. This might indicate that the server is not running, or that there is something wrong with the given connection parameters (for example, wrong port number), or that there is a network connectivity problem (for example, a firewall blocking the connection request).

`PQPING_NO_ATTEMPT`

No attempt was made to contact the server, because the supplied parameters were obviously incorrect or there was some client-side problem (for example, out of memory).

PQping

`PQping` reports the status of the server. It accepts connection parameters identical to those of `PQconnectdb`, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.



```
PGPing PQping(const char *conninfo);
```

The return values are the same as for `PQpingParams`.

`PQsetSSLKeyPassHook_OpenSSL`

`PQsetSSLKeyPassHook_OpenSSL` lets an application override libpq's default handling of encrypted client certificate key files using `sslpassword` or interactive prompting.

```
void PQsetSSLKeyPassHook_OpenSSL(PQsslKeyPassHook_OpenSSL_type
    hook);
```

The application passes a pointer to a callback function with signature:

```
int callback_fn(char *buf, int size, PGconn *conn);
```

which libpq will then call *instead of* its default `PQdefaultSSLKeyPassHook_OpenSSL` handler. The callback should determine the password for the key and copy it to result-buffer *buf* of size *size*. The string in *buf* must be null-terminated. The callback must return the length of the password stored in *buf* excluding the null terminator. On failure, the callback should set `buf[0] = '\0'` and return 0. See `PQdefaultSSLKeyPassHook_OpenSSL` in libpq's source code for an example.

If the user specified an explicit key location, its path will be in `conn->sslkey` when the callback is invoked. This will be empty if the default key path is being used. For keys that are engine specifiers, it is up to engine implementations whether they use the OpenSSL password callback or define their own handling.

The app callback may choose to delegate unhandled cases to `PQdefaultSSLKeyPassHook_OpenSSL`, or call it first and try something else if it returns 0, or completely override it.

The callback *must not* escape normal flow control with exceptions, `longjmp(...)`, etc. It must return normally.

`PQgetSSLKeyPassHook_OpenSSL`

`PQgetSSLKeyPassHook_OpenSSL` returns the current client certificate key password hook, or NULL if none has been set.

```
PQsslKeyPassHook_OpenSSL_type PQgetSSLKeyPassHook_OpenSSL(void);
```

## 32.1.1. Connection Strings

Several libpq functions parse a user-specified string to obtain connection parameters. There are two accepted formats for these strings: plain keyword/value strings and URIs. URIs generally follow RFC 3986<sup>1</sup>, except that multi-host connection strings are allowed as further described below.

### 32.1.1.1. Keyword/Value Connection Strings

In the keyword/value format, each parameter setting is in the form `keyword = value`, with space(s) between settings. Spaces around a setting's equal sign are optional. To write an empty value, or a value containing spaces, surround it with single quotes, for example `keyword = 'a value'`. Single quotes and backslashes within a value must be escaped with a backslash, i.e., `\'` and `\\`.

<sup>1</sup> <https://tools.ietf.org/html/rfc3986>

Example:

```
host=localhost port=5432 dbname=mydb connect_timeout=10
```

The recognized parameter key words are listed in Section 32.1.2.

### 32.1.1.2. Connection URIs

The general form for a connection URI is:

```
postgresql://[userspec@][hostspec][/dbname][?paramspec]
```

where *userspec* is:

```
user[:password]
```

and *hostspec* is:

```
[host][:port][,...]
```

and *paramspec* is:

```
name=value[&...]
```

The URI scheme designator can be either `postgresql://` or `postgres://`. Each of the remaining URI parts is optional. The following examples illustrate valid URI syntax:

```
postgresql://
postgresql://localhost
postgresql://localhost:5433
postgresql://localhost/mydb
postgresql://user@localhost
postgresql://user:secret@localhost
postgresql://other@localhost/otherdb?
connect_timeout=10&application_name=myapp
postgresql://host1:123,host2:456/somedb?
target_session_attrs=any&application_name=myapp
```

Values that would normally appear in the hierarchical part of the URI can alternatively be given as named parameters. For example:

```
postgresql:///mydb?host=localhost&port=5433
```

All named parameters must match key words listed in Section 32.1.2, except that for compatibility with JDBC connection URIs, instances of `ssl=true` are translated into `sslmode=require`.

The connection URI needs to be encoded with percent-encoding<sup>2</sup> if it includes symbols with special meaning in any of its parts. Here is an example where the equal sign (=) is replaced with `%3D` and the space character with `%20`:

```
postgresql://user@localhost:5433/mydb?options=-c
%20synchronous_commit%3Doff
```

<sup>2</sup> <https://tools.ietf.org/html/rfc3986#section-2.1>

The host part may be either a host name or an IP address. To specify an IPv6 address, enclose it in square brackets:

```
postgresql://[2001:db8::1234]/database
```

The host part is interpreted as described for the parameter `host`. In particular, a Unix-domain socket connection is chosen if the host part is either empty or looks like an absolute path name, otherwise a TCP/IP connection is initiated. Note, however, that the slash is a reserved character in the hierarchical part of the URI. So, to specify a non-standard Unix-domain socket directory, either omit the host part of the URI and specify the host as a named parameter, or percent-encode the path in the host part of the URI:

```
postgresql:///dbname?host=/var/lib/postgresql
postgresql://%2Fvar%2Flib%2Fpostgresql/dbname
```

It is possible to specify multiple host components, each with an optional port component, in a single URI. A URI of the form `postgresql://host1:port1,host2:port2,host3:port3/` is equivalent to a connection string of the form `host=host1,host2,host3 port=port1,port2,port3`. As further described below, each host will be tried in turn until a connection is successfully established.

### 32.1.1.3. Specifying Multiple Hosts

It is possible to specify multiple hosts to connect to, so that they are tried in the given order. In the Keyword/Value format, the `host`, `hostaddr`, and `port` options accept comma-separated lists of values. The same number of elements must be given in each option that is specified, such that e.g., the first `hostaddr` corresponds to the first host name, the second `hostaddr` corresponds to the second host name, and so forth. As an exception, if only one `port` is specified, it applies to all the hosts.

In the connection URI format, you can list multiple `host:port` pairs separated by commas in the `host` component of the URI.

In either format, a single host name can translate to multiple network addresses. A common example of this is a host that has both an IPv4 and an IPv6 address.

When multiple hosts are specified, or when a single host name is translated to multiple addresses, all the hosts and addresses will be tried in order, until one succeeds. If none of the hosts can be reached, the connection fails. If a connection is established successfully, but authentication fails, the remaining hosts in the list are not tried.

If a password file is used, you can have different passwords for different hosts. All the other connection options are the same for every host in the list; it is not possible to e.g., specify different usernames for different hosts.

### 32.1.2. Parameter Key Words

The currently recognized parameter key words are:

`host`

Name of host to connect to. If a host name looks like an absolute path name, it specifies Unix-domain communication rather than TCP/IP communication; the value is the name of the directory in which the socket file is stored. (On Unix, an absolute path name begins with a slash. On Windows, paths starting with drive letters are also recognized.) The default behavior when `host` is not specified, or is empty, is to connect to a Unix-domain socket in `/tmp` (or whatever socket directory was specified when LightDB was built). On Windows and on machines without Unix-domain sockets, the default is to connect to `localhost`.

A comma-separated list of host names is also accepted, in which case each host name in the list is tried in order; an empty item in the list selects the default behavior as explained above. See Section 32.1.1.3 for details.

#### hostaddr

Numeric IP address of host to connect to. This should be in the standard IPv4 address format, e.g., 172.28.40.9. If your machine supports IPv6, you can also use those addresses. TCP/IP communication is always used when a nonempty string is specified for this parameter. If this parameter is not specified, the value of `host` will be looked up to find the corresponding IP address — or, if `host` specifies an IP address, that value will be used directly.

Using `hostaddr` allows the application to avoid a host name look-up, which might be important in applications with time constraints. However, a host name is required for GSSAPI or SSPI authentication methods, as well as for `verify-full` SSL certificate verification. The following rules are used:

- If `host` is specified without `hostaddr`, a host name lookup occurs. (When using `PQconnectPoll`, the lookup occurs when `PQconnectPoll` first considers this host name, and it may cause `PQconnectPoll` to block for a significant amount of time.)
- If `hostaddr` is specified without `host`, the value for `hostaddr` gives the server network address. The connection attempt will fail if the authentication method requires a host name.
- If both `host` and `hostaddr` are specified, the value for `hostaddr` gives the server network address. The value for `host` is ignored unless the authentication method requires it, in which case it will be used as the host name.

Note that authentication is likely to fail if `host` is not the name of the server at network address `hostaddr`. Also, when both `host` and `hostaddr` are specified, `host` is used to identify the connection in a password file (see Section 32.15).

A comma-separated list of `hostaddr` values is also accepted, in which case each host in the list is tried in order. An empty item in the list causes the corresponding host name to be used, or the default host name if that is empty as well. See Section 32.1.1.3 for details.

Without either a host name or host address, `libpq` will connect using a local Unix-domain socket; or on Windows and on machines without Unix-domain sockets, it will attempt to connect to `localhost`.

#### port

Port number to connect to at the server host, or socket file name extension for Unix-domain connections. If multiple hosts were given in the `host` or `hostaddr` parameters, this parameter may specify a comma-separated list of ports of the same length as the host list, or it may specify a single port number to be used for all hosts. An empty string, or an empty item in a comma-separated list, specifies the default port number established when LightDB was built.

#### dbname

The database name. Defaults to be the same as the user name. In certain contexts, the value is checked for extended formats; see Section 32.1.1 for more details on those.

#### user

LightDB user name to connect as. Defaults to be the same as the operating system name of the user running the application.

#### password

Password to be used if the server demands password authentication.

**passfile**

Specifies the name of the file used to store passwords (see Section 32.15). Defaults to `~/ .pgpass`, or `%APPDATA%\postgresql\pgpass.conf` on Microsoft Windows. (No error is reported if this file does not exist.)

**channel\_binding**

This option controls the client's use of channel binding. A setting of `require` means that the connection must employ channel binding, `prefer` means that the client will choose channel binding if available, and `disable` prevents the use of channel binding. The default is `prefer` if LightDB is compiled with SSL support; otherwise the default is `disable`.

Channel binding is a method for the server to authenticate itself to the client. It is only supported over SSL connections with LightDB 11 or later servers using the SCRAM authentication method.

**connect\_timeout**

Maximum time to wait while connecting, in seconds (write as a decimal integer, e.g., 10). Zero, negative, or not specified means wait indefinitely. The minimum allowed timeout is 2 seconds, therefore a value of 1 is interpreted as 2. This timeout applies separately to each host name or IP address. For example, if you specify two hosts and `connect_timeout` is 5, each host will time out if no connection is made within 5 seconds, so the total time spent waiting for a connection might be up to 10 seconds.

**client\_encoding**

This sets the `client_encoding` configuration parameter for this connection. In addition to the values accepted by the corresponding server option, you can use `auto` to determine the right encoding from the current locale in the client (`LC_CTYPE` environment variable on Unix systems).

**options**

Specifies command-line options to send to the server at connection start. For example, setting this to `-c geqo=off` sets the session's value of the `geqo` parameter to `off`. Spaces within this string are considered to separate command-line arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash. For a detailed discussion of the available options, consult Chapter 17.

**application\_name**

Specifies a value for the `application_name` configuration parameter.

**fallback\_application\_name**

Specifies a fallback value for the `application_name` configuration parameter. This value will be used if no value has been given for `application_name` via a connection parameter or the `LTAPPNAME` environment variable. Specifying a fallback name is useful in generic utility programs that wish to set a default application name but allow it to be overridden by the user.

**keepalives**

Controls whether client-side TCP keepalives are used. The default value is 1, meaning on, but you can change this to 0, meaning off, if keepalives are not wanted. This parameter is ignored for connections made via a Unix-domain socket.

**keepalives\_idle**

Controls the number of seconds of inactivity after which TCP should send a keepalive message to the server. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems

where `TCP_KEEPIDLE` or an equivalent socket option is available, and on Windows; on other systems, it has no effect.

#### `keepalives_interval`

Controls the number of seconds after which a TCP keepalive message that is not acknowledged by the server should be retransmitted. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where `TCP_KEEPINTVL` or an equivalent socket option is available, and on Windows; on other systems, it has no effect.

#### `keepalives_count`

Controls the number of TCP keepalives that can be lost before the client's connection to the server is considered dead. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where `TCP_KEEPCNT` or an equivalent socket option is available; on other systems, it has no effect.

#### `tcp_user_timeout`

Controls the number of milliseconds that transmitted data may remain unacknowledged before a connection is forcibly closed. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket. It is only supported on systems where `TCP_USER_TIMEOUT` is available; on other systems, it has no effect.

#### `tty`

Ignored (formerly, this specified where to send server debug output).

#### `replication`

This option determines whether the connection should use the replication protocol instead of the normal protocol. This is what LightDB replication connections as well as tools such as `pg_basebackup` use internally, but it can also be used by third-party applications. For a description of the replication protocol, consult Section 49.4.

The following values, which are case-insensitive, are supported:

`true`, `on`, `yes`, `1`

The connection goes into physical replication mode.

`database`

The connection goes into logical replication mode, connecting to the database specified in the `dbname` parameter.

`false`, `off`, `no`, `0`

The connection is a regular one, which is the default behavior.

In physical or logical replication mode, only the simple query protocol can be used.

#### `gssencmode`

This option determines whether or with what priority a secure GSS TCP/IP connection will be negotiated with the server. There are three modes:

`disable`

only try a non-GSSAPI-encrypted connection

`prefer` (default)

if there are GSSAPI credentials present (i.e., in a credentials cache), first try a GSSAPI-encrypted connection; if that fails or there are no credentials, try a non-GSSAPI-encrypted connection. This is the default when LightDB has been compiled with GSSAPI support.

`require`

only try a GSSAPI-encrypted connection

`gssencmode` is ignored for Unix domain socket communication. If LightDB is compiled without GSSAPI support, using the `require` option will cause an error, while `prefer` will be accepted but libpq will not actually attempt a GSSAPI-encrypted connection.

`sslmode`

This option determines whether or with what priority a secure SSL TCP/IP connection will be negotiated with the server. There are six modes:

`disable`

only try a non-SSL connection

`allow`

first try a non-SSL connection; if that fails, try an SSL connection

`prefer` (default)

first try an SSL connection; if that fails, try a non-SSL connection

`require`

only try an SSL connection. If a root CA file is present, verify the certificate in the same way as if `verify-ca` was specified

`verify-ca`

only try an SSL connection, and verify that the server certificate is issued by a trusted certificate authority (CA)

`verify-full`

only try an SSL connection, verify that the server certificate is issued by a trusted CA and that the requested server host name matches that in the certificate

See Section 32.18 for a detailed description of how these options work.

`sslmode` is ignored for Unix domain socket communication. If LightDB is compiled without SSL support, using options `require`, `verify-ca`, or `verify-full` will cause an error, while options `allow` and `prefer` will be accepted but libpq will not actually attempt an SSL connection.

Note that if GSSAPI encryption is possible, that will be used in preference to SSL encryption, regardless of the value of `sslmode`. To force use of SSL encryption in an environment that has working GSSAPI infrastructure (such as a Kerberos server), also set `gssencmode` to `disable`.

`requiressl`

This option is deprecated in favor of the `sslmode` setting.

If set to 1, an SSL connection to the server is required (this is equivalent to `sslmode require`). libpq will then refuse to connect if the server does not accept an SSL connection. If set to

0 (default), libpq will negotiate the connection type with the server (equivalent to `sslmode prefer`). This option is only available if LightDB is compiled with SSL support.

#### `sslcompression`

If set to 1, data sent over SSL connections will be compressed. If set to 0, compression will be disabled. The default is 0. This parameter is ignored if a connection without SSL is made.

SSL compression is nowadays considered insecure and its use is no longer recommended. OpenSSL 1.1.0 disables compression by default, and many operating system distributions disable it in prior versions as well, so setting this parameter to on will not have any effect if the server does not accept compression.

If security is not a primary concern, compression can improve throughput if the network is the bottleneck. Disabling compression can improve response time and throughput if CPU performance is the limiting factor.

#### `sslcert`

This parameter specifies the file name of the client SSL certificate, replacing the default `~/.postgresql/postgresql.crt`. This parameter is ignored if an SSL connection is not made.

#### `sslkey`

This parameter specifies the location for the secret key used for the client certificate. It can either specify a file name that will be used instead of the default `~/.postgresql/postgresql.key`, or it can specify a key obtained from an external “engine” (engines are OpenSSL loadable modules). An external engine specification should consist of a colon-separated engine name and an engine-specific key identifier. This parameter is ignored if an SSL connection is not made.

#### `sslpassword`

This parameter specifies the password for the secret key specified in `sslkey`, allowing client certificate private keys to be stored in encrypted form on disk even when interactive passphrase input is not practical.

Specifying this parameter with any non-empty value suppresses the `Enter PEM passphrase: prompt` that OpenSSL will emit by default when an encrypted client certificate key is provided to libpq.

If the key is not encrypted this parameter is ignored. The parameter has no effect on keys specified by OpenSSL engines unless the engine uses the OpenSSL password callback mechanism for prompts.

There is no environment variable equivalent to this option, and no facility for looking it up in `.pgpass`. It can be used in a service file connection definition. Users with more sophisticated uses should consider using openssl engines and tools like PKCS#11 or USB crypto offload devices.

#### `sslrootcert`

This parameter specifies the name of a file containing SSL certificate authority (CA) certificate(s). If the file exists, the server's certificate will be verified to be signed by one of these authorities. The default is `~/.postgresql/root.crt`.

#### `sslcr1`

This parameter specifies the file name of the SSL server certificate revocation list (CRL). Certificates listed in this file, if it exists, will be rejected while attempting to authenticate the server's certificate. The default is `~/.postgresql/root.crl`.



**requirepeer**

This parameter specifies the operating-system user name of the server, for example `requirepeer=postgres`. When making a Unix-domain socket connection, if this parameter is set, the client checks at the beginning of the connection that the server process is running under the specified user name; if it is not, the connection is aborted with an error. This parameter can be used to provide server authentication similar to that available with SSL certificates on TCP/IP connections. (Note that if the Unix-domain socket is in `/tmp` or another publicly writable location, any user could start a server listening there. Use this parameter to ensure that you are connected to a server run by a trusted user.) This option is only supported on platforms for which the `peer` authentication method is implemented; see Section 18.9.

**ssl\_min\_protocol\_version**

This parameter specifies the minimum SSL/TLS protocol version to allow for the connection. Valid values are `TLSv1`, `TLSv1.1`, `TLSv1.2` and `TLSv1.3`. The supported protocols depend on the version of OpenSSL used, older versions not supporting the most modern protocol versions. If not specified, the default is `TLSv1.2`, which satisfies industry best practices as of this writing.

**ssl\_max\_protocol\_version**

This parameter specifies the maximum SSL/TLS protocol version to allow for the connection. Valid values are `TLSv1`, `TLSv1.1`, `TLSv1.2` and `TLSv1.3`. The supported protocols depend on the version of OpenSSL used, older versions not supporting the most modern protocol versions. If not set, this parameter is ignored and the connection will use the maximum bound defined by the backend, if set. Setting the maximum protocol version is mainly useful for testing or if some component has issues working with a newer protocol.

**krbsrvname**

Kerberos service name to use when authenticating with GSSAPI. This must match the service name specified in the server configuration for Kerberos authentication to succeed. (See also Section 18.6.) The default value is normally `postgres`, but that can be changed when building LightDB via the `--with-krb-srvnam` option of `configure`. In most environments, this parameter never needs to be changed. Some Kerberos implementations might require a different service name, such as Microsoft Active Directory which requires the service name to be in upper case (`POSTGRES`).

**gsslib**

GSS library to use for GSSAPI authentication. Currently this is disregarded except on Windows builds that include both GSSAPI and SSPI support. In that case, set this to `gssapi` to cause libpq to use the GSSAPI library for authentication instead of the default SSPI.

**service**

Service name to use for additional parameters. It specifies a service name in `pg_service.conf` that holds additional connection parameters. This allows applications to specify only a service name so connection parameters can be centrally maintained. See Section 32.16.

**target\_session\_attrs**

If this parameter is set to `read-write`, only a connection in which read-write transactions are accepted by default is considered acceptable. The query `SHOW transaction_read_only` will be sent upon any successful connection; if it returns `on`, the connection will be closed. If multiple hosts were specified in the connection string, any remaining servers will be tried just as if the connection attempt had failed. The default value of this parameter, `any`, regards all connections as acceptable.

## 32.2. Connection Status Functions

These functions can be used to interrogate the status of an existing database connection object.

### Tip

libpq application programmers should be careful to maintain the `PGconn` abstraction. Use the accessor functions described below to get at the contents of `PGconn`. Reference to internal `PGconn` fields using `libpq-int.h` is not recommended because they are subject to change in the future.

The following functions return parameter values established at connection. These values are fixed for the life of the connection. If a multi-host connection string is used, the values of `PQhost`, `PQport`, and `PQpass` can change if a new connection is established using the same `PGconn` object. Other values are fixed for the lifetime of the `PGconn` object.

#### `PQdb`

Returns the database name of the connection.

```
char *PQdb(const PGconn *conn);
```

#### `PQuser`

Returns the user name of the connection.

```
char *PQuser(const PGconn *conn);
```

#### `PQpass`

Returns the password of the connection.

```
char *PQpass(const PGconn *conn);
```

`PQpass` will return either the password specified in the connection parameters, or if there was none and the password was obtained from the password file, it will return that. In the latter case, if multiple hosts were specified in the connection parameters, it is not possible to rely on the result of `PQpass` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

#### `PQhost`

Returns the server host name of the active connection. This can be a host name, an IP address, or a directory path if the connection is via Unix socket. (The path case can be distinguished because it will always be an absolute path, beginning with `/`.)

```
char *PQhost(const PGconn *conn);
```

If the connection parameters specified both `host` and `hostaddr`, then `PQhost` will return the `host` information. If only `hostaddr` was specified, then that is returned. If multiple hosts were specified in the connection parameters, `PQhost` returns the host actually connected to.

`PQhost` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the host information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

If multiple hosts were specified in the connection parameters, it is not possible to rely on the result of `PQhost` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

#### `PQhostaddr`

Returns the server IP address of the active connection. This can be the address that a host name resolved to, or an IP address provided through the `hostaddr` parameter.

```
char *PQhostaddr(const PGconn *conn);
```

`PQhostaddr` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the host information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

#### `PQport`

Returns the port of the active connection.

```
char *PQport(const PGconn *conn);
```

If multiple ports were specified in the connection parameters, `PQport` returns the port actually connected to.

`PQport` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the port information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

If multiple ports were specified in the connection parameters, it is not possible to rely on the result of `PQport` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

#### `PQtty`

Returns the debug TTY of the connection. (This is obsolete, since the server no longer pays attention to the TTY setting, but the function remains for backward compatibility.)

```
char *PQtty(const PGconn *conn);
```

#### `PQoptions`

Returns the command-line options passed in the connection request.

```
char *PQoptions(const PGconn *conn);
```

The following functions return status data that can change as operations are executed on the `PGconn` object.

#### `PQstatus`

Returns the status of the connection.

```
ConnStatusType PQstatus(const PGconn *conn);
```

The status can be one of a number of values. However, only two of these are seen outside of an asynchronous connection procedure: `CONNECTION_OK` and `CONNECTION_BAD`. A good

connection to the database has the status `CONNECTION_OK`. A failed connection attempt is signaled by status `CONNECTION_BAD`. Ordinarily, an OK status will remain so until `PQfinish`, but a communications failure might result in the status changing to `CONNECTION_BAD` prematurely. In that case the application could try to recover by calling `PQreset`.

See the entry for `PQconnectStartParams`, `PQconnectStart` and `PQconnectPoll` with regards to other status codes that might be returned.

#### `PQtransactionStatus`

Returns the current in-transaction status of the server.

```
PGTransactionStatusType PQtransactionStatus(const PGconn *conn);
```

The status can be `PQTRANS_IDLE` (currently idle), `PQTRANS_ACTIVE` (a command is in progress), `PQTRANS_INTRANS` (idle, in a valid transaction block), or `PQTRANS_INERROR` (idle, in a failed transaction block). `PQTRANS_UNKNOWN` is reported if the connection is bad. `PQTRANS_ACTIVE` is reported only when a query has been sent to the server and not yet completed.

#### `PQparameterStatus`

Looks up a current parameter setting of the server.

```
const char *PQparameterStatus(const PGconn *conn, const char
    *paramName);
```

Certain parameter values are reported by the server automatically at connection startup or whenever their values change. `PQparameterStatus` can be used to interrogate these settings. It returns the current value of a parameter if known, or `NULL` if the parameter is not known.

Parameters reported as of the current release include `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. Note that `server_version`, `server_encoding` and `integer_datetimes` cannot change after startup.

Pre-3.0-protocol servers do not report parameter settings, but libpq includes logic to obtain values for `server_version` and `client_encoding` anyway. Applications are encouraged to use `PQparameterStatus` rather than *ad hoc* code to determine these values. (Beware however that on a pre-3.0 connection, changing `client_encoding` via `SET` after connection startup will not be reflected by `PQparameterStatus`.) For `server_version`, see also `PQserverVersion`, which returns the information in a numeric form that is much easier to compare against.

If no value for `standard_conforming_strings` is reported, applications can assume it is off, that is, backslashes are treated as escapes in string literals. Also, the presence of this parameter can be taken as an indication that the escape string syntax (`E' . . .'`) is accepted.

Although the returned pointer is declared `const`, it in fact points to mutable storage associated with the `PGconn` structure. It is unwise to assume the pointer will remain valid across queries.

#### `PQprotocolVersion`

Interrogates the frontend/backend protocol being used.

```
int PQprotocolVersion(const PGconn *conn);
```

Applications might wish to use this function to determine whether certain features are supported. Currently, the possible values are 2 (2.0 protocol), 3 (3.0 protocol), or zero (connection bad). The protocol version will not change after connection startup is complete, but it could theoretically change during a connection reset. The 3.0 protocol will normally be used when communicating with LightDB 7.4 or later servers; pre-7.4 servers support only protocol 2.0. (Protocol 1.0 is obsolete and not supported by libpq.)

#### PQserverVersion

Returns an integer representing the server version.

```
int PQserverVersion(const PGconn *conn);
```

Applications might use this function to determine the version of the database server they are connected to. The result is formed by multiplying the server's major version number by 10000 and adding the minor version number. For example, version 10.1 will be returned as 100001, and version 11.0 will be returned as 110000. Zero is returned if the connection is bad.

Prior to major version 10, LightDB used three-part version numbers in which the first two parts together represented the major version. For those versions, `PQserverVersion` uses two digits for each part; for example version 9.1.5 will be returned as 90105, and version 9.2.0 will be returned as 90200.

Therefore, for purposes of determining feature compatibility, applications should divide the result of `PQserverVersion` by 100 not 10000 to determine a logical major version number. In all release series, only the last two digits differ between minor releases (bug-fix releases).

#### PQlightdbserverVersion

Returns an integer representing the lightdb server version.

```
int PQlightdbserverVersion(const PGconn *conn);
```

Applications might use this function to determine the lightdb version of the database server they are connected to. The result is formed by multiplying the server's major version number by 10000 and adding the minor version number by 100. For example, version 22.3 will be returned as 220300, and version 23.0 will be returned as 230000. Zero is returned if the connection is bad.

#### PQerrorMessage

Returns the error message most recently generated by an operation on the connection.

```
char *PQerrorMessage(const PGconn *conn);
```

Nearly all libpq functions will set a message for `PQerrorMessage` if they fail. Note that by libpq convention, a nonempty `PQerrorMessage` result can consist of multiple lines, and will include a trailing newline. The caller should not free the result directly. It will be freed when the associated `PGconn` handle is passed to `PQfinish`. The result string should not be expected to remain the same across operations on the `PGconn` structure.

#### PQsocket

Obtains the file descriptor number of the connection socket to the server. A valid descriptor will be greater than or equal to 0; a result of -1 indicates that no server connection is currently open. (This will not change during normal operation, but could change during connection setup or reset.)

```
int PQsocket(const PGconn *conn);
```

#### PQbackendPID

Returns the process ID (PID) of the backend process handling this connection.

```
int PQbackendPID(const PGconn *conn);
```

The backend PID is useful for debugging purposes and for comparison to NOTIFY messages (which include the PID of the notifying backend process). Note that the PID belongs to a process executing on the database server host, not the local host!

#### PQconnectionNeedsPassword

Returns true (1) if the connection authentication method required a password, but none was available. Returns false (0) if not.

```
int PQconnectionNeedsPassword(const PGconn *conn);
```

This function can be applied after a failed connection attempt to decide whether to prompt the user for a password.

#### PQconnectionUsedPassword

Returns true (1) if the connection authentication method used a password. Returns false (0) if not.

```
int PQconnectionUsedPassword(const PGconn *conn);
```

This function can be applied after either a failed or successful connection attempt to detect whether the server demanded a password.

The following functions return information related to SSL. This information usually doesn't change after a connection is established.

#### PQsslInUse

Returns true (1) if the connection uses SSL, false (0) if not.

```
int PQsslInUse(const PGconn *conn);
```

#### PQsslAttribute

Returns SSL-related information about the connection.

```
const char *PQsslAttribute(const PGconn *conn, const char
    *attribute_name);
```

The list of available attributes varies depending on the SSL library being used, and the type of connection. If an attribute is not available, returns NULL.

The following attributes are commonly available:

library

Name of the SSL implementation in use. (Currently, only "OpenSSL" is implemented)

protocol

SSL/TLS version in use. Common values are "TLSv1", "TLSv1.1" and "TLSv1.2", but an implementation may return other strings if some other protocol is used.

key\_bits

Number of key bits used by the encryption algorithm.

cipher

A short name of the ciphersuite used, e.g., "DHE-RSA-DES-CBC3-SHA". The names are specific to each SSL implementation.

compression

If SSL compression is in use, returns the name of the compression algorithm, or "on" if compression is used but the algorithm is not known. If compression is not in use, returns "off".

PQsslAttributeNames

Return an array of SSL attribute names available. The array is terminated by a NULL pointer.

```
const char * const * PQsslAttributeNames(const PGconn *conn);
```

PQsslStruct

Return a pointer to an SSL-implementation-specific object describing the connection.

```
void *PQsslStruct(const PGconn *conn, const char *struct_name);
```

The struct(s) available depend on the SSL implementation in use. For OpenSSL, there is one struct, available under the name "OpenSSL", and it returns a pointer to the OpenSSL SSL struct. To use this function, code along the following lines could be used:

```
#include <libpq-fe.h>
#include <openssl/ssl.h>

...

SSL *ssl;

dbconn = PQconnectdb(...);
...

ssl = PQsslStruct(dbconn, "OpenSSL");
if (ssl)
{
    /* use OpenSSL functions to access ssl */
}
```

This structure can be used to verify encryption levels, check server certificates, and more. Refer to the OpenSSL documentation for information about this structure.

PQgetssl

Returns the SSL structure used in the connection, or null if SSL is not in use.

```
void *PQgetssl(const PGconn *conn);
```

This function is equivalent to `PQsslStruct(conn, "OpenSSL")`. It should not be used in new applications, because the returned struct is specific to OpenSSL and will not be available if another SSL implementation is used. To check if a connection uses SSL, call `PQsslInUse` instead, and for more details about the connection, use `PQsslAttribute`.

## 32.3. Command Execution Functions

Once a connection to a database server has been successfully established, the functions described here are used to perform SQL queries and commands.

### 32.3.1. Main Functions

`PQexec`

Submits a command to the server and waits for the result.

```
PGresult *PQexec(PGconn *conn, const char *command);
```

Returns a `PGresult` pointer or possibly a null pointer. A non-null pointer will generally be returned except in out-of-memory conditions or serious errors such as inability to send the command to the server. The `PQresultStatus` function should be called to check the return value for any errors (including the value of a null pointer, in which case it will return `PGRES_FATAL_ERROR`). Use `PQerrorMessage` to get more information about such errors.

The command string can include multiple SQL commands (separated by semicolons). Multiple queries sent in a single `PQexec` call are processed in a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the query string to divide it into multiple transactions. (See Section 49.2.2.1 for more details about how the server handles multi-query strings.) Note however that the returned `PGresult` structure describes only the result of the last command executed from the string. Should one of the commands fail, processing of the string stops with it and the returned `PGresult` describes the error condition.

`PQexecParams`

Submits a command to the server and waits for the result, with the ability to pass parameters separately from the SQL command text.

```
PGresult *PQexecParams(PGconn *conn,
                       const char *command,
                       int nParams,
                       const Oid *paramTypes,
                       const char * const *paramValues,
                       const int *paramLengths,
                       const int *paramFormats,
                       int resultFormat);
```

`PQexecParams` is like `PQexec`, but offers additional functionality: parameter values can be specified separately from the command string proper, and query results can be requested in either text or binary format. `PQexecParams` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function arguments are:

*conn*

The connection object to send the command through.



*command*

The SQL command string to be executed. If parameters are used, they are referred to in the command string as \$1, \$2, etc.

*nParams*

The number of parameters supplied; it is the length of the arrays *paramTypes[]*, *paramValues[]*, *paramLengths[]*, and *paramFormats[]*. (The array pointers can be NULL when *nParams* is zero.)

*paramTypes[]*

Specifies, by OID, the data types to be assigned to the parameter symbols. If *paramTypes* is NULL, or any particular element in the array is zero, the server infers a data type for the parameter symbol in the same way it would do for an untyped literal string.

*paramValues[]*

Specifies the actual values of the parameters. A null pointer in this array means the corresponding parameter is null; otherwise the pointer points to a zero-terminated text string (for text format) or binary data in the format expected by the server (for binary format).

*paramLengths[]*

Specifies the actual data lengths of binary-format parameters. It is ignored for null parameters and text-format parameters. The array pointer can be null when there are no binary parameters.

*paramFormats[]*

Specifies whether parameters are text (put a zero in the array entry for the corresponding parameter) or binary (put a one in the array entry for the corresponding parameter). If the array pointer is null then all parameters are presumed to be text strings.

Values passed in binary format require knowledge of the internal representation expected by the backend. For example, integers must be passed in network byte order. Passing numeric values requires knowledge of the server storage format, as implemented in `src/backend/utils/adt/numeric.c::numeric_send()` and `src/backend/utils/adt/numeric.c::numeric_recv()`.

Lightdb 23.3 introduced a new database level GUC parameter `lightdb_ascii_zero_store_value`, the value must be within the valid range of 0 to 32, inclusive of both 0 and 32. If the database compatible type is set to Oracle or Mysql, and `lightdb_ascii_zero_store_value` is set to non-zero ASCII value, if the param is in text format, character '\0' would be replaced by `lightdb_ascii_zero_store_value`.

For more information about GUC `lightdb_ascii_zero_store_value`, See `lightdb_ascii_zero_store_value`

*resultFormat*

Specify zero to obtain results in text format, or one to obtain results in binary format. (There is not currently a provision to obtain different result columns in different formats, although that is possible in the underlying protocol.)

The primary advantage of `PQexecParams` over `PQexec` is that parameter values can be separated from the command string, thus avoiding the need for tedious and error-prone quoting and escaping.

Unlike `PQexec`, `PQexecParams` allows at most one SQL command in the given string. (There can be semicolons in it, but not more than one nonempty command.) This is a limitation of the underlying protocol, but has some usefulness as an extra defense against SQL-injection attacks.

**Tip**

Specifying parameter types via OIDs is tedious, particularly if you prefer not to hard-wire particular OID values into your program. However, you can avoid doing so even in cases where the server by itself cannot determine the type of the parameter, or chooses a different type than you want. In the SQL command text, attach an explicit cast to the parameter symbol to show what data type you will send. For example:

```
SELECT * FROM mytable WHERE x = $1::bigint;
```

This forces parameter \$1 to be treated as `bigint`, whereas by default it would be assigned the same type as `x`. Forcing the parameter type decision, either this way or by specifying a numeric type OID, is strongly recommended when sending parameter values in binary format, because binary format has less redundancy than text format and so there is less chance that the server will detect a type mismatch mistake for you.

**PQprepare**

Submits a request to create a prepared statement with the given parameters, and waits for completion.

```
PGresult *PQprepare(PGconn *conn,
                   const char *stmtName,
                   const char *query,
                   int nParams,
                   const Oid *paramTypes);
```

`PQprepare` creates a prepared statement for later execution with `PQexecPrepared`. This feature allows commands to be executed repeatedly without being parsed and planned each time; see `PREPARE` for details. `PQprepare` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function creates a prepared statement named `stmtName` from the `query` string, which must contain a single SQL command. `stmtName` can be `"` to create an unnamed statement, in which case any pre-existing unnamed statement is automatically replaced; otherwise it is an error if the statement name is already defined in the current session. If any parameters are used, they are referred to in the query as `$1`, `$2`, etc. `nParams` is the number of parameters for which types are pre-specified in the array `paramTypes[]`. (The array pointer can be `NULL` when `nParams` is zero.) `paramTypes[]` specifies, by OID, the data types to be assigned to the parameter symbols. If `paramTypes` is `NULL`, or any particular element in the array is zero, the server assigns a data type to the parameter symbol in the same way it would do for an untyped literal string. Also, the query can use parameter symbols with numbers higher than `nParams`; data types will be inferred for these symbols as well. (See `PQdescribePrepared` for a means to find out what data types were inferred.)

As with `PQexec`, the result is normally a `PGresult` object whose contents indicate server-side success or failure. A null result indicates out-of-memory or inability to send the command at all. Use `PQerrorMessage` to get more information about such errors.

Prepared statements for use with `PQexecPrepared` can also be created by executing SQL `PREPARE` statements. Also, although there is no `libpq` function for deleting a prepared statement, the SQL `DEALLOCATE` statement can be used for that purpose.

**PQexecPrepared**

Sends a request to execute a prepared statement with given parameters, and waits for the result.

```
PGresult *PQexecPrepared(PGconn *conn,
                        const char *stmtName,
                        int nParams,
                        const char * const *paramValues,
                        const int *paramLengths,
                        const int *paramFormats,
                        int resultFormat);
```

`PQexecPrepared` is like `PQexecParams`, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. This feature allows commands that will be used repeatedly to be parsed and planned just once, rather than each time they are executed. The statement must have been prepared previously in the current session. `PQexecPrepared` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The parameters are identical to `PQexecParams`, except that the name of a prepared statement is given instead of a query string, and the `paramTypes[ ]` parameter is not present (it is not needed since the prepared statement's parameter types were determined when it was created).

#### `PQdescribePrepared`

Submits a request to obtain information about the specified prepared statement, and waits for completion.

```
PGresult *PQdescribePrepared(PGconn *conn, const char
                             *stmtName);
```

`PQdescribePrepared` allows an application to obtain information about a previously prepared statement. `PQdescribePrepared` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

`stmtName` can be "" or NULL to reference the unnamed statement, otherwise it must be the name of an existing prepared statement. On success, a `PGresult` with status `PGRES_COMMAND_OK` is returned. The functions `PQnparams` and `PQparamtype` can be applied to this `PGresult` to obtain information about the parameters of the prepared statement, and the functions `PQnfields`, `PQfname`, `PQftype`, etc provide information about the result columns (if any) of the statement.

#### `PQdescribePortal`

Submits a request to obtain information about the specified portal, and waits for completion.

```
PGresult *PQdescribePortal(PGconn *conn, const char
                           *portalName);
```

`PQdescribePortal` allows an application to obtain information about a previously created portal. (libpq does not provide any direct access to portals, but you can use this function to inspect the properties of a cursor created with a `DECLARE CURSOR SQL` command.) `PQdescribePortal` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

`portalName` can be "" or NULL to reference the unnamed portal, otherwise it must be the name of an existing portal. On success, a `PGresult` with status `PGRES_COMMAND_OK` is returned. The functions `PQnfields`, `PQfname`, `PQftype`, etc can be applied to the `PGresult` to obtain information about the result columns (if any) of the portal.

The `PGresult` structure encapsulates the result returned by the server. libpq application programmers should be careful to maintain the `PGresult` abstraction. Use the accessor functions

below to get at the contents of `PGresult`. Avoid directly referencing the fields of the `PGresult` structure because they are subject to change in the future.

### `PQresultStatus`

Returns the result status of the command.

```
ExecStatusType PQresultStatus(const PGresult *res);
```

`PQresultStatus` can return one of the following values:

`PGRES_EMPTY_QUERY`

The string sent to the server was empty.

`PGRES_COMMAND_OK`

Successful completion of a command returning no data.

`PGRES_TUPLES_OK`

Successful completion of a command returning data (such as a `SELECT` or `SHOW`).

`PGRES_COPY_OUT`

Copy Out (from server) data transfer started.

`PGRES_COPY_IN`

Copy In (to server) data transfer started.

`PGRES_BAD_RESPONSE`

The server's response was not understood.

`PGRES_NONFATAL_ERROR`

A nonfatal error (a notice or warning) occurred.

`PGRES_FATAL_ERROR`

A fatal error occurred.

`PGRES_COPY_BOTH`

Copy In/Out (to and from server) data transfer started. This feature is currently used only for streaming replication, so this status should not occur in ordinary applications.

`PGRES_SINGLE_TUPLE`

The `PGresult` contains a single result tuple from the current command. This status occurs only when single-row mode has been selected for the query (see Section 32.5).

If the result status is `PGRES_TUPLES_OK` or `PGRES_SINGLE_TUPLE`, then the functions described below can be used to retrieve the rows returned by the query. Note that a `SELECT` command that happens to retrieve zero rows still shows `PGRES_TUPLES_OK`. `PGRES_COMMAND_OK` is for commands that can never return rows (`INSERT` or `UPDATE` without a `RETURNING` clause, etc.). A response of `PGRES_EMPTY_QUERY` might indicate a bug in the client software.

A result of status `PGRES_NONFATAL_ERROR` will never be returned directly by `PQexec` or other query execution functions; results of this kind are instead passed to the notice processor (see Section 32.12).

#### `PQresStatus`

Converts the enumerated type returned by `PQresultStatus` into a string constant describing the status code. The caller should not free the result.

```
char *PQresStatus(ExecStatusType status);
```

#### `PQresultErrorMessage`

Returns the error message associated with the command, or an empty string if there was no error.

```
char *PQresultErrorMessage(const PGresult *res);
```

If there was an error, the returned string will include a trailing newline. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

Immediately following a `PQexec` or `PQgetResult` call, `PQerrorMessage` (on the connection) will return the same string as `PQresultErrorMessage` (on the result). However, a `PGresult` will retain its error message until destroyed, whereas the connection's error message will change when subsequent operations are done. Use `PQresultErrorMessage` when you want to know the status associated with a particular `PGresult`; use `PQerrorMessage` when you want to know the status from the latest operation on the connection.

#### `PQresultVerboseErrorMessage`

Returns a reformatted version of the error message associated with a `PGresult` object.

```
char *PQresultVerboseErrorMessage(const PGresult *res,
                                  PGVerbosity verbosity,
                                  PGContextVisibility
                                  show_context);
```

In some situations a client might wish to obtain a more detailed version of a previously-reported error. `PQresultVerboseErrorMessage` addresses this need by computing the message that would have been produced by `PQresultErrorMessage` if the specified verbosity settings had been in effect for the connection when the given `PGresult` was generated. If the `PGresult` is not an error result, “PGresult is not an error result” is reported instead. The returned string includes a trailing newline.

Unlike most other functions for extracting data from a `PGresult`, the result of this function is a freshly allocated string. The caller must free it using `PQfreemem()` when the string is no longer needed.

A NULL return is possible if there is insufficient memory.

#### `PQresultErrorField`

Returns an individual field of an error report.

```
char *PQresultErrorField(const PGresult *res, int fieldcode);
```

*fieldcode* is an error field identifier; see the symbols listed below. NULL is returned if the `PGresult` is not an error or warning result, or does not include the specified field. Field values

will normally not include a trailing newline. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

The following field codes are available:

`PG_DIAG_SEVERITY`

The severity; the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message), or a localized translation of one of these. Always present.

`PG_DIAG_SEVERITY_NONLOCALIZED`

The severity; the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message). This is identical to the `PG_DIAG_SEVERITY` field except that the contents are never localized. This is present only in reports generated by LightDB versions 9.6 and later.

`PG_DIAG_SQLSTATE`

The `SQLSTATE` code for the error. The `SQLSTATE` code identifies the type of error that has occurred; it can be used by front-end applications to perform specific operations (such as error handling) in response to a particular database error. For a list of the possible `SQLSTATE` codes, see Appendix A. This field is not localizable, and is always present.

`PG_DIAG_MESSAGE_PRIMARY`

The primary human-readable error message (typically one line). Always present.

`PG_DIAG_MESSAGE_DETAIL`

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

`PG_DIAG_MESSAGE_HINT`

Hint: an optional suggestion what to do about the problem. This is intended to differ from detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

`PG_DIAG_STATEMENT_POSITION`

A string containing a decimal integer indicating an error cursor position as an index into the original statement string. The first character has index 1, and positions are measured in characters not bytes.

`PG_DIAG_INTERNAL_POSITION`

This is defined the same as the `PG_DIAG_STATEMENT_POSITION` field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The `PG_DIAG_INTERNAL_QUERY` field will always appear when this field appears.

`PG_DIAG_INTERNAL_QUERY`

The text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

`PG_DIAG_CONTEXT`

An indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

PG\_DIAG\_SCHEMA\_NAME

If the error was associated with a specific database object, the name of the schema containing that object, if any.

PG\_DIAG\_TABLE\_NAME

If the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

PG\_DIAG\_COLUMN\_NAME

If the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

PG\_DIAG\_DATATYPE\_NAME

If the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

PG\_DIAG\_CONSTRAINT\_NAME

If the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

PG\_DIAG\_SOURCE\_FILE

The file name of the source-code location where the error was reported.

PG\_DIAG\_SOURCE\_LINE

The line number of the source-code location where the error was reported.

PG\_DIAG\_SOURCE\_FUNCTION

The name of the source-code function reporting the error.

### Note

The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Do not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, do not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

Errors generated internally by libpq will have severity and primary message, but typically no other fields. Errors returned by a pre-3.0-protocol server will include severity and primary message, and sometimes a detail message, but no other fields.

Note that error fields are only available from `PGresult` objects, not `PGconn` objects; there is no `PQerrorMessage` function.

### PQclear

Frees the storage associated with a `PGresult`. Every command result should be freed via `PQclear` when it is no longer needed.

```
void PQclear(PGresult *res);
```

You can keep a `PGresult` object around for as long as you need it; it does not go away when you issue a new command, nor even if you close the connection. To get rid of it, you must call `PQclear`. Failure to do this will result in memory leaks in your application.

## 32.3.2. Retrieving Query Result Information

These functions are used to extract information from a `PGresult` object that represents a successful query result (that is, one that has status `PGRES_TUPLES_OK` or `PGRES_SINGLE_TUPLE`). They can also be used to extract information from a successful Describe operation: a Describe's result has all the same column information that actual execution of the query would provide, but it has zero rows. For objects with other status values, these functions will act as though the result has zero rows and zero columns.

### PQntuples

Returns the number of rows (tuples) in the query result. (Note that `PGresult` objects are limited to no more than `INT_MAX` rows, so an `int` result is sufficient.)

```
int PQntuples(const PGresult *res);
```

### PQnfields

Returns the number of columns (fields) in each row of the query result.

```
int PQnfields(const PGresult *res);
```

### PQfname

Returns the column name associated with the given column number. Column numbers start at 0. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

```
char *PQfname(const PGresult *res,  
              int column_number);
```

NULL is returned if the column number is out of range.

### PQfnumber

Returns the column number associated with the given column name.

```
int PQfnumber(const PGresult *res,  
              const char *column_name);
```

-1 is returned if the given name does not match any column.

The given name is treated like an identifier in an SQL command, that is, it is downcased unless double-quoted. For example, given a query result generated from the SQL command:



```
SELECT 1 AS FOO, 2 AS "BAR";
```

we would have the results:

```
PQfname(res, 0)          foo
PQfname(res, 1)          BAR
PQfnumber(res, "FOO")    0
PQfnumber(res, "foo")    0
PQfnumber(res, "BAR")    -1
PQfnumber(res, "\"BAR\"") 1
```

#### PQftable

Returns the OID of the table from which the given column was fetched. Column numbers start at 0.

```
Oid PQftable(const PGresult *res,
             int column_number);
```

`InvalidOid` is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol. You can query the system table `pg_class` to determine exactly which table is referenced.

The type `Oid` and the constant `InvalidOid` will be defined when you include the libpq header file. They will both be some integer type.

#### PQftablecol

Returns the column number (within its table) of the column making up the specified query result column. Query-result column numbers start at 0, but table columns have nonzero numbers.

```
int PQftablecol(const PGresult *res,
               int column_number);
```

Zero is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol.

#### PQfformat

Returns the format code indicating the format of the given column. Column numbers start at 0.

```
int PQfformat(const PGresult *res,
             int column_number);
```

Format code zero indicates textual data representation, while format code one indicates binary representation. (Other codes are reserved for future definition.)

#### PQftype

Returns the data type associated with the given column number. The integer returned is the internal OID number of the type. Column numbers start at 0.

```
Oid PQftype(const PGresult *res,
           int column_number);
```

You can query the system table `pg_type` to obtain the names and properties of the various data types. The OIDs of the built-in data types are defined in the file `include/server/catalog/pg_type_d.h` in the install directory.

### PQfmod

Returns the type modifier of the column associated with the given column number. Column numbers start at 0.

```
int PQfmod(const PGresult *res,
           int column_number);
```

The interpretation of modifier values is type-specific; they typically indicate precision or size limits. The value -1 is used to indicate “no information available”. Most data types do not use modifiers, in which case the value is always -1.

### PQfsize

Returns the size in bytes of the column associated with the given column number. Column numbers start at 0.

```
int PQfsize(const PGresult *res,
            int column_number);
```

`PQfsize` returns the space allocated for this column in a database row, in other words the size of the server's internal representation of the data type. (Accordingly, it is not really very useful to clients.) A negative value indicates the data type is variable-length.

### PQbinaryTuples

Returns 1 if the `PGresult` contains binary data and 0 if it contains text data.

```
int PQbinaryTuples(const PGresult *res);
```

This function is deprecated (except for its use in connection with `COPY`), because it is possible for a single `PGresult` to contain text data in some columns and binary data in others. `PQfformat` is preferred. `PQbinaryTuples` returns 1 only if all columns of the result are binary (format 1).

### PQgetvalue

Returns a single field value of one row of a `PGresult`. Row and column numbers start at 0. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

```
char *PQgetvalue(const PGresult *res,
                 int row_number,
                 int column_number);
```

For data in text format, the value returned by `PQgetvalue` is a null-terminated character string representation of the field value. For data in binary format, the value is in the binary representation determined by the data type's `typsend` and `typreceive` functions. (The value is actually followed by a zero byte in this case too, but that is not ordinarily useful, since the value is likely to contain embedded nulls.)

An empty string is returned if the field value is null. See `PQgetisnull` to distinguish null values from empty-string values.

The pointer returned by `PQgetvalue` points to storage that is part of the `PGresult` structure. One should not modify the data it points to, and one must explicitly copy the data into other storage if it is to be used past the lifetime of the `PGresult` structure itself.

### PQgetisnull

Tests a field for a null value. Row and column numbers start at 0.

```
int PQgetisnull(const PGresult *res,
                int row_number,
                int column_number);
```

This function returns 1 if the field is null and 0 if it contains a non-null value. (Note that `PQgetvalue` will return an empty string, not a null pointer, for a null field.)

### PQgetlength

Returns the actual length of a field value in bytes. Row and column numbers start at 0.

```
int PQgetlength(const PGresult *res,
                int row_number,
                int column_number);
```

This is the actual data length for the particular data value, that is, the size of the object pointed to by `PQgetvalue`. For text data format this is the same as `strlen()`. For binary format this is essential information. Note that one should *not* rely on `PQfsize` to obtain the actual data length.

### PQnparams

Returns the number of parameters of a prepared statement.

```
int PQnparams(const PGresult *res);
```

This function is only useful when inspecting the result of `PQdescribePrepared`. For other types of queries it will return zero.

### PQparamtype

Returns the data type of the indicated statement parameter. Parameter numbers start at 0.

```
Oid PQparamtype(const PGresult *res, int param_number);
```

This function is only useful when inspecting the result of `PQdescribePrepared`. For other types of queries it will return zero.

### PQprint

Prints out all the rows and, optionally, the column names to the specified output stream.

```
void PQprint(FILE *fout,          /* output stream */
             const PGresult *res,
             const PQprintOpt *po);
typedef struct
{
    pqbool header;          /* print output field headings and row
count */
    pqbool align;          /* fill align the fields */
    pqbool standard;       /* old brain dead format */
    pqbool html3;          /* output HTML tables */
};
```

```

    pqbool  expanded;    /* expand tables */
    pqbool  pager;      /* use pager for output if needed */
    char    *fieldSep;  /* field separator */
    char    *tableOpt;  /* attributes for HTML table element */
    char    *caption;   /* HTML table caption */
    char    **fieldName; /* null-terminated array of replacement
    field names */
} PQprintOpt;

```

This function was formerly used by `ltsql` to print query results, but this is no longer the case. Note that it assumes all the data is in text format.

### 32.3.3. Retrieving Other Result Information

These functions are used to extract other information from `PGresult` objects.

#### `PQcmdStatus`

Returns the command status tag from the SQL command that generated the `PGresult`.

```
char *PQcmdStatus(PGresult *res);
```

Commonly this is just the name of the command, but it might include additional data such as the number of rows processed. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

#### `PQcmdTuples`

Returns the number of rows affected by the SQL command.

```
char *PQcmdTuples(PGresult *res);
```

This function returns a string containing the number of rows affected by the SQL statement that generated the `PGresult`. This function can only be used following the execution of a `SELECT`, `CREATE TABLE AS`, `INSERT`, `UPDATE`, `DELETE`, `MOVE`, `FETCH`, or `COPY` statement, or an `EXECUTE` of a prepared query that contains an `INSERT`, `UPDATE`, or `DELETE` statement. If the command that generated the `PGresult` was anything else, `PQcmdTuples` returns an empty string. The caller should not free the return value directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

#### `PQoidValue`

Returns the OID of the inserted row, if the SQL command was an `INSERT` that inserted exactly one row into a table that has OIDs, or a `EXECUTE` of a prepared query containing a suitable `INSERT` statement. Otherwise, this function returns `InvalidOid`. This function will also return `InvalidOid` if the table affected by the `INSERT` statement does not contain OIDs.

```
Oid PQoidValue(const PGresult *res);
```

#### `PQoidStatus`

This function is deprecated in favor of `PQoidValue` and is not thread-safe. It returns a string with the OID of the inserted row, while `PQoidValue` returns the OID value.

```
char *PQoidStatus(const PGresult *res);
```

## 32.3.4. Escaping Strings for Inclusion in SQL Commands

`PQescapeLiteral`

```
char *PQescapeLiteral(PGconn *conn, const char *str, size_t
    length);
```

`PQescapeLiteral` escapes a string for use within an SQL command. This is useful when inserting data values as literal constants in SQL commands. Certain characters (such as quotes and backslashes) must be escaped to prevent them from being interpreted specially by the SQL parser. `PQescapeLiteral` performs this operation.

`PQescapeLiteral` returns an escaped version of the `str` parameter in memory allocated with `malloc()`. This memory should be freed using `PQfreemem()` when the result is no longer needed. A terminating zero byte is not required, and should not be counted in `length`. (If a terminating zero byte is found before `length` bytes are processed, `PQescapeLiteral` stops at the zero; the behavior is thus rather like `strncpy`.) The return string has all special characters replaced so that they can be properly processed by the LightDB string literal parser. A terminating zero byte is also added. The single quotes that must surround LightDB string literals are included in the result string.

On error, `PQescapeLiteral` returns NULL and a suitable message is stored in the `conn` object.

### Tip

It is especially important to do proper escaping when handling strings that were received from an untrustworthy source. Otherwise there is a security risk: you are vulnerable to “SQL injection” attacks wherein unwanted SQL commands are fed to your database.

Note that it is neither necessary nor correct to do escaping when a data value is passed as a separate parameter in `PQexecParams` or its sibling routines.

`PQescapeIdentifier`

```
char *PQescapeIdentifier(PGconn *conn, const char *str, size_t
    length);
```

`PQescapeIdentifier` escapes a string for use as an SQL identifier, such as a table, column, or function name. This is useful when a user-supplied identifier might contain special characters that would otherwise not be interpreted as part of the identifier by the SQL parser, or when the identifier might contain upper case characters whose case should be preserved.

`PQescapeIdentifier` returns a version of the `str` parameter escaped as an SQL identifier in memory allocated with `malloc()`. This memory must be freed using `PQfreemem()` when the result is no longer needed. A terminating zero byte is not required, and should not be counted in `length`. (If a terminating zero byte is found before `length` bytes are processed, `PQescapeIdentifier` stops at the zero; the behavior is thus rather like `strncpy`.) The return string has all special characters replaced so that it will be properly processed as an SQL identifier. A terminating zero byte is also added. The return string will also be surrounded by double quotes.

On error, `PQescapeIdentifier` returns NULL and a suitable message is stored in the `conn` object.

**Tip**

As with string literals, to prevent SQL injection attacks, SQL identifiers must be escaped when they are received from an untrustworthy source.

## PQescapeStringConn

```
size_t PQescapeStringConn(PGconn *conn,
                          char *to, const char *from, size_t
                          length,
                          int *error);
```

PQescapeStringConn escapes string literals, much like PQescapeLiteral. Unlike PQescapeLiteral, the caller is responsible for providing an appropriately sized buffer. Furthermore, PQescapeStringConn does not generate the single quotes that must surround LightDB string literals; they should be provided in the SQL command that the result is inserted into. The parameter *from* points to the first character of the string that is to be escaped, and the *length* parameter gives the number of bytes in this string. A terminating zero byte is not required, and should not be counted in *length*. (If a terminating zero byte is found before *length* bytes are processed, PQescapeStringConn stops at the zero; the behavior is thus rather like `strncpy`.) *to* shall point to a buffer that is able to hold at least one more byte than twice the value of *length*, otherwise the behavior is undefined. Behavior is likewise undefined if the *to* and *from* strings overlap.

If the *error* parameter is not NULL, then *\*error* is set to zero on success, nonzero on error. Presently the only possible error conditions involve invalid multibyte encoding in the source string. The output string is still generated on error, but it can be expected that the server will reject it as malformed. On error, a suitable message is stored in the *conn* object, whether or not *error* is NULL.

PQescapeStringConn returns the number of bytes written to *to*, not including the terminating zero byte.

## PQescapeString

PQescapeString is an older, deprecated version of PQescapeStringConn.

```
size_t PQescapeString(char *to, const char *from, size_t
                     length);
```

The only difference from PQescapeStringConn is that PQescapeString does not take PGconn or *error* parameters. Because of this, it cannot adjust its behavior depending on the connection properties (such as character encoding) and therefore *it might give the wrong results*. Also, it has no way to report error conditions.

PQescapeString can be used safely in client programs that work with only one LightDB connection at a time (in this case it can find out what it needs to know “behind the scenes”). In other contexts it is a security hazard and should be avoided in favor of PQescapeStringConn.

## PQescapeByteaConn

Escapes binary data for use within an SQL command with the type `bytea`. As with PQescapeStringConn, this is only used when inserting data directly into an SQL command string.

```
unsigned char *PQescapeByteaConn(PGconn *conn,
```

```
const unsigned char *from,
size_t from_length,
size_t *to_length);
```

Certain byte values must be escaped when used as part of a bytea literal in an SQL statement. `PQescapeByteaConn` escapes bytes using either hex encoding or backslash escaping. See Section 8.4 for more information.

The *from* parameter points to the first byte of the string that is to be escaped, and the *from\_length* parameter gives the number of bytes in this binary string. (A terminating zero byte is neither necessary nor counted.) The *to\_length* parameter points to a variable that will hold the resultant escaped string length. This result string length includes the terminating zero byte of the result.

`PQescapeByteaConn` returns an escaped version of the *from* parameter binary string in memory allocated with `malloc()`. This memory should be freed using `PQfreemem()` when the result is no longer needed. The return string has all special characters replaced so that they can be properly processed by the LightDB string literal parser, and the bytea input function. A terminating zero byte is also added. The single quotes that must surround LightDB string literals are not part of the result string.

On error, a null pointer is returned, and a suitable error message is stored in the *conn* object. Currently, the only possible error is insufficient memory for the result string.

#### `PQescapeBytea`

`PQescapeBytea` is an older, deprecated version of `PQescapeByteaConn`.

```
unsigned char *PQescapeBytea(const unsigned char *from,
                             size_t from_length,
                             size_t *to_length);
```

The only difference from `PQescapeByteaConn` is that `PQescapeBytea` does not take a `PGconn` parameter. Because of this, `PQescapeBytea` can only be used safely in client programs that use a single LightDB connection at a time (in this case it can find out what it needs to know “behind the scenes”). It *might give the wrong results* if used in programs that use multiple database connections (use `PQescapeByteaConn` in such cases).

#### `PQunescapeBytea`

Converts a string representation of binary data into binary data — the reverse of `PQescapeBytea`. This is needed when retrieving bytea data in text format, but not when retrieving it in binary format.

```
unsigned char *PQunescapeBytea(const unsigned char *from, size_t
                               *to_length);
```

The *from* parameter points to a string such as might be returned by `PQgetvalue` when applied to a bytea column. `PQunescapeBytea` converts this string representation into its binary representation. It returns a pointer to a buffer allocated with `malloc()`, or `NULL` on error, and puts the size of the buffer in *to\_length*. The result must be freed using `PQfreemem` when it is no longer needed.

This conversion is not exactly the inverse of `PQescapeBytea`, because the string is not expected to be “escaped” when received from `PQgetvalue`. In particular this means there is no need for string quoting considerations, and so no need for a `PGconn` parameter.

## 32.4. Asynchronous Command Processing

The `PQexec` function is adequate for submitting commands in normal, synchronous applications. It has a few deficiencies, however, that can be of importance to some users:

- `PQexec` waits for the command to be completed. The application might have other work to do (such as maintaining a user interface), in which case it won't want to block waiting for the response.
- Since the execution of the client application is suspended while it waits for the result, it is hard for the application to decide that it would like to try to cancel the ongoing command. (It can be done from a signal handler, but not otherwise.)
- `PQexec` can return only one `PGresult` structure. If the submitted command string contains multiple SQL commands, all but the last `PGresult` are discarded by `PQexec`.
- `PQexec` always collects the command's entire result, buffering it in a single `PGresult`. While this simplifies error-handling logic for the application, it can be impractical for results containing many rows.

Applications that do not like these limitations can instead use the underlying functions that `PQexec` is built from: `PQsendQuery` and `PQgetResult`. There are also `PQsendQueryParams`, `PQsendPrepare`, `PQsendQueryPrepared`, `PQsendDescribePrepared`, and `PQsendDescribePortal`, which can be used with `PQgetResult` to duplicate the functionality of `PQexecParams`, `PQprepare`, `PQexecPrepared`, `PQdescribePrepared`, and `PQdescribePortal` respectively.

#### `PQsendQuery`

Submits a command to the server without waiting for the result(s). 1 is returned if the command was successfully dispatched and 0 if not (in which case, use `PQerrorMessage` to get more information about the failure).

```
int PQsendQuery(PGconn *conn, const char *command);
```

After successfully calling `PQsendQuery`, call `PQgetResult` one or more times to obtain the results. `PQsendQuery` cannot be called again (on the same connection) until `PQgetResult` has returned a null pointer, indicating that the command is done.

#### `PQsendQueryParams`

Submits a command and separate parameters to the server without waiting for the result(s).

```
int PQsendQueryParams(PGconn *conn,
                     const char *command,
                     int nParams,
                     const Oid *paramTypes,
                     const char * const *paramValues,
                     const int *paramLengths,
                     const int *paramFormats,
                     int resultFormat);
```

This is equivalent to `PQsendQuery` except that query parameters can be specified separately from the query string. The function's parameters are handled identically to `PQexecParams`. Like `PQexecParams`, it will not work on 2.0-protocol connections, and it allows only one command in the query string.

#### `PQsendPrepare`

Sends a request to create a prepared statement with the given parameters, without waiting for completion.



```
int PQsendPrepare(PGconn *conn,
                 const char *stmtName,
                 const char *query,
                 int nParams,
                 const Oid *paramTypes);
```

This is an asynchronous version of `PQprepare`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to determine whether the server successfully created the prepared statement. The function's parameters are handled identically to `PQprepare`. Like `PQprepare`, it will not work on 2.0-protocol connections.

#### `PQsendQueryPrepared`

Sends a request to execute a prepared statement with given parameters, without waiting for the result(s).

```
int PQsendQueryPrepared(PGconn *conn,
                       const char *stmtName,
                       int nParams,
                       const char * const *paramValues,
                       const int *paramLengths,
                       const int *paramFormats,
                       int resultFormat);
```

This is similar to `PQsendQueryParams`, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. The function's parameters are handled identically to `PQexecPrepared`. Like `PQexecPrepared`, it will not work on 2.0-protocol connections.

#### `PQsendDescribePrepared`

Submits a request to obtain information about the specified prepared statement, without waiting for completion.

```
int PQsendDescribePrepared(PGconn *conn, const char *stmtName);
```

This is an asynchronous version of `PQdescribePrepared`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to obtain the results. The function's parameters are handled identically to `PQdescribePrepared`. Like `PQdescribePrepared`, it will not work on 2.0-protocol connections.

#### `PQsendDescribePortal`

Submits a request to obtain information about the specified portal, without waiting for completion.

```
int PQsendDescribePortal(PGconn *conn, const char *portalName);
```

This is an asynchronous version of `PQdescribePortal`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to obtain the results. The function's parameters are handled identically to `PQdescribePortal`. Like `PQdescribePortal`, it will not work on 2.0-protocol connections.

#### `PQgetResult`

Waits for the next result from a prior `PQsendQuery`, `PQsendQueryParams`, `PQsendPrepare`, `PQsendQueryPrepared`, `PQsendDescribePrepared`, or

`PQsendDescribePortal` call, and returns it. A null pointer is returned when the command is complete and there will be no more results.

```
PGresult *PQgetResult(PGconn *conn);
```

`PQgetResult` must be called repeatedly until it returns a null pointer, indicating that the command is done. (If called when no command is active, `PQgetResult` will just return a null pointer at once.) Each non-null result from `PQgetResult` should be processed using the same `PGresult` accessor functions previously described. Don't forget to free each result object with `PQclear` when done with it. Note that `PQgetResult` will block only if a command is active and the necessary response data has not yet been read by `PQconsumeInput`.

### Note

Even when `PQresultStatus` indicates a fatal error, `PQgetResult` should be called until it returns a null pointer, to allow libpq to process the error information completely.

Using `PQsendQuery` and `PQgetResult` solves one of `PQexec`'s problems: If a command string contains multiple SQL commands, the results of those commands can be obtained individually. (This allows a simple form of overlapped processing, by the way: the client can be handling the results of one command while the server is still working on later queries in the same command string.)

Another frequently-desired feature that can be obtained with `PQsendQuery` and `PQgetResult` is retrieving large query results a row at a time. This is discussed in Section 32.5.

By itself, calling `PQgetResult` will still cause the client to block until the server completes the next SQL command. This can be avoided by proper use of two more functions:

`PQconsumeInput`

If input is available from the server, consume it.

```
int PQconsumeInput(PGconn *conn);
```

`PQconsumeInput` normally returns 1 indicating “no error”, but returns 0 if there was some kind of trouble (in which case `PQerrorMessage` can be consulted). Note that the result does not say whether any input data was actually collected. After calling `PQconsumeInput`, the application can check `PQisBusy` and/or `PQnotifies` to see if their state has changed.

`PQconsumeInput` can be called even if the application is not prepared to deal with a result or notification just yet. The function will read available data and save it in a buffer, thereby causing a `select()` read-ready indication to go away. The application can thus use `PQconsumeInput` to clear the `select()` condition immediately, and then examine the results at leisure.

`PQisBusy`

Returns 1 if a command is busy, that is, `PQgetResult` would block waiting for input. A 0 return indicates that `PQgetResult` can be called with assurance of not blocking.

```
int PQisBusy(PGconn *conn);
```

`PQisBusy` will not itself attempt to read data from the server; therefore `PQconsumeInput` must be invoked first, or the busy state will never end.

A typical application using these functions will have a main loop that uses `select()` or `poll()` to wait for all the conditions that it must respond to. One of the conditions will be input available from the server, which in terms of `select()` means readable data on the file descriptor identified by `PQsocket`. When the main loop detects input ready, it should call `PQconsumeInput` to read the input. It can then call `PQisBusy`, followed by `PQgetResult` if `PQisBusy` returns false (0). It can also call `PQnotifies` to detect NOTIFY messages (see Section 32.8).

A client that uses `PQsendQuery/PQgetResult` can also attempt to cancel a command that is still being processed by the server; see Section 32.6. But regardless of the return value of `PQcancel`, the application must continue with the normal result-reading sequence using `PQgetResult`. A successful cancellation will simply cause the command to terminate sooner than it would have otherwise.

By using the functions described above, it is possible to avoid blocking while waiting for input from the database server. However, it is still possible that the application will block waiting to send output to the server. This is relatively uncommon but can happen if very long SQL commands or data values are sent. (It is much more probable if the application sends data via `COPY IN`, however.) To prevent this possibility and achieve completely nonblocking database operation, the following additional functions can be used.

#### `PQsetnonblocking`

Sets the nonblocking status of the connection.

```
int PQsetnonblocking(PGconn *conn, int arg);
```

Sets the state of the connection to nonblocking if `arg` is 1, or blocking if `arg` is 0. Returns 0 if OK, -1 if error.

In the nonblocking state, calls to `PQsendQuery`, `PQputline`, `PQputnbytes`, `PQputCopyData`, and `PQendcopy` will not block but instead return an error if they need to be called again.

Note that `PQexec` does not honor nonblocking mode; if it is called, it will act in blocking fashion anyway.

#### `PQisnonblocking`

Returns the blocking status of the database connection.

```
int PQisnonblocking(const PGconn *conn);
```

Returns 1 if the connection is set to nonblocking mode and 0 if blocking.

#### `PQflush`

Attempts to flush any queued output data to the server. Returns 0 if successful (or if the send queue is empty), -1 if it failed for some reason, or 1 if it was unable to send all the data in the send queue yet (this case can only occur if the connection is nonblocking).

```
int PQflush(PGconn *conn);
```

After sending any command or data on a nonblocking connection, call `PQflush`. If it returns 1, wait for the socket to become read- or write-ready. If it becomes write-ready, call `PQflush` again. If it becomes read-ready, call `PQconsumeInput`, then call `PQflush` again. Repeat until `PQflush` returns 0. (It is necessary to check for read-ready and drain the input with `PQconsumeInput`, because the server can block trying to send us data, e.g., NOTIFY messages, and won't read our data

until we read its.) Once `PQflush` returns 0, wait for the socket to be read-ready and then read the response as described above.

## 32.5. Retrieving Query Results Row-by-Row

Ordinarily, libpq collects a SQL command's entire result and returns it to the application as a single `PGresult`. This can be unworkable for commands that return a large number of rows. For such cases, applications can use `PQsendQuery` and `PQgetResult` in *single-row mode*. In this mode, the result row(s) are returned to the application one at a time, as they are received from the server.

To enter single-row mode, call `PQsetSingleRowMode` immediately after a successful call of `PQsendQuery` (or a sibling function). This mode selection is effective only for the currently executing query. Then call `PQgetResult` repeatedly, until it returns null, as documented in Section 32.4. If the query returns any rows, they are returned as individual `PGresult` objects, which look like normal query results except for having status code `PGRES_SINGLE_TUPLE` instead of `PGRES_TUPLES_OK`. After the last row, or immediately if the query returns zero rows, a zero-row object with status `PGRES_TUPLES_OK` is returned; this is the signal that no more rows will arrive. (But note that it is still necessary to continue calling `PQgetResult` until it returns null.) All of these `PGresult` objects will contain the same row description data (column names, types, etc) that an ordinary `PGresult` object for the query would have. Each object should be freed with `PQclear` as usual.

`PQsetSingleRowMode`

Select single-row mode for the currently-executing query.

```
int PQsetSingleRowMode(PGconn *conn);
```

This function can only be called immediately after `PQsendQuery` or one of its sibling functions, before any other operation on the connection such as `PQconsumeInput` or `PQgetResult`. If called at the correct time, the function activates single-row mode for the current query and returns 1. Otherwise the mode stays unchanged and the function returns 0. In any case, the mode reverts to normal after completion of the current query.

### Caution

While processing a query, the server may return some rows and then encounter an error, causing the query to be aborted. Ordinarily, libpq discards any such rows and reports only the error. But in single-row mode, those rows will have already been returned to the application. Hence, the application will see some `PGRES_SINGLE_TUPLE` `PGresult` objects followed by a `PGRES_FATAL_ERROR` object. For proper transactional behavior, the application must be designed to discard or undo whatever has been done with the previously-processed rows, if the query ultimately fails.

## 32.6. Canceling Queries in Progress

A client application can request cancellation of a command that is still being processed by the server, using the functions described in this section.

`PQgetCancel`

Creates a data structure containing the information needed to cancel a command issued through a particular database connection.

```
PGcancel *PQgetCancel(PGconn *conn);
```

`PQgetCancel` creates a `PGcancel` object given a `PGconn` connection object. It will return `NULL` if the given `conn` is `NULL` or an invalid connection. The `PGcancel` object is an opaque structure that is not meant to be accessed directly by the application; it can only be passed to `PQcancel` or `PQfreeCancel`.

#### `PQfreeCancel`

Frees a data structure created by `PQgetCancel`.

```
void PQfreeCancel(PGcancel *cancel);
```

`PQfreeCancel` frees a data object previously created by `PQgetCancel`.

#### `PQcancel`

Requests that the server abandon processing of the current command.

```
int PQcancel(PGcancel *cancel, char *errbuf, int errbufsize);
```

The return value is 1 if the cancel request was successfully dispatched and 0 if not. If not, `errbuf` is filled with an explanatory error message. `errbuf` must be a char array of size `errbufsize` (the recommended size is 256 bytes).

Successful dispatch is no guarantee that the request will have any effect, however. If the cancellation is effective, the current command will terminate early and return an error result. If the cancellation fails (say, because the server was already done processing the command), then there will be no visible result at all.

`PQcancel` can safely be invoked from a signal handler, if the `errbuf` is a local variable in the signal handler. The `PGcancel` object is read-only as far as `PQcancel` is concerned, so it can also be invoked from a thread that is separate from the one manipulating the `PGconn` object.

#### `PQrequestCancel`

`PQrequestCancel` is a deprecated variant of `PQcancel`.

```
int PQrequestCancel(PGconn *conn);
```

Requests that the server abandon processing of the current command. It operates directly on the `PGconn` object, and in case of failure stores the error message in the `PGconn` object (whence it can be retrieved by `PQerrorMessage`). Although the functionality is the same, this approach creates hazards for multiple-thread programs and signal handlers, since it is possible that overwriting the `PGconn`'s error message will mess up the operation currently in progress on the connection.

## 32.7. The Fast-Path Interface

LightDB provides a fast-path interface to send simple function calls to the server.

### Tip

This interface is somewhat obsolete, as one can achieve similar performance and greater functionality by setting up a prepared statement to define the function call. Then, executing the statement with binary transmission of parameters and results substitutes for a fast-path function call.

The function `PQfn` requests execution of a server function via the fast-path interface:

```
PGresult *PQfn(PGconn *conn,
               int fnid,
               int *result_buf,
               int *result_len,
               int result_is_int,
               const PQArgBlock *args,
               int nargs);

typedef struct
{
    int len;
    int isint;
    union
    {
        int *ptr;
        int integer;
    } u;
} PQArgBlock;
```

The *fnid* argument is the OID of the function to be executed. *args* and *nargs* define the parameters to be passed to the function; they must match the declared function argument list. When the *isint* field of a parameter structure is true, the *u.integer* value is sent to the server as an integer of the indicated length (this must be 2 or 4 bytes); proper byte-swapping occurs. When *isint* is false, the indicated number of bytes at *\*u.ptr* are sent with no processing; the data must be in the format expected by the server for binary transmission of the function's argument data type. (The declaration of *u.ptr* as being of type `int *` is historical; it would be better to consider it `void *`.) *result\_buf* points to the buffer in which to place the function's return value. The caller must have allocated sufficient space to store the return value. (There is no check!) The actual result length in bytes will be returned in the integer pointed to by *result\_len*. If a 2- or 4-byte integer result is expected, set *result\_is\_int* to 1, otherwise set it to 0. Setting *result\_is\_int* to 1 causes libpq to byte-swap the value if necessary, so that it is delivered as a proper `int` value for the client machine; note that a 4-byte integer is delivered into *\*result\_buf* for either allowed result size. When *result\_is\_int* is 0, the binary-format byte string sent by the server is returned unmodified. (In this case it's better to consider *result\_buf* as being of type `void *`.)

`PQfn` always returns a valid `PGresult` pointer, with status `PGRES_COMMAND_OK` for success or `PGRES_FATAL_ERROR` if some problem was encountered. The result status should be checked before the result is used. The caller is responsible for freeing the `PGresult` with `PQclear` when it is no longer needed.

To pass a NULL argument to the function, set the *len* field of that parameter structure to -1; the *isint* and *u* fields are then irrelevant. (But this works only in protocol 3.0 and later connections.)

If the function returns NULL, *\*result\_len* is set to -1, and *\*result\_buf* is not modified. (This works only in protocol 3.0 and later connections; in protocol 2.0, neither *\*result\_len* nor *\*result\_buf* are modified.)

Note that it is not possible to handle set-valued results when using this interface. Also, the function must be a plain function, not an aggregate, window function, or procedure.

## 32.8. Asynchronous Notification

LightDB offers asynchronous notification via the `LISTEN` and `NOTIFY` commands. A client session registers its interest in a particular notification channel with the `LISTEN` command (and can stop listening with the `UNLISTEN` command). All sessions listening on a particular channel will be notified

asynchronously when a NOTIFY command with that channel name is executed by any session. A “payload” string can be passed to communicate additional data to the listeners.

libpq applications submit LISTEN, UNLISTEN, and NOTIFY commands as ordinary SQL commands. The arrival of NOTIFY messages can subsequently be detected by calling PQnotifies.

The function PQnotifies returns the next notification from a list of unhandled notification messages received from the server. It returns a null pointer if there are no pending notifications. Once a notification is returned from PQnotifies, it is considered handled and will be removed from the list of notifications.

```
PGnotify *PQnotifies(PGconn *conn);

typedef struct pgNotify
{
    char *relname;           /* notification channel name */
    int  be_pid;           /* process ID of notifying server
    process */
    char *extra;           /* notification payload string */
} PGnotify;
```

After processing a PGnotify object returned by PQnotifies, be sure to free it with PQfreemem. It is sufficient to free the PGnotify pointer; the relname and extra fields do not represent separate allocations. (The names of these fields are historical; in particular, channel names need not have anything to do with relation names.)

Example 32.2 gives a sample program that illustrates the use of asynchronous notification.

PQnotifies does not actually read data from the server; it just returns messages previously absorbed by another libpq function. In ancient releases of libpq, the only way to ensure timely receipt of NOTIFY messages was to constantly submit commands, even empty ones, and then check PQnotifies after each PQexec. While this still works, it is deprecated as a waste of processing power.

A better way to check for NOTIFY messages when you have no useful commands to execute is to call PQconsumeInput, then check PQnotifies. You can use select() to wait for data to arrive from the server, thereby using no CPU power unless there is something to do. (See PQsocket to obtain the file descriptor number to use with select().) Note that this will work OK whether you submit commands with PQsendQuery/PQgetResult or simply use PQexec. You should, however, remember to check PQnotifies after each PQgetResult or PQexec, to see if any notifications came in during the processing of the command.

## 32.9. Functions Associated with the COPY Command

The COPY command in LightDB has options to read from or write to the network connection used by libpq. The functions described in this section allow applications to take advantage of this capability by supplying or consuming copied data.

The overall process is that the application first issues the SQL COPY command via PQexec or one of the equivalent functions. The response to this (if there is no error in the command) will be a PGresult object bearing a status code of PGRES\_COPY\_OUT or PGRES\_COPY\_IN (depending on the specified copy direction). The application should then use the functions of this section to receive or transmit data rows. When the data transfer is complete, another PGresult object is returned to indicate success or failure of the transfer. Its status will be PGRES\_COMMAND\_OK for success or PGRES\_FATAL\_ERROR if some problem was encountered. At this point further SQL commands can be issued via PQexec. (It is not possible to execute other SQL commands using the same connection while the COPY operation is in progress.)

If a `COPY` command is issued via `PQexec` in a string that could contain additional commands, the application must continue fetching results via `PQgetResult` after completing the `COPY` sequence. Only when `PQgetResult` returns `NULL` is it certain that the `PQexec` command string is done and it is safe to issue more commands.

The functions of this section should be executed only after obtaining a result status of `PGRES_COPY_OUT` or `PGRES_COPY_IN` from `PQexec` or `PQgetResult`.

A `PGresult` object bearing one of these status values carries some additional data about the `COPY` operation that is starting. This additional data is available using functions that are also used in connection with query results:

`PQnfields`

Returns the number of columns (fields) to be copied.

`PQbinaryTuples`

0 indicates the overall copy format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary. See `COPY` for more information.

`PQfformat`

Returns the format code (0 for text, 1 for binary) associated with each column of the copy operation. The per-column format codes will always be zero when the overall copy format is textual, but the binary format can support both text and binary columns. (However, as of the current implementation of `COPY`, only binary columns appear in a binary copy; so the per-column formats always match the overall format at present.)

### Note

These additional data values are only available when using protocol 3.0. When using protocol 2.0, all these functions will return 0.

## 32.9.1. Functions for Sending COPY Data

These functions are used to send data during `COPY FROM STDIN`. They will fail if called when the connection is not in `COPY_IN` state.

`PQputCopyData`

Sends data to the server during `COPY_IN` state.

```
int PQputCopyData(PGconn *conn,
                  const char *buffer,
                  int nbytes);
```

Transmits the `COPY` data in the specified *buffer*, of length *nbytes*, to the server. The result is 1 if the data was queued, zero if it was not queued because of full buffers (this will only happen in nonblocking mode), or -1 if an error occurred. (Use `PQerrorMessage` to retrieve details if the return value is -1. If the value is zero, wait for write-ready and try again.)

The application can divide the `COPY` data stream into buffer loads of any convenient size. Buffer-load boundaries have no semantic significance when sending. The contents of the data stream must match the data format expected by the `COPY` command; see `COPY` for details.



### PQputCopyEnd

Sends end-of-data indication to the server during COPY\_IN state.

```
int PQputCopyEnd(PGconn *conn,
                 const char *errmsg);
```

Ends the COPY\_IN operation successfully if *errmsg* is NULL. If *errmsg* is not NULL then the COPY is forced to fail, with the string pointed to by *errmsg* used as the error message. (One should not assume that this exact error message will come back from the server, however, as the server might have already failed the COPY for its own reasons. Also note that the option to force failure does not work when using pre-3.0-protocol connections.)

The result is 1 if the termination message was sent; or in nonblocking mode, this may only indicate that the termination message was successfully queued. (In nonblocking mode, to be certain that the data has been sent, you should next wait for write-ready and call PQflush, repeating until it returns zero.) Zero indicates that the function could not queue the termination message because of full buffers; this will only happen in nonblocking mode. (In this case, wait for write-ready and try the PQputCopyEnd call again.) If a hard error occurs, -1 is returned; you can use PQerrorMessage to retrieve details.

After successfully calling PQputCopyEnd, call PQgetResult to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

## 32.9.2. Functions for Receiving COPY Data

These functions are used to receive data during COPY TO STDOUT. They will fail if called when the connection is not in COPY\_OUT state.

### PQgetCopyData

Receives data from the server during COPY\_OUT state.

```
int PQgetCopyData(PGconn *conn,
                  char **buffer,
                  int async);
```

Attempts to obtain another row of data from the server during a COPY. Data is always returned one data row at a time; if only a partial row is available, it is not returned. Successful return of a data row involves allocating a chunk of memory to hold the data. The *buffer* parameter must be non-NULL. *\*buffer* is set to point to the allocated memory, or to NULL in cases where no buffer is returned. A non-NULL result buffer should be freed using PQfreemem when no longer needed.

When a row is successfully returned, the return value is the number of data bytes in the row (this will always be greater than zero). The returned string is always null-terminated, though this is probably only useful for textual COPY. A result of zero indicates that the COPY is still in progress, but no row is yet available (this is only possible when *async* is true). A result of -1 indicates that the COPY is done. A result of -2 indicates that an error occurred (consult PQerrorMessage for the reason).

When *async* is true (not zero), PQgetCopyData will not block waiting for input; it will return zero if the COPY is still in progress but no complete row is available. (In this case wait for read-ready and then call PQconsumeInput before calling PQgetCopyData again.) When *async* is false (zero), PQgetCopyData will block until data is available or the operation completes.

After PQgetCopyData returns -1, call PQgetResult to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

### 32.9.3. Obsolete Functions for COPY

These functions represent older methods of handling COPY. Although they still work, they are deprecated due to poor error handling, inconvenient methods of detecting end-of-data, and lack of support for binary or nonblocking transfers.

#### PQgetline

Reads a newline-terminated line of characters (transmitted by the server) into a buffer string of size *length*.

```
int PQgetline(PGconn *conn,
             char *buffer,
             int length);
```

This function copies up to *length*-1 characters into the buffer and converts the terminating newline into a zero byte. `PQgetline` returns EOF at the end of input, 0 if the entire line has been read, and 1 if the buffer is full but the terminating newline has not yet been read.

Note that the application must check to see if a new line consists of the two characters `\.`, which indicates that the server has finished sending the results of the COPY command. If the application might receive lines that are more than *length*-1 characters long, care is needed to be sure it recognizes the `\.` line correctly (and does not, for example, mistake the end of a long data line for a terminator line).

#### PQgetlineAsync

Reads a row of COPY data (transmitted by the server) into a buffer without blocking.

```
int PQgetlineAsync(PGconn *conn,
                 char *buffer,
                 int bufsize);
```

This function is similar to `PQgetline`, but it can be used by applications that must read COPY data asynchronously, that is, without blocking. Having issued the COPY command and gotten a `PGRES_COPY_OUT` response, the application should call `PQconsumeInput` and `PQgetlineAsync` until the end-of-data signal is detected.

Unlike `PQgetline`, this function takes responsibility for detecting end-of-data.

On each call, `PQgetlineAsync` will return data if a complete data row is available in libpq's input buffer. Otherwise, no data is returned until the rest of the row arrives. The function returns -1 if the end-of-copy-data marker has been recognized, or 0 if no data is available, or a positive number giving the number of bytes of data returned. If -1 is returned, the caller must next call `PQendcopy`, and then return to normal processing.

The data returned will not extend beyond a data-row boundary. If possible a whole row will be returned at one time. But if the buffer offered by the caller is too small to hold a row sent by the server, then a partial data row will be returned. With textual data this can be detected by testing whether the last returned byte is `\n` or not. (In a binary COPY, actual parsing of the COPY data format will be needed to make the equivalent determination.) The returned string is not null-terminated. (If you want to add a terminating null, be sure to pass a *bufsize* one smaller than the room actually available.)

#### PQputline

Sends a null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputline(PGconn *conn,
              const char *string);
```

The COPY data stream sent by a series of calls to `PQputline` has the same format as that returned by `PQgetlineAsync`, except that applications are not obliged to send exactly one data row per `PQputline` call; it is okay to send a partial line or multiple lines per call.

### Note

Before LightDB protocol 3.0, it was necessary for the application to explicitly send the two characters `\.` as a final line to indicate to the server that it had finished sending COPY data. While this still works, it is deprecated and the special meaning of `\.` can be expected to be removed in a future release. It is sufficient to call `PQendcopy` after having sent the actual data.

### PQputnbytes

Sends a non-null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputnbytes(PGconn *conn,
                const char *buffer,
                int nbytes);
```

This is exactly like `PQputline`, except that the data buffer need not be null-terminated since the number of bytes to send is specified directly. Use this procedure when sending binary data.

### PQendcopy

Synchronizes with the server.

```
int PQendcopy(PGconn *conn);
```

This function waits until the server has finished the copying. It should either be issued when the last string has been sent to the server using `PQputline` or when the last string has been received from the server using `PQgetline`. It must be issued or the server will get “out of sync” with the client. Upon return from this function, the server is ready to receive the next SQL command. The return value is 0 on successful completion, nonzero otherwise. (Use `PQerrorMessage` to retrieve details if the return value is nonzero.)

When using `PQgetResult`, the application should respond to a `PGRES_COPY_OUT` result by executing `PQgetline` repeatedly, followed by `PQendcopy` after the terminator line is seen. It should then return to the `PQgetResult` loop until `PQgetResult` returns a null pointer. Similarly a `PGRES_COPY_IN` result is processed by a series of `PQputline` calls followed by `PQendcopy`, then return to the `PQgetResult` loop. This arrangement will ensure that a COPY command embedded in a series of SQL commands will be executed correctly.

Older applications are likely to submit a COPY via `PQexec` and assume that the transaction is done after `PQendcopy`. This will work correctly only if the COPY is the only SQL command in the command string.

## 32.10. Control Functions

These functions control miscellaneous details of libpq's behavior.

`PQclientEncoding`

Returns the client encoding.

```
int PQclientEncoding(const PGconn *conn);
```

Note that it returns the encoding ID, not a symbolic string such as `EUC_JP`. If unsuccessful, it returns -1. To convert an encoding ID to an encoding name, you can use:

```
char *pg_encoding_to_char(int encoding_id);
```

`PQsetClientEncoding`

Sets the client encoding.

```
int PQsetClientEncoding(PGconn *conn, const char *encoding);
```

`conn` is a connection to the server, and `encoding` is the encoding you want to use. If the function successfully sets the encoding, it returns 0, otherwise -1. The current encoding for this connection can be determined by using `PQclientEncoding`.

`PQsetErrorVerbosity`

Determines the verbosity of messages returned by `PQerrorMessage` and `PQresultErrorMessage`.

```
typedef enum
{
    PQERRORS_TERSE,
    PQERRORS_DEFAULT,
    PQERRORS_VERBOSE,
    PQERRORS_SQLSTATE
} PGVerbosity;
```

```
PGVerbosity PQsetErrorVerbosity(PGconn *conn, PGVerbosity
    verbosity);
```

`PQsetErrorVerbosity` sets the verbosity mode, returning the connection's previous setting. In *TERSE* mode, returned messages include severity, primary text, and position only; this will normally fit on a single line. The *DEFAULT* mode produces messages that include the above plus any detail, hint, or context fields (these might span multiple lines). The *VERBOSE* mode includes all available fields. The *SQLSTATE* mode includes only the error severity and the *SQLSTATE* error code, if one is available (if not, the output is like *TERSE* mode).

Changing the verbosity setting does not affect the messages available from already-existing `PGresult` objects, only subsequently-created ones. (But see `PQresultVerboseErrorMessage` if you want to print a previous error with a different verbosity.)

`PQsetErrorContextVisibility`

Determines the handling of `CONTEXT` fields in messages returned by `PQerrorMessage` and `PQresultErrorMessage`.

```
typedef enum
{
```

```

    PQSHOW_CONTEXT_NEVER,
    PQSHOW_CONTEXT_ERRORS,
    PQSHOW_CONTEXT_ALWAYS
} PGContextVisibility;

```

```

PGContextVisibility PQsetErrorContextVisibility(PGconn *conn,
    PGContextVisibility show_context);

```

`PQsetErrorContextVisibility` sets the context display mode, returning the connection's previous setting. This mode controls whether the `CONTEXT` field is included in messages. The *NEVER* mode never includes `CONTEXT`, while *ALWAYS* always includes it if available. In *ERRORS* mode (the default), `CONTEXT` fields are included only in error messages, not in notices and warnings. (However, if the verbosity setting is *TERSE* or *SQLSTATE*, `CONTEXT` fields are omitted regardless of the context display mode.)

Changing this mode does not affect the messages available from already-existing `PGresult` objects, only subsequently-created ones. (But see `PQresultVerboseErrorMessage` if you want to print a previous error with a different display mode.)

#### PQtrace

Enables tracing of the client/server communication to a debugging file stream.

```
void PQtrace(PGconn *conn, FILE *stream);
```

#### Note

On Windows, if the libpq library and an application are compiled with different flags, this function call will crash the application because the internal representation of the `FILE` pointers differ. Specifically, multithreaded/single-threaded, release/debug, and static/dynamic flags should be the same for the library and all applications using that library.

#### PQuntrace

Disables tracing started by `PQtrace`.

```
void PQuntrace(PGconn *conn);
```

## 32.11. Miscellaneous Functions

As always, there are some functions that just don't fit anywhere.

#### PQfreemem

Frees memory allocated by libpq.

```
void PQfreemem(void *ptr);
```

Frees memory allocated by libpq, particularly `PQescapeByteaConn`, `PQescapeBytea`, `PQunescapeBytea`, and `PQnotifies`. It is particularly important that this function, rather than `free()`, be used on Microsoft Windows. This is because allocating memory in a DLL and releasing it in the application works only if multithreaded/single-threaded, release/debug, and static/dynamic flags are the same for the DLL and the application. On non-Microsoft Windows platforms, this function is the same as the standard library function `free()`.

### PQconninfoFree

Frees the data structures allocated by `PQconndefaults` or `PQconninfoParse`.

```
void PQconninfoFree(PQconninfoOption *connOptions);
```

A simple `PQfreemem` will not do for this, since the array contains references to subsidiary strings.

### PQencryptPasswordConn

Prepares the encrypted form of a LightDB password.

```
char *PQencryptPasswordConn(PGconn *conn, const char *passwd,
                             const char *user, const char *algorithm);
```

This function is intended to be used by client applications that wish to send commands like `ALTER USER joe PASSWORD 'pwd'`. It is good practice not to send the original cleartext password in such a command, because it might be exposed in command logs, activity displays, and so on. Instead, use this function to convert the password to encrypted form before it is sent.

The *passwd* and *user* arguments are the cleartext password, and the SQL name of the user it is for. *algorithm* specifies the encryption algorithm to use to encrypt the password. Currently supported algorithms are `md5` and `scram-sha-256` (`on` and `off` are also accepted as aliases for `md5`, for compatibility with older server versions). Note that support for `scram-sha-256` was introduced in LightDB version 10, and will not work correctly with older server versions. If *algorithm* is `NULL`, this function will query the server for the current value of the `password_encryption` setting. That can block, and will fail if the current transaction is aborted, or if the connection is busy executing another query. If you wish to use the default algorithm for the server but want to avoid blocking, query `password_encryption` yourself before calling `PQencryptPasswordConn`, and pass that value as the *algorithm*.

The return value is a string allocated by `malloc`. The caller can assume the string doesn't contain any special characters that would require escaping. Use `PQfreemem` to free the result when done with it. On error, returns `NULL`, and a suitable message is stored in the connection object.

### PQencryptPassword

Prepares the md5-encrypted form of a LightDB password.

```
char *PQencryptPassword(const char *passwd, const char *user);
```

`PQencryptPassword` is an older, deprecated version of `PQencryptPasswordConn`. The difference is that `PQencryptPassword` does not require a connection object, and `md5` is always used as the encryption algorithm.

### PQmakeEmptyPGresult

Constructs an empty `PGresult` object with the given status.

```
PGresult *PQmakeEmptyPGresult(PGconn *conn, ExecStatusType
                               status);
```

This is libpq's internal function to allocate and initialize an empty `PGresult` object. This function returns `NULL` if memory could not be allocated. It is exported because some applications find it useful to generate result objects (particularly objects with error status) themselves. If *conn*

is not null and *status* indicates an error, the current error message of the specified connection is copied into the `PGresult`. Also, if *conn* is not null, any event procedures registered in the connection are copied into the `PGresult`. (They do not get `PGEVT_RESULTCREATE` calls, but see `PQfireResultCreateEvents`.) Note that `PQclear` should eventually be called on the object, just as with a `PGresult` returned by `libpq` itself.

#### `PQfireResultCreateEvents`

Fires a `PGEVT_RESULTCREATE` event (see Section 32.13) for each event procedure registered in the `PGresult` object. Returns non-zero for success, zero if any event procedure fails.

```
int PQfireResultCreateEvents(PGconn *conn, PGresult *res);
```

The *conn* argument is passed through to event procedures but not used directly. It can be `NULL` if the event procedures won't use it.

Event procedures that have already received a `PGEVT_RESULTCREATE` or `PGEVT_RESULTCOPY` event for this object are not fired again.

The main reason that this function is separate from `PQmakeEmptyPGresult` is that it is often appropriate to create a `PGresult` and fill it with data before invoking the event procedures.

#### `PQcopyResult`

Makes a copy of a `PGresult` object. The copy is not linked to the source result in any way and `PQclear` must be called when the copy is no longer needed. If the function fails, `NULL` is returned.

```
PGresult *PQcopyResult(const PGresult *src, int flags);
```

This is not intended to make an exact copy. The returned result is always put into `PGRES_TUPLES_OK` status, and does not copy any error message in the source. (It does copy the command status string, however.) The *flags* argument determines what else is copied. It is a bitwise OR of several flags. `PG_COPYRES_ATTRS` specifies copying the source result's attributes (column definitions). `PG_COPYRES_TUPLES` specifies copying the source result's tuples. (This implies copying the attributes, too.) `PG_COPYRES_NOTICEHOOKS` specifies copying the source result's notify hooks. `PG_COPYRES_EVENTS` specifies copying the source result's events. (But any instance data associated with the source is not copied.)

#### `PQsetResultAttrs`

Sets the attributes of a `PGresult` object.

```
int PQsetResultAttrs(PGresult *res, int numAttributes,
    PGresAttDesc *attDescs);
```

The provided *attDescs* are copied into the result. If the *attDescs* pointer is `NULL` or *numAttributes* is less than one, the request is ignored and the function succeeds. If *res* already contains attributes, the function will fail. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

#### `PQsetvalue`

Sets a tuple field value of a `PGresult` object.

```
int PQsetvalue(PGresult *res, int tup_num, int field_num, char
    *value, int len);
```

The function will automatically grow the result's internal tuples array as needed. However, the `tup_num` argument must be less than or equal to `PQntuples`, meaning this function can only grow the tuples array one tuple at a time. But any field of any existing tuple can be modified in any order. If a value at `field_num` already exists, it will be overwritten. If `len` is -1 or `value` is `NULL`, the field value will be set to an SQL null value. The `value` is copied into the result's private storage, thus is no longer needed after the function returns. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

#### PQresultAlloc

Allocate subsidiary storage for a `PGresult` object.

```
void *PQresultAlloc(PGresult *res, size_t nBytes);
```

Any memory allocated with this function will be freed when `res` is cleared. If the function fails, the return value is `NULL`. The result is guaranteed to be adequately aligned for any type of data, just as for `malloc`.

#### PQresultMemorySize

Retrieves the number of bytes allocated for a `PGresult` object.

```
size_t PQresultMemorySize(const PGresult *res);
```

This value is the sum of all `malloc` requests associated with the `PGresult` object, that is, all the space that will be freed by `PQclear`. This information can be useful for managing memory consumption.

#### PQlibVersion

Return the version of libpq that is being used.

```
int PQlibVersion(void);
```

The result of this function can be used to determine, at run time, whether specific functionality is available in the currently loaded version of libpq. The function can be used, for example, to determine which connection options are available in `PQconnectdb`.

The result is formed by multiplying the library's major version number by 10000 and adding the minor version number. For example, version 10.1 will be returned as 100001, and version 11.0 will be returned as 110000.

Prior to major version 10, LightDB used three-part version numbers in which the first two parts together represented the major version. For those versions, `PQlibVersion` uses two digits for each part; for example version 9.1.5 will be returned as 90105, and version 9.2.0 will be returned as 90200.

Therefore, for purposes of determining feature compatibility, applications should divide the result of `PQlibVersion` by 100 not 10000 to determine a logical major version number. In all release series, only the last two digits differ between minor releases (bug-fix releases).

### Note

This function appeared in LightDB version 9.1, so it cannot be used to detect required functionality in earlier versions, since calling it will create a link dependency on version 9.1 or later.



## 32.12. Notice Processing

Notice and warning messages generated by the server are not returned by the query execution functions, since they do not imply failure of the query. Instead they are passed to a notice handling function, and execution continues normally after the handler returns. The default notice handling function prints the message on `stderr`, but the application can override this behavior by supplying its own handling function.

For historical reasons, there are two levels of notice handling, called the notice receiver and notice processor. The default behavior is for the notice receiver to format the notice and pass a string to the notice processor for printing. However, an application that chooses to provide its own notice receiver will typically ignore the notice processor layer and just do all the work in the notice receiver.

The function `PQsetNoticeReceiver` sets or examines the current notice receiver for a connection object. Similarly, `PQsetNoticeProcessor` sets or examines the current notice processor.

```
typedef void (*PQnoticeReceiver) (void *arg, const PGresult *res);

PQnoticeReceiver
PQsetNoticeReceiver(PGconn *conn,
                   PQnoticeReceiver proc,
                   void *arg);

typedef void (*PQnoticeProcessor) (void *arg, const char *message);

PQnoticeProcessor
PQsetNoticeProcessor(PGconn *conn,
                    PQnoticeProcessor proc,
                    void *arg);
```

Each of these functions returns the previous notice receiver or processor function pointer, and sets the new value. If you supply a null function pointer, no action is taken, but the current pointer is returned.

When a notice or warning message is received from the server, or generated internally by libpq, the notice receiver function is called. It is passed the message in the form of a `PGRES_NONFATAL_ERROR` `PGresult`. (This allows the receiver to extract individual fields using `PQresultErrorField`, or obtain a complete preformatted message using `PQresultErrorMessage` or `PQresultVerboseErrorMessage`.) The same void pointer passed to `PQsetNoticeReceiver` is also passed. (This pointer can be used to access application-specific state if needed.)

The default notice receiver simply extracts the message (using `PQresultErrorMessage`) and passes it to the notice processor.

The notice processor is responsible for handling a notice or warning message given in text form. It is passed the string text of the message (including a trailing newline), plus a void pointer that is the same one passed to `PQsetNoticeProcessor`. (This pointer can be used to access application-specific state if needed.)

The default notice processor is simply:

```
static void
defaultNoticeProcessor(void *arg, const char *message)
{
    fprintf(stderr, "%s", message);
}
```

```
}

```

Once you have set a notice receiver or processor, you should expect that that function could be called as long as either the `PGconn` object or `PGresult` objects made from it exist. At creation of a `PGresult`, the `PGconn`'s current notice handling pointers are copied into the `PGresult` for possible use by functions like `PQgetValue`.

## 32.13. Event System

libpq's event system is designed to notify registered event handlers about interesting libpq events, such as the creation or destruction of `PGconn` and `PGresult` objects. A principal use case is that this allows applications to associate their own data with a `PGconn` or `PGresult` and ensure that that data is freed at an appropriate time.

Each registered event handler is associated with two pieces of data, known to libpq only as opaque `void *` pointers. There is a *passthrough* pointer that is provided by the application when the event handler is registered with a `PGconn`. The passthrough pointer never changes for the life of the `PGconn` and all `PGresults` generated from it; so if used, it must point to long-lived data. In addition there is an *instance data* pointer, which starts out `NULL` in every `PGconn` and `PGresult`. This pointer can be manipulated using the `PQinstanceData`, `PQsetInstanceData`, `PQresultInstanceData` and `PQsetResultInstanceData` functions. Note that unlike the passthrough pointer, instance data of a `PGconn` is not automatically inherited by `PGresults` created from it. libpq does not know what passthrough and instance data pointers point to (if anything) and will never attempt to free them — that is the responsibility of the event handler.

### 32.13.1. Event Types

The enum `PGEventId` names the types of events handled by the event system. All its values have names beginning with `PGEVT`. For each event type, there is a corresponding event info structure that carries the parameters passed to the event handlers. The event types are:

`PGEVT_REGISTER`

The register event occurs when `PQregisterEventProc` is called. It is the ideal time to initialize any `instanceData` an event procedure may need. Only one register event will be fired per event handler per connection. If the event procedure fails, the registration is aborted.

```
typedef struct
{
    PGconn *conn;
} PGEventRegister;
```

When a `PGEVT_REGISTER` event is received, the `evtInfo` pointer should be cast to a `PGEventRegister *`. This structure contains a `PGconn` that should be in the `CONNECTION_OK` status; guaranteed if one calls `PQregisterEventProc` right after obtaining a good `PGconn`. When returning a failure code, all cleanup must be performed as no `PGEVT_CONNDESTROY` event will be sent.

`PGEVT_CONNRESET`

The connection reset event is fired on completion of `PQreset` or `PQresetPoll`. In both cases, the event is only fired if the reset was successful. If the event procedure fails, the entire connection reset will fail; the `PGconn` is put into `CONNECTION_BAD` status and `PQresetPoll` will return `PGRES_POLLING_FAILED`.

```
typedef struct
```

```
{
    PGconn *conn;
} PGEvtConnReset;
```

When a `PGEVT_CONNRESET` event is received, the `evtInfo` pointer should be cast to a `PGEvtConnReset *`. Although the contained `PGconn` was just reset, all event data remains unchanged. This event should be used to reset/reload/requery any associated `instanceData`. Note that even if the event procedure fails to process `PGEVT_CONNRESET`, it will still receive a `PGEVT_CONNDESTROY` event when the connection is closed.

#### PGEVT\_CONNDESTROY

The connection destroy event is fired in response to `PQfinish`. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```
typedef struct
{
    PGconn *conn;
} PGEvtConnDestroy;
```

When a `PGEVT_CONNDESTROY` event is received, the `evtInfo` pointer should be cast to a `PGEvtConnDestroy *`. This event is fired prior to `PQfinish` performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from `PQfinish`. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

#### PGEVT\_RESULTCREATE

The result creation event is fired in response to any query execution function that generates a result, including `PQgetResult`. This event will only be fired after the result has been created successfully.

```
typedef struct
{
    PGconn *conn;
    PGresult *result;
} PGEvtResultCreate;
```

When a `PGEVT_RESULTCREATE` event is received, the `evtInfo` pointer should be cast to a `PGEvtResultCreate *`. The `conn` is the connection used to generate the result. This is the ideal place to initialize any `instanceData` that needs to be associated with the result. If the event procedure fails, the result will be cleared and the failure will be propagated. The event procedure must not try to `PQclear` the result object for itself. When returning a failure code, all cleanup must be performed as no `PGEVT_RESULTDESTROY` event will be sent.

#### PGEVT\_RESULTCOPY

The result copy event is fired in response to `PQcopyResult`. This event will only be fired after the copy is complete. Only event procedures that have successfully handled the `PGEVT_RESULTCREATE` or `PGEVT_RESULTCOPY` event for the source result will receive `PGEVT_RESULTCOPY` events.

```
typedef struct
{
    const PGresult *src;
```

```

    PGresult *dest;
} PGEventResultCopy;

```

When a `PGEVT_RESULTCOPY` event is received, the `evtInfo` pointer should be cast to a `PGEventResultCopy *`. The `src` result is what was copied while the `dest` result is the copy destination. This event can be used to provide a deep copy of `instanceData`, since `PQcopyResult` cannot do that. If the event procedure fails, the entire copy operation will fail and the `dest` result will be cleared. When returning a failure code, all cleanup must be performed as no `PGEVT_RESULTDESTROY` event will be sent for the destination result.

#### PGEVT\_RESULTDESTROY

The result destroy event is fired in response to a `PQclear`. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```

typedef struct
{
    PGresult *result;
} PGEventResultDestroy;

```

When a `PGEVT_RESULTDESTROY` event is received, the `evtInfo` pointer should be cast to a `PGEventResultDestroy *`. This event is fired prior to `PQclear` performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from `PQclear`. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

## 32.13.2. Event Callback Procedure

#### PGEventProc

`PGEventProc` is a typedef for a pointer to an event procedure, that is, the user callback function that receives events from libpq. The signature of an event procedure must be

```
int eventproc(PGEventId evtId, void *evtInfo, void *passThrough)
```

The `evtId` parameter indicates which `PGEVT` event occurred. The `evtInfo` pointer must be cast to the appropriate structure type to obtain further information about the event. The `passThrough` parameter is the pointer provided to `PQregisterEventProc` when the event procedure was registered. The function should return a non-zero value if it succeeds and zero if it fails.

A particular event procedure can be registered only once in any `PGconn`. This is because the address of the procedure is used as a lookup key to identify the associated instance data.

### Caution

On Windows, functions can have two different addresses: one visible from outside a DLL and another visible from inside the DLL. One should be careful that only one of these addresses is used with libpq's event-procedure functions, else confusion will result. The simplest rule for writing code that will work is to ensure that event procedures are declared `static`. If the procedure's address must be available outside its own source file, expose a separate function to return the address.

### 32.13.3. Event Support Functions

#### PQregisterEventProc

Registers an event callback procedure with libpq.

```
int PQregisterEventProc(PGconn *conn, PGEventProc proc,
                       const char *name, void *passThrough);
```

An event procedure must be registered once on each PGconn you want to receive events about. There is no limit, other than memory, on the number of event procedures that can be registered with a connection. The function returns a non-zero value if it succeeds and zero if it fails.

The *proc* argument will be called when a libpq event is fired. Its memory address is also used to lookup *instanceData*. The *name* argument is used to refer to the event procedure in error messages. This value cannot be NULL or a zero-length string. The name string is copied into the PGconn, so what is passed need not be long-lived. The *passThrough* pointer is passed to the *proc* whenever an event occurs. This argument can be NULL.

#### PQsetInstanceData

Sets the connection *conn*'s *instanceData* for procedure *proc* to *data*. This returns non-zero for success and zero for failure. (Failure is only possible if *proc* has not been properly registered in *conn*.)

```
int PQsetInstanceData(PGconn *conn, PGEventProc proc, void
                      *data);
```

#### PQinstanceData

Returns the connection *conn*'s *instanceData* associated with procedure *proc*, or NULL if there is none.

```
void *PQinstanceData(const PGconn *conn, PGEventProc proc);
```

#### PQresultSetInstanceData

Sets the result's *instanceData* for *proc* to *data*. This returns non-zero for success and zero for failure. (Failure is only possible if *proc* has not been properly registered in the result.)

```
int PQresultSetInstanceData(PGresult *res, PGEventProc proc,
                            void *data);
```

Beware that any storage represented by *data* will not be accounted for by *PQresultMemorySize*, unless it is allocated using *PQresultAlloc*. (Doing so is recommendable because it eliminates the need to free such storage explicitly when the result is destroyed.)

#### PQresultInstanceData

Returns the result's *instanceData* associated with *proc*, or NULL if there is none.

```
void *PQresultInstanceData(const PGresult *res, PGEventProc
                           proc);
```

## 32.13.4. Event Example

Here is a skeleton example of managing private data associated with libpq connections and results.

```

/* required header for libpq events (note: includes libpq-fe.h) */
#include <libpq-events.h>

/* The instanceData */
typedef struct
{
    int n;
    char *str;
} mydata;

/* PGEventProc */
static int myEventProc(PGEventId evtId, void *evtInfo, void
    *passThrough);

int
main(void)
{
    mydata *data;
    PGresult *res;
    PGconn *conn =
        PQconnectdb("dbname=postgres options=-csearch_path=");

    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
        PQfinish(conn);
        return 1;
    }

    /* called once on any connection that should receive events.
     * Sends a PGEVT_REGISTER to myEventProc.
     */
    if (!PQregisterEventProc(conn, myEventProc, "mydata_proc",
        NULL))
    {
        fprintf(stderr, "Cannot register PGEventProc\n");
        PQfinish(conn);
        return 1;
    }

    /* conn instanceData is available */
    data = PQinstanceData(conn, myEventProc);

    /* Sends a PGEVT_RESULTCREATE to myEventProc */
    res = PQexec(conn, "SELECT 1 + 1");

    /* result instanceData is available */
    data = PQresultInstanceData(res, myEventProc);

    /* If PG_COPYRES_EVENTS is used, sends a PGEVT_RESULTCOPY to
    myEventProc */

```

```

    res_copy = PQcopyResult(res, PG_COPYRES_TUPLES |
PG_COPYRES_EVENTS);

    /* result instanceData is available if PG_COPYRES_EVENTS was
    * used during the PQcopyResult call.
    */
    data = PQresultInstanceData(res_copy, myEventProc);

    /* Both clears send a PGEVT_RESULTDESTROY to myEventProc */
    PQclear(res);
    PQclear(res_copy);

    /* Sends a PGEVT_CONNDESTROY to myEventProc */
    PQfinish(conn);

    return 0;
}

static int
myEventProc(PGEventId evtId, void *evtInfo, void *passThrough)
{
    switch (evtId)
    {
        case PGEVT_REGISTER:
        {
            PGEventRegister *e = (PGEventRegister *)evtInfo;
            mydata *data = get_mydata(e->conn);

            /* associate app specific data with connection */
            PQsetInstanceData(e->conn, myEventProc, data);
            break;
        }

        case PGEVT_CONNRESET:
        {
            PGEventConnReset *e = (PGEventConnReset *)evtInfo;
            mydata *data = PQinstanceData(e->conn, myEventProc);

            if (data)
                memset(data, 0, sizeof(mydata));
            break;
        }

        case PGEVT_CONNDESTROY:
        {
            PGEventConnDestroy *e = (PGEventConnDestroy *)evtInfo;
            mydata *data = PQinstanceData(e->conn, myEventProc);

            /* free instance data because the conn is being
            destroyed */
            if (data)
                free_mydata(data);
            break;
        }

        case PGEVT_RESULTCREATE:
        {

```

```

        PGEventResultCreate *e = (PGEventResultCreate
*)evtInfo;
        mydata *conn_data = PQinstanceData(e->conn,
myEventProc);
        mydata *res_data = dup_mydata(conn_data);

        /* associate app specific data with result (copy it
from conn) */
        PQsetResultInstanceData(e->result, myEventProc,
res_data);
        break;
    }

    case PGEVT_RESULTCOPY:
    {
        PGEventResultCopy *e = (PGEventResultCopy *)evtInfo;
        mydata *src_data = PQresultInstanceData(e->src,
myEventProc);
        mydata *dest_data = dup_mydata(src_data);

        /* associate app specific data with result (copy it
from a result) */
        PQsetResultInstanceData(e->dest, myEventProc,
dest_data);
        break;
    }

    case PGEVT_RESULTDESTROY:
    {
        PGEventResultDestroy *e = (PGEventResultDestroy
*)evtInfo;
        mydata *data = PQresultInstanceData(e->result,
myEventProc);

        /* free instance data because the result is being
destroyed */
        if (data)
            free_mydata(data);
        break;
    }

    /* unknown event ID, just return true. */
    default:
        break;
}

return true; /* event processing succeeded */
}

```

## 32.14. Environment Variables

The following environment variables can be used to select default connection parameter values, which will be used by `PQconnectdb`, `PQsetdbLogin` and `PQsetdb` if no value is directly specified by the calling code. These are useful to avoid hard-coding database connection information into simple client applications, for example.

- `LTHOST` behaves the same as the host connection parameter.



- `LTHOSTADDR` behaves the same as the `hostaddr` connection parameter. This can be set instead of or in addition to `LTHOST` to avoid DNS lookup overhead.
- `LTPORT` behaves the same as the `port` connection parameter.
- `LTDATABASE` behaves the same as the `dbname` connection parameter.
- `LTUSER` behaves the same as the `user` connection parameter.
- `LTPASSWORD` behaves the same as the `password` connection parameter. Use of this environment variable is not recommended for security reasons, as some operating systems allow non-root users to see process environment variables via `ps`; instead consider using a password file (see Section 32.15).
- `LTPASSFILE` behaves the same as the `passfile` connection parameter.
- `LTCHANNELBINDING` behaves the same as the `channel_binding` connection parameter.
- `LTSERVICE` behaves the same as the `service` connection parameter.
- `LTSERVICEFILE` specifies the name of the per-user connection service file (see Section 32.16). Defaults to `~/ .pg_service.conf`, or `%APPDATA%\postgresql\ .pg_service.conf` on Microsoft Windows.
- `LTOPTIONS` behaves the same as the `options` connection parameter.
- `LTAPPNAME` behaves the same as the `application_name` connection parameter.
- `LTSSLMODE` behaves the same as the `sslmode` connection parameter.
- `LTREQUIRESSL` behaves the same as the `requiressl` connection parameter. This environment variable is deprecated in favor of the `LTSSLMODE` variable; setting both variables suppresses the effect of this one.
- `LTSSLCOMPRESSION` behaves the same as the `sslcompression` connection parameter.
- `LTSSLCERT` behaves the same as the `sslcert` connection parameter.
- `LTSSLKEY` behaves the same as the `sslkey` connection parameter.
- `LTSSLROOTCERT` behaves the same as the `sslrootcert` connection parameter.
- `LTSSLCRL` behaves the same as the `sslcrll` connection parameter.
- `LTREQUIREPEER` behaves the same as the `requirepeer` connection parameter.
- `LTSSLMINPROTOCOLVERSION` behaves the same as the `ssl_min_protocol_version` connection parameter.
- `LTSSLMAXPROTOCOLVERSION` behaves the same as the `ssl_max_protocol_version` connection parameter.
- `LTGSSENCMODE` behaves the same as the `gssencmode` connection parameter.
- `LTKRBSRVNAME` behaves the same as the `krbsrvname` connection parameter.
- `LTGSSLIB` behaves the same as the `gsslib` connection parameter.
- `LTCONNECT_TIMEOUT` behaves the same as the `connect_timeout` connection parameter.
- `LTCLIENTENCODING` behaves the same as the `client_encoding` connection parameter.
- `LTTARGETSESSIONATTRS` behaves the same as the `target_session_attrs` connection parameter.

The following environment variables can be used to specify default behavior for each LightDB session. (See also the `ALTER ROLE` and `ALTER DATABASE` commands for ways to set default behavior on a per-user or per-database basis.)

- `LTDATESTYLE` sets the default style of date/time representation. (Equivalent to `SET datestyle TO ...`.)
- `LTTZ` sets the default time zone. (Equivalent to `SET timezone TO ...`.)
- `LTGEO` sets the default mode for the genetic query optimizer. (Equivalent to `SET geqo TO ...`.)

Refer to the SQL command `SET` for information on correct values for these environment variables.

The following environment variables determine internal behavior of libpq; they override compiled-in defaults.

- `LTSYSCONFDIR` sets the directory containing the `pg_service.conf` file and in a future version possibly other system-wide configuration files.
- `LTLOCALEDIR` sets the directory containing the `locale` files for message localization.

## 32.15. The Password File

The file `.pgpass` in a user's home directory can contain passwords to be used if the connection requires a password (and no password has been specified otherwise). On Microsoft Windows the file is named `%APPDATA%\postgresql\pgpass.conf` (where `%APPDATA%` refers to the Application Data subdirectory in the user's profile). Alternatively, the password file to use can be specified using the connection parameter `passfile` or the environment variable `LTPASSFILE`.

This file should contain lines of the following format:

```
hostname:port:database:username:password
```

(You can add a reminder comment to the file by copying the line above and preceding it with `#`.) Each of the first four fields can be a literal value, or `*`, which matches anything. The password field from the first line that matches the current connection parameters will be used. (Therefore, put more-specific entries first when you are using wildcards.) If an entry needs to contain `:` or `\`, escape this character with `\`. The host name field is matched to the `host` connection parameter if that is specified, otherwise to the `hostaddr` parameter if that is specified; if neither are given then the host name `localhost` is searched for. The host name `localhost` is also searched for when the connection is a Unix-domain socket connection and the `host` parameter matches libpq's default socket directory path. In a standby server, a database field of `replication` matches streaming replication connections made to the master server. The database field is of limited usefulness otherwise, because users have the same password for all databases in the same cluster.

On Unix systems, the permissions on a password file must disallow any access to world or group; achieve this by a command such as `chmod 0600 ~/.pgpass`. If the permissions are less strict than this, the file will be ignored. On Microsoft Windows, it is assumed that the file is stored in a directory that is secure, so no special permissions check is made.

## 32.16. The Connection Service File

The connection service file allows libpq connection parameters to be associated with a single service name. That service name can then be specified in a libpq connection string, and the associated settings will be used. This allows connection parameters to be modified without requiring a recompile of the libpq-using application. The service name can also be specified using the `LTSERVICE` environment variable.

Service names can be defined in either a per-user service file or a system-wide file. If the same service name exists in both the user and the system file, the user file takes precedence. By default, the per-user service file is named `~/.pg_service.conf`. On Microsoft Windows, it is named `%APPDATA%\postgresql\.pg_service.conf` (where `%APPDATA%` refers to the

Application Data subdirectory in the user's profile). A different file name can be specified by setting the environment variable `LTSERVICEFILE`. The system-wide file is named `pg_service.conf`. By default it is sought in the `etc` directory of the LightDB installation (use `lt_config --sysconfdir` to identify this directory precisely). Another directory, but not a different file name, can be specified by setting the environment variable `LTSYSCONFDIR`.

Either service file uses an “INI file” format where the section name is the service name and the parameters are connection parameters; see Section 32.1.2 for a list. For example:

```
# comment
[mydb]
host=somehost
port=5433
user=admin
```

An example file is provided in the LightDB installation at `share/pg_service.conf.sample`.

Connection parameters obtained from a service file are combined with parameters obtained from other sources. A service file setting overrides the corresponding environment variable, and in turn can be overridden by a value given directly in the connection string. For example, using the above service file, a connection string `service=mydb port=5434` will use host `somehost`, port `5434`, user `admin`, and other parameters as set by environment variables or built-in defaults.

## 32.17. LDAP Lookup of Connection Parameters

If libpq has been compiled with LDAP support (option `--with-ldap` for `configure`) it is possible to retrieve connection options like `host` or `dbname` via LDAP from a central server. The advantage is that if the connection parameters for a database change, the connection information doesn't have to be updated on all client machines.

LDAP connection parameter lookup uses the connection service file `pg_service.conf` (see Section 32.16). A line in a `pg_service.conf` stanza that starts with `ldap://` will be recognized as an LDAP URL and an LDAP query will be performed. The result must be a list of `keyword = value` pairs which will be used to set connection options. The URL must conform to RFC 1959 and be of the form

```
ldap://[hostname[:port]]/search_base?attribute?search_scope?filter
```

where `hostname` defaults to `localhost` and `port` defaults to `389`.

Processing of `pg_service.conf` is terminated after a successful LDAP lookup, but is continued if the LDAP server cannot be contacted. This is to provide a fallback with further LDAP URL lines that point to different LDAP servers, classical `keyword = value` pairs, or default connection options. If you would rather get an error message in this case, add a syntactically incorrect line after the LDAP URL.

A sample LDAP entry that has been created with the LDIF file

```
version:1
dn:cn=mydatabase,dc=mycompany,dc=com
changetype:add
objectclass:top
objectclass:device
cn:mydatabase
description:host=dbserver.mycompany.com
```

```
description:port=5439
description:dbname=mydb
description:user=mydb_user
description:sslmode=require
```

might be queried with the following LDAP URL:

```
ldap://ldap.mycompany.com/dc=mycompany,dc=com?description?one?
(cn=mydatabase)
```

You can also mix regular service file entries with LDAP lookups. A complete example for a stanza in `pg_service.conf` would be:

```
# only host and port are stored in LDAP, specify dbname and user
  explicitly
[customerdb]
dbname=customer
user=appuser
ldap://ldap.acme.com/cn=dbserver,cn=hosts?pgconnectinfo?base?
(objectclass=*)
```

## 32.18. SSL Support

LightDB has native support for using SSL connections to encrypt client/server communications for increased security. See Section 16.9 for details about the server-side SSL functionality.

libpq reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

### 32.18.1. Client Verification of Server Certificates

By default, LightDB will not perform any verification of the server certificate. This means that it is possible to spoof the server identity (for example by modifying a DNS record or by taking over the server IP address) without the client knowing. In order to prevent spoofing, the client must be able to verify the server's identity via a chain of trust. A chain of trust is established by placing a root (self-signed) certificate authority (CA) certificate on one computer and a leaf certificate *signed* by the root certificate on another computer. It is also possible to use an “intermediate” certificate which is signed by the root certificate and signs leaf certificates.

To allow the client to verify the identity of the server, place a root certificate on the client and a leaf certificate signed by the root certificate on the server. To allow the server to verify the identity of the client, place a root certificate on the server and a leaf certificate signed by the root certificate on the client. One or more intermediate certificates (usually stored with the leaf certificate) can also be used to link the leaf certificate to the root certificate.

Once a chain of trust has been established, there are two ways for the client to validate the leaf certificate sent by the server. If the parameter `sslmode` is set to `verify-ca`, libpq will verify that the server is trustworthy by checking the certificate chain up to the root certificate stored on the client. If `sslmode` is set to `verify-full`, libpq will *also* verify that the server host name matches the name stored in the server certificate. The SSL connection will fail if the server certificate cannot be verified. `verify-full` is recommended in most security-sensitive environments.

In `verify-full` mode, the host name is matched against the certificate's Subject Alternative Name attribute(s), or against the Common Name attribute if no Subject Alternative Name of type `dNSName` is present. If the certificate's name attribute starts with an asterisk (\*), the asterisk will be treated as a wildcard, which will match all characters *except* a dot (.). This means the certificate will not match

subdomains. If the connection is made using an IP address instead of a host name, the IP address will be matched (without doing any DNS lookups).

To allow server certificate verification, one or more root certificates must be placed in the file `~/.postgresql/root.crt` in the user's home directory. (On Microsoft Windows the file is named `%APPDATA%\postgresql\root.crt`.) Intermediate certificates should also be added to the file if they are needed to link the certificate chain sent by the server to the root certificates stored on the client.

Certificate Revocation List (CRL) entries are also checked if the file `~/.postgresql/root.crl` exists (`%APPDATA%\postgresql\root.crl` on Microsoft Windows).

The location of the root certificate file and the CRL can be changed by setting the connection parameters `sslrootcert` and `sslcrl` or the environment variables `LTSSLROOTCERT` and `LTSSLCRL`.

### Note

For backwards compatibility with earlier versions of LightDB, if a root CA file exists, the behavior of `sslmode=require` will be the same as that of `verify-ca`, meaning the server certificate is validated against the CA. Relying on this behavior is discouraged, and applications that need certificate validation should always use `verify-ca` or `verify-full`.

## 32.18.2. Client Certificates

If the server attempts to verify the identity of the client by requesting the client's leaf certificate, libpq will send the certificate(s) stored in file `~/.postgresql/postgresql.crt` in the user's home directory. The certificates must chain to the root certificate trusted by the server. A matching private key file `~/.postgresql/postgresql.key` must also be present. On Microsoft Windows these files are named `%APPDATA%\postgresql\postgresql.crt` and `%APPDATA%\postgresql\postgresql.key`. The location of the certificate and key files can be overridden by the connection parameters `sslcert` and `sslkey`, or by the environment variables `LTSSLCERT` and `LTSSLKEY`.

On Unix systems, the permissions on the private key file must disallow any access to world or group; achieve this by a command such as `chmod 0600 ~/.postgresql/postgresql.key`. Alternatively, the file can be owned by root and have group read access (that is, 0640 permissions). That setup is intended for installations where certificate and key files are managed by the operating system. The user of libpq should then be made a member of the group that has access to those certificate and key files. (On Microsoft Windows, there is no file permissions check, since the `%APPDATA%\postgresql` directory is presumed secure.)

The first certificate in `postgresql.crt` must be the client's certificate because it must match the client's private key. “Intermediate” certificates can be optionally appended to the file — doing so avoids requiring storage of intermediate certificates on the server (`ssl_ca_file`).

The certificate and key may be in PEM or ASN.1 DER format.

The key may be stored in cleartext or encrypted with a passphrase using any algorithm supported by OpenSSL, like AES-128. If the key is stored encrypted, then the passphrase may be provided in the `sslpassword` connection option. If an encrypted key is supplied and the `sslpassword` option is absent or blank, a password will be prompted for interactively by OpenSSL with a `Enter PEM pass phrase:` prompt if a TTY is available. Applications can override the client certificate prompt and the handling of the `sslpassword` parameter by supplying their own key password callback; see `PQsetSSLKeyPassHook_OpenSSL`.

For instructions on creating certificates, see Section 16.9.5.

### 32.18.3. Protection Provided in Different Modes

The different values for the `sslmode` parameter provide different levels of protection. SSL can provide protection against three types of attacks:

#### Eavesdropping

If a third party can examine the network traffic between the client and the server, it can read both connection information (including the user name and password) and the data that is passed. SSL uses encryption to prevent this.

#### Man in the middle (MITM)

If a third party can modify the data while passing between the client and server, it can pretend to be the server and therefore see and modify data *even if it is encrypted*. The third party can then forward the connection information and data to the original server, making it impossible to detect this attack. Common vectors to do this include DNS poisoning and address hijacking, whereby the client is directed to a different server than intended. There are also several other attack methods that can accomplish this. SSL uses certificate verification to prevent this, by authenticating the server to the client.

#### Impersonation

If a third party can pretend to be an authorized client, it can simply access data it should not have access to. Typically this can happen through insecure password management. SSL uses client certificates to prevent this, by making sure that only holders of valid certificates can access the server.

For a connection to be known SSL-secured, SSL usage must be configured on *both the client and the server* before the connection is made. If it is only configured on the server, the client may end up sending sensitive information (e.g., passwords) before it knows that the server requires high security. In libpq, secure connections can be ensured by setting the `sslmode` parameter to `verify-full` or `verify-ca`, and providing the system with a root certificate to verify against. This is analogous to using an `https` URL for encrypted web browsing.

Once the server has been authenticated, the client can pass sensitive data. This means that up until this point, the client does not need to know if certificates will be used for authentication, making it safe to specify that only in the server configuration.

All SSL options carry overhead in the form of encryption and key-exchange, so there is a trade-off that has to be made between performance and security. Table 32.1 illustrates the risks the different `sslmode` values protect against, and what statement they make about security and overhead.

**Table 32.1. SSL Mode Descriptions**

<code>sslmode</code>	Eavesdropping protection	MITM protection	Statement
<code>disable</code>	No	No	I don't care about security, and I don't want to pay the overhead of encryption.
<code>allow</code>	Maybe	No	I don't care about security, but I will pay the overhead of encryption if the server insists on it.
<code>prefer</code>	Maybe	No	I don't care about encryption, but I wish to pay the overhead of encryption if the server supports it.
<code>require</code>	Yes	No	I want my data to be encrypted, and I accept the overhead. I trust that

sslmode	Eavesdropping protection	MITM protection	Statement
			the network will make sure I always connect to the server I want.
verify-ca	Yes	Depends on CA policy	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server that I trust.
verify-full	Yes	Yes	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server I trust, and that it's the one I specify.

The difference between `verify-ca` and `verify-full` depends on the policy of the root CA. If a public CA is used, `verify-ca` allows connections to a server that *somebody else* may have registered with the CA. In this case, `verify-full` should always be used. If a local CA is used, or even a self-signed certificate, using `verify-ca` often provides enough protection.

The default value for `sslmode` is `prefer`. As is shown in the table, this makes no sense from a security point of view, and it only promises performance overhead if possible. It is only provided as the default for backward compatibility, and is not recommended in secure deployments.

## 32.18.4. SSL Client File Usage

Table 32.2 summarizes the files that are relevant to the SSL setup on the client.

**Table 32.2. Libpq/Client SSL File Usage**

File	Contents	Effect
~/.postgresql/postgresql.crt	client certificate	sent to server
~/.postgresql/postgresql.key	client private key	proves client certificate sent by owner; does not indicate certificate owner is trustworthy
~/.postgresql/root.crt	trusted certificate authorities	checks that server certificate is signed by a trusted certificate authority
~/.postgresql/root.crl	certificates revoked by certificate authorities	server certificate must not be on this list

## 32.18.5. SSL Library Initialization

If your application initializes `libssl` and/or `libcrypto` libraries and `libpq` is built with SSL support, you should call `PQinitOpenSSL` to tell `libpq` that the `libssl` and/or `libcrypto` libraries have been initialized by your application, so that `libpq` will not also initialize those libraries.

`PQinitOpenSSL`

Allows applications to select which security libraries to initialize.

```
void PQinitOpenSSL(int do_ssl, int do_crypto);
```

When `do_ssl` is non-zero, `libpq` will initialize the OpenSSL library before first opening a database connection. When `do_crypto` is non-zero, the `libcrypto` library will be initialized. By default (if `PQinitOpenSSL` is not called), both libraries are initialized. When SSL support is not compiled in, this function is present but does nothing.

If your application uses and initializes either OpenSSL or its underlying `libcrypto` library, you *must* call this function with zeroes for the appropriate parameter(s) before first opening a database connection. Also be sure that you have done that initialization before opening a database connection.

### PQinitSSL

Allows applications to select which security libraries to initialize.

```
void PQinitSSL(int do_ssl);
```

This function is equivalent to `PQinitOpenSSL(do_ssl, do_ssl)`. It is sufficient for applications that initialize both or neither of OpenSSL and `libcrypto`.

`PQinitSSL` has been present since LightDB 8.0, while `PQinitOpenSSL` was added in LightDB 8.4, so `PQinitSSL` might be preferable for applications that need to work with older versions of libpq.

## 32.19. Behavior in Threaded Programs

libpq is reentrant and thread-safe by default. You might need to use special compiler command-line options when you compile your application code. Refer to your system's documentation for information about how to build thread-enabled applications, or look in `src/Makefile.global` for `PTHREAD_CFLAGS` and `PTHREAD_LIBS`. This function allows the querying of libpq's thread-safe status:

### PQisthreadsafe

Returns the thread safety status of the libpq library.

```
int PQisthreadsafe();
```

Returns 1 if the libpq is thread-safe and 0 if it is not.

One thread restriction is that no two threads attempt to manipulate the same `PGconn` object at the same time. In particular, you cannot issue concurrent commands from different threads through the same connection object. (If you need to run concurrent commands, use multiple connections.)

`PGresult` objects are normally read-only after creation, and so can be passed around freely between threads. However, if you use any of the `PGresult`-modifying functions described in Section 32.11 or Section 32.13, it's up to you to avoid concurrent operations on the same `PGresult`, too.

The deprecated functions `PQrequestCancel` and `PQoidStatus` are not thread-safe and should not be used in multithread programs. `PQrequestCancel` can be replaced by `PQcancel`. `PQoidStatus` can be replaced by `PQoidValue`.

If you are using Kerberos inside your application (in addition to inside libpq), you will need to do locking around Kerberos calls because Kerberos functions are not thread-safe. See function `PQregisterThreadLock` in the libpq source code for a way to do cooperative locking between libpq and your application.

## 32.20. Building libpq Programs

To build (i.e., compile and link) a program using libpq you need to do all of the following things:

- Include the `libpq-fe.h` header file:

```
#include <libpq-fe.h>
```



If you failed to do that then you will normally get error messages from your compiler similar to:

```
foo.c: In function `main':
foo.c:34: `PGconn' undeclared (first use in this function)
foo.c:35: `PGresult' undeclared (first use in this function)
foo.c:54: `CONNECTION_BAD' undeclared (first use in this
function)
foo.c:68: `PGRES_COMMAND_OK' undeclared (first use in this
function)
foo.c:95: `PGRES_TUPLES_OK' undeclared (first use in this
function)
```

- Point your compiler to the directory where the LightDB header files were installed, by supplying the `-Idirectory` option to your compiler. (In some cases the compiler will look into the directory in question by default, so you can omit this option.) For instance, your compile command line could look like:

```
cc -c -I/usr/local/lightdb-x/include testprog.c
```

If you are using makefiles then add the option to the `CPPFLAGS` variable:

```
CPPFLAGS += -I/usr/local/lightdb-x/include
```

If there is any chance that your program might be compiled by other users then you should not hardcode the directory location like that. Instead, you can run the utility `lt_config` to find out where the header files are on the local system:

```
$ lt_config --includedir
/usr/local/include
```

If you have `pkg-config` installed, you can run instead:

```
$ pkg-config --cflags libpq
-I/usr/local/include
```

Note that this will already include the `-I` in front of the path.

Failure to specify the correct option to the compiler will result in an error message such as:

```
testlibpq.c:8:22: libpq-fe.h: No such file or directory
```

- When linking the final program, specify the option `-lpq` so that the `libpq` library gets pulled in, as well as the option `-Ldirectory` to point the compiler to the directory where the `libpq` library resides. (Again, the compiler will search some directories by default.) For maximum portability, put the `-L` option before the `-lpq` option. For example:

```
cc -o testprog testprog1.o testprog2.o -L/usr/local/lightdb-x/lib
-lpq
```

You can find out the library directory using `lt_config` as well:

```
$ lt_config --libdir
```

```
/usr/local/lightdb-x/lib
```

Or again use `pkg-config`:

```
$ pkg-config --libs libpq
-L/usr/local/lightdb-x/lib -lpq
```

Note again that this prints the full options, not only the path.

Error messages that point to problems in this area could look like the following:

```
testlibpq.o: In function `main':
testlibpq.o(.text+0x60): undefined reference to `PQsetdbLogin'
testlibpq.o(.text+0x71): undefined reference to `PQstatus'
testlibpq.o(.text+0xa4): undefined reference to `PQerrorMessage'
```

This means you forgot `-lpq`.

```
/usr/bin/ld: cannot find -lpq
```

This means you forgot the `-L` option or did not specify the right directory.

## 32.21. Example Programs

These examples and others can be found in the directory `src/test/examples` in the source code distribution.

### Example 32.1. libpq Example Program 1

```
/*
 * src/test/examples/testlibpq.c
 *
 *
 * testlibpq.c
 *
 *      Test the C version of libpq, the LightDB frontend library.
 */
#include <stdio.h>
#include <stdlib.h>
#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
```

```
int          nFields;
int          i,
            j;

/*
 * If the user supplies a parameter on the command line, use it
as the
 * conninfo string; otherwise default to setting
dbname=postgres and using
 * environment variables or defaults for all other connection
parameters.
 */
if (argc > 1)
    conninfo = argv[1];
else
    conninfo = "dbname = postgres";

/* Make a connection to the database */
conn = PQconnectdb(conninfo);

/* Check to see that the backend connection was successfully
made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/* Set always-secure search path, so malicious users can't take
control. */
res = PQexec(conn,
              "SELECT pg_catalog.set_config('search_path', '',
false)");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

/*
 * Should PQclear PGresult whenever it is no longer needed to
avoid memory
 * leaks
 */
PQclear(res);

/*
 * Our test case here involves using a cursor, for which we
must be inside
 * a transaction block. We could do the whole thing with a
single
 * PQexec() of "select * from pg_database", but that's too
trivial to make
 * a good example.
 */
```

```
/* Start a transaction block */
res = PQexec(conn, "BEGIN");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "BEGIN command failed: %s",
PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

/*
 * Fetch rows from pg_database, the system catalog of databases
 */
res = PQexec(conn, "DECLARE myportal CURSOR FOR select * from
pg_database");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "DECLARE CURSOR failed: %s",
PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

res = PQexec(conn, "FETCH ALL in myportal");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "FETCH ALL failed: %s",
PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

/* first, print out the attribute names */
nFields = PQnfields(res);
for (i = 0; i < nFields; i++)
    printf("%-15s", PQfname(res, i));
printf("\n\n");

/* next, print out the rows */
for (i = 0; i < PQntuples(res); i++)
{
    for (j = 0; j < nFields; j++)
        printf("%-15s", PQgetvalue(res, i, j));
    printf("\n");
}

PQclear(res);

/* close the portal ... we don't bother to check for errors ...
*/
res = PQexec(conn, "CLOSE myportal");
PQclear(res);

/* end the transaction */
res = PQexec(conn, "END");
PQclear(res);
```

```

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}

```

### Example 32.2. libpq Example Program 2

```

/*
 * src/test/examples/testlibpq2.c
 *
 *
 * testlibpq2.c
 *     Test of the asynchronous notification interface
 *
 * Start this program, then from ltsql in another window do
 *     NOTIFY TBL2;
 * Repeat four times to get this program to exit.
 *
 * Or, if you want to get fancy, try this:
 * populate a database with the following commands
 * (provided in src/test/examples/testlibpq2.sql):
 *
 *     CREATE SCHEMA TESTLIBPQ2;
 *     SET search_path = TESTLIBPQ2;
 *     CREATE TABLE TBL1 (i int4);
 *     CREATE TABLE TBL2 (i int4);
 *     CREATE RULE r1 AS ON INSERT TO TBL1 DO
 *         (INSERT INTO TBL2 VALUES (new.i); NOTIFY TBL2);
 *
 * Start this program, then from ltsql do this four times:
 *
 *     INSERT INTO TESTLIBPQ2.TBL1 VALUES (10);
 */

#ifdef WIN32
#include <windows.h>
#endif
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <errno.h>
#include <sys/time.h>
#include <sys/types.h>
#ifdef HAVE_SYS_SELECT_H
#include <sys/select.h>
#endif

#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
}

```

```
        exit(1);
    }

    int
    main(int argc, char **argv)
    {
        const char *conninfo;
        PGconn      *conn;
        PGresult     *res;
        PGnotify     *notify;
        int          nnotifies;

        /*
         * If the user supplies a parameter on the command line, use it
         as the
         * conninfo string; otherwise default to setting
         dbname=postgres and using
         * environment variables or defaults for all other connection
         parameters.
         */
        if (argc > 1)
            conninfo = argv[1];
        else
            conninfo = "dbname = postgres";

        /* Make a connection to the database */
        conn = PQconnectdb(conninfo);

        /* Check to see that the backend connection was successfully
         made */
        if (PQstatus(conn) != CONNECTION_OK)
        {
            fprintf(stderr, "Connection to database failed: %s",
                    PQerrorMessage(conn));
            exit_nicely(conn);
        }

        /* Set always-secure search path, so malicious users can't take
         control. */
        res = PQexec(conn,
                     "SELECT pg_catalog.set_config('search_path', '',
false)");
        if (PQresultStatus(res) != PGRES_TUPLES_OK)
        {
            fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
            PQclear(res);
            exit_nicely(conn);
        }

        /*
         * Should PQclear PGresult whenever it is no longer needed to
         avoid memory
         * leaks
         */
        PQclear(res);

        /*
```

```

    * Issue LISTEN command to enable notifications from the rule's
NOTIFY.
    */
    res = PQexec(conn, "LISTEN TBL2");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "LISTEN command failed: %s",
PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }
    PQclear(res);

    /* Quit after four notifies are received. */
    nnotifies = 0;
    while (nnotifies < 4)
    {
        /*
        * Sleep until something happens on the connection. We use
select(2)
        * to wait for input, but you could also use poll() or
similar
        * facilities.
        */
        int         sock;
        fd_set      input_mask;

        sock = PQsocket(conn);

        if (sock < 0)
            break;          /* shouldn't happen */

        FD_ZERO(&input_mask);
        FD_SET(sock, &input_mask);

        if (select(sock + 1, &input_mask, NULL, NULL, NULL) < 0)
        {
            fprintf(stderr, "select() failed: %s\n",
strerror(errno));
            exit_nicely(conn);
        }

        /* Now check for input */
        PQconsumeInput(conn);
        while ((notify = PQnotifies(conn)) != NULL)
        {
            fprintf(stderr,
                "ASYNC NOTIFY of '%s' received from backend PID
%d\n",
                notify->relname, notify->be_pid);
            PQfreemem(notify);
            nnotifies++;
            PQconsumeInput(conn);
        }
    }

    fprintf(stderr, "Done.\n");

```

```

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}

```

### Example 32.3. libpq Example Program 3

```

/*
 * src/test/examples/testlibpq3.c
 *
 *
 * testlibpq3.c
 *     Test out-of-line parameters and binary I/O.
 *
 * Before running this, populate a database with the following
 * commands
 * (provided in src/test/examples/testlibpq3.sql):
 *
 * CREATE SCHEMA testlibpq3;
 * SET search_path = testlibpq3;
 * SET standard_conforming_strings = ON;
 * CREATE TABLE test1 (i int4, t text, b bytea);
 * INSERT INTO test1 values (1, 'joe's place',
 * '\000\001\002\003\004');
 * INSERT INTO test1 values (2, 'ho there',
 * '\004\003\002\001\000');
 *
 * The expected output is:
 *
 * tuple 0: got
 *   i = (4 bytes) 1
 *   t = (11 bytes) 'joe's place'
 *   b = (5 bytes) \000\001\002\003\004
 *
 * tuple 0: got
 *   i = (4 bytes) 2
 *   t = (8 bytes) 'ho there'
 *   b = (5 bytes) \004\003\002\001\000
 */

#ifdef WIN32
#include <windows.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <string.h>
#include <sys/types.h>
#include "libpq-fe.h"

/* for ntohs/htonl */
#include <netinet/in.h>
#include <arpa/inet.h>

```



```
static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

/*
 * This function prints a query result that is a binary-format
 * fetch from
 * a table defined as in the comment above. We split it out
 * because the
 * main() function uses it twice.
 */
static void
show_binary_results(PGresult *res)
{
    int        i,
              j;
    int        i_fnum,
              t_fnum,
              b_fnum;

    /* Use PQfnumber to avoid assumptions about field order in
    result */
    i_fnum = PQfnumber(res, "i");
    t_fnum = PQfnumber(res, "t");
    b_fnum = PQfnumber(res, "b");

    for (i = 0; i < PQntuples(res); i++)
    {
        char    *iptr;
        char    *tptr;
        char    *bptr;
        int     blen;
        int     ival;

        /* Get the field values (we ignore possibility they are
        null!) */
        iptr = PQgetvalue(res, i, i_fnum);
        tptr = PQgetvalue(res, i, t_fnum);
        bptr = PQgetvalue(res, i, b_fnum);

        /*
         * The binary representation of INT4 is in network byte
         * order, which
         * we'd better coerce to the local byte order.
         */
        ival = ntohl(*(uint32_t *) iptr);

        /*
         * The binary representation of TEXT is, well, text, and
         * since libpq
         * was nice enough to append a zero byte to it, it'll work
         * just fine
         * as a C string.
         */
    }
}
```

```

        *
        * The binary representation of BYTEA is a bunch of bytes,
which could
        * include embedded nulls so we have to pay attention to
field length.
        */
        blen = PQgetlength(res, i, b_fnum);

        printf("tuple %d: got\n", i);
        printf(" i = (%d bytes) %d\n",
            PQgetlength(res, i, i_fnum), ival);
        printf(" t = (%d bytes) '%s'\n",
            PQgetlength(res, i, t_fnum), tptr);
        printf(" b = (%d bytes) ", blen);
        for (j = 0; j < blen; j++)
            printf("\\%03o", bptr[j]);
        printf("\n\n");
    }
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    const char *paramValues[1];
    int         paramLengths[1];
    int         paramFormats[1];
    uint32_t    binaryIntVal;

    /*
     * If the user supplies a parameter on the command line, use it
as the
     * conninfo string; otherwise default to setting
dbname=postgres and using
     * environment variables or defaults for all other connection
parameters.
     */
    if (argc > 1)
        conninfo = argv[1];
    else
        conninfo = "dbname = postgres";

    /* Make a connection to the database */
    conn = PQconnectdb(conninfo);

    /* Check to see that the backend connection was successfully
made */
    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
        exit_nicely(conn);
    }

    /* Set always-secure search path, so malicious users can't take
control. */

```

---

```

res = PQexec(conn, "SET search_path = testlibpq3");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

/*
 * The point of this program is to illustrate use of
PQexecParams() with
 * out-of-line parameters, as well as binary transmission of
data.
 *
 * This first example transmits the parameters as text, but
receives the
 * results in binary format. By using out-of-line parameters
we can avoid
 * a lot of tedious mucking about with quoting and escaping,
even though
 * the data is text. Notice how we don't have to do anything
special with
 * the quote mark in the parameter value.
 */

/* Here is our out-of-line parameter value */
paramValues[0] = "joe's place";

res = PQexecParams(conn,
                    "SELECT * FROM test1 WHERE t = $1",
                    1,      /* one param */
                    NULL,  /* let the backend deduce param
type */
                    paramValues,
                    NULL,  /* don't need param lengths since
text */
                    NULL,  /* default to all text params */
                    1);    /* ask for binary results */

if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

show_binary_results(res);

PQclear(res);

/*
 * In this second example we transmit an integer parameter in
binary form,
 * and again retrieve the results in binary form.
 *
 * Although we tell PQexecParams we are letting the backend
deduce

```

```
    * parameter type, we really force the decision by casting the
parameter
    * symbol in the query text. This is a good safety measure
when sending
    * binary parameters.
    */

/* Convert integer value "2" to network byte order */
binaryIntVal = htonl((uint32_t) 2);

/* Set up parameter arrays for PQexecParams */
paramValues[0] = (char *) &binaryIntVal;
paramLengths[0] = sizeof(binaryIntVal);
paramFormats[0] = 1;          /* binary */

res = PQexecParams(conn,
                  "SELECT * FROM test1 WHERE i = $1::int4",
                  1,          /* one param */
                  NULL,      /* let the backend deduce param
type */
                  paramValues,
                  paramLengths,
                  paramFormats,
                  1);        /* ask for binary results */

if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

show_binary_results(res);

PQclear(res);

/* close the connection to the database and cleanup */
PQfinish(conn);

return 0;
}
```

---

# Chapter 33. Large Objects

LightDB has a *large object* facility, which provides stream-style access to user data that is stored in a special large-object structure. Streaming access is useful when working with data values that are too large to manipulate conveniently as a whole.

This chapter describes the implementation and the programming and query language interfaces to LightDB large object data. We use the libpq C library for the examples in this chapter, but most programming interfaces native to LightDB support equivalent functionality. Other interfaces might use the large object interface internally to provide generic support for large values. This is not described here.

## 33.1. Introduction

All large objects are stored in a single system table named `pg_largeobject`. Each large object also has an entry in the system table `pg_largeobject_metadata`. Large objects can be created, modified, and deleted using a read/write API that is similar to standard operations on files.

LightDB also supports a storage system called “TOAST”, which automatically stores values larger than a single database page into a secondary storage area per table. This makes the large object facility partially obsolete. One remaining advantage of the large object facility is that it allows values up to 4 TB in size, whereas TOASTed fields can be at most 1 GB. Also, reading and updating portions of a large object can be done efficiently, while most operations on a TOASTed field will read or write the whole value as a unit.

## 33.2. Implementation Features

The large object implementation breaks large objects up into “chunks” and stores the chunks in rows in the database. A B-tree index guarantees fast searches for the correct chunk number when doing random access reads and writes.

The chunks stored for a large object do not have to be contiguous. For example, if an application opens a new large object, seeks to offset 1000000, and writes a few bytes there, this does not result in allocation of 1000000 bytes worth of storage; only of chunks covering the range of data bytes actually written. A read operation will, however, read out zeroes for any unallocated locations preceding the last existing chunk. This corresponds to the common behavior of “sparsely allocated” files in Unix file systems.

As of LightDB 9.0, large objects have an owner and a set of access permissions, which can be managed using `GRANT` and `REVOKE`. `SELECT` privileges are required to read a large object, and `UPDATE` privileges are required to write or truncate it. Only the large object's owner (or a database superuser) can delete, comment on, or change the owner of a large object. To adjust this behavior for compatibility with prior releases, see the `lo_compat_privileges` run-time parameter.

## 33.3. Client Interfaces

This section describes the facilities that LightDB's libpq client interface library provides for accessing large objects. The LightDB large object interface is modeled after the Unix file-system interface, with analogues of `open`, `read`, `write`, `lseek`, etc.

All large object manipulation using these functions *must* take place within an SQL transaction block, since large object file descriptors are only valid for the duration of a transaction.

If an error occurs while executing any one of these functions, the function will return an otherwise-impossible value, typically 0 or -1. A message describing the error is stored in the connection object and can be retrieved with `PQerrorMessage`.

Client applications that use these functions should include the header file `libpq/libpq-fs.h` and link with the `libpq` library.

### 33.3.1. Creating a Large Object

The function

```
Oid lo_creat(PGconn *conn, int mode);
```

creates a new large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. *mode* is unused and ignored as of LightDB 8.1; however, for backward compatibility with earlier releases it is best to set it to `INV_READ`, `INV_WRITE`, or `INV_READ | INV_WRITE`. (These symbolic constants are defined in the header file `libpq/libpq-fs.h`.)

An example:

```
inv_oid = lo_creat(conn, INV_READ|INV_WRITE);
```

The function

```
Oid lo_create(PGconn *conn, Oid lobjId);
```

also creates a new large object. The OID to be assigned can be specified by *lobjId*; if so, failure occurs if that OID is already in use for some large object. If *lobjId* is `InvalidOid` (zero) then `lo_create` assigns an unused OID (this is the same behavior as `lo_creat`). The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure.

`lo_create` is new as of LightDB 8.1; if this function is run against an older server version, it will fail and return `InvalidOid`.

An example:

```
inv_oid = lo_create(conn, desired_oid);
```

### 33.3.2. Importing a Large Object

To import an operating system file as a large object, call

```
Oid lo_import(PGconn *conn, const char *filename);
```

*filename* specifies the operating system name of the file to be imported as a large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. Note that the file is read by the client interface library, not by the server; so it must exist in the client file system and be readable by the client application.

The function

```
Oid lo_import_with_oid(PGconn *conn, const char *filename, Oid lobjId);
```

also imports a new large object. The OID to be assigned can be specified by *lobjId*; if so, failure occurs if that OID is already in use for some large object. If *lobjId* is `InvalidOid` (zero) then

`lo_import_with_oid` assigns an unused OID (this is the same behavior as `lo_import`). The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure.

`lo_import_with_oid` is new as of LightDB 8.4 and uses `lo_create` internally which is new in 8.1; if this function is run against 8.0 or before, it will fail and return `InvalidOid`.

### 33.3.3. Exporting a Large Object

To export a large object into an operating system file, call

```
int lo_export(PGconn *conn, Oid lobjId, const char *filename);
```

The `lobjId` argument specifies the OID of the large object to export and the `filename` argument specifies the operating system name of the file. Note that the file is written by the client interface library, not by the server. Returns 1 on success, -1 on failure.

### 33.3.4. Opening an Existing Large Object

To open an existing large object for reading or writing, call

```
int lo_open(PGconn *conn, Oid lobjId, int mode);
```

The `lobjId` argument specifies the OID of the large object to open. The `mode` bits control whether the object is opened for reading (`INV_READ`), writing (`INV_WRITE`), or both. (These symbolic constants are defined in the header file `libpq/libpq-fs.h`.) `lo_open` returns a (non-negative) large object descriptor for later use in `lo_read`, `lo_write`, `lo_lseek`, `lo_lseek64`, `lo_tell`, `lo_tell64`, `lo_truncate`, `lo_truncate64`, and `lo_close`. The descriptor is only valid for the duration of the current transaction. On failure, -1 is returned.

The server currently does not distinguish between modes `INV_WRITE` and `INV_READ | INV_WRITE`: you are allowed to read from the descriptor in either case. However there is a significant difference between these modes and `INV_READ` alone: with `INV_READ` you cannot write on the descriptor, and the data read from it will reflect the contents of the large object at the time of the transaction snapshot that was active when `lo_open` was executed, regardless of later writes by this or other transactions. Reading from a descriptor opened with `INV_WRITE` returns data that reflects all writes of other committed transactions as well as writes of the current transaction. This is similar to the behavior of `REPEATABLE READ` versus `READ COMMITTED` transaction modes for ordinary SQL `SELECT` commands.

`lo_open` will fail if `SELECT` privilege is not available for the large object, or if `INV_WRITE` is specified and `UPDATE` privilege is not available. (Prior to LightDB 11, these privilege checks were instead performed at the first actual read or write call using the descriptor.) These privilege checks can be disabled with the `lo_compat_privileges` run-time parameter.

An example:

```
inv_fd = lo_open(conn, inv_oid, INV_READ|INV_WRITE);
```

### 33.3.5. Writing Data to a Large Object

The function

```
int lo_write(PGconn *conn, int fd, const char *buf, size_t len);
```

writes `len` bytes from `buf` (which must be of size `len`) to large object descriptor `fd`. The `fd` argument must have been returned by a previous `lo_open`. The number of bytes actually written is

returned (in the current implementation, this will always equal *len* unless there is an error). In the event of an error, the return value is -1.

Although the *len* parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

### 33.3.6. Reading Data from a Large Object

The function

```
int lo_read(PGconn *conn, int fd, char *buf, size_t len);
```

reads up to *len* bytes from large object descriptor *fd* into *buf* (which must be of size *len*). The *fd* argument must have been returned by a previous `lo_open`. The number of bytes actually read is returned; this will be less than *len* if the end of the large object is reached first. In the event of an error, the return value is -1.

Although the *len* parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

### 33.3.7. Seeking in a Large Object

To change the current read or write location associated with a large object descriptor, call

```
int lo_lseek(PGconn *conn, int fd, int offset, int whence);
```

This function moves the current location pointer for the large object descriptor identified by *fd* to the new location specified by *offset*. The valid values for *whence* are `SEEK_SET` (seek from object start), `SEEK_CUR` (seek from current position), and `SEEK_END` (seek from object end). The return value is the new location pointer, or -1 on error.

When dealing with large objects that might exceed 2GB in size, instead use

```
pg_int64 lo_lseek64(PGconn *conn, int fd, pg_int64 offset, int  
whence);
```

This function has the same behavior as `lo_lseek`, but it can accept an *offset* larger than 2GB and/or deliver a result larger than 2GB. Note that `lo_lseek` will fail if the new location pointer would be greater than 2GB.

`lo_lseek64` is new as of LightDB 9.3. If this function is run against an older server version, it will fail and return -1.

### 33.3.8. Obtaining the Seek Position of a Large Object

To obtain the current read or write location of a large object descriptor, call

```
int lo_tell(PGconn *conn, int fd);
```

If there is an error, the return value is -1.

When dealing with large objects that might exceed 2GB in size, instead use



```
pg_int64 lo_tell64(PGconn *conn, int fd);
```

This function has the same behavior as `lo_tell`, but it can deliver a result larger than 2GB. Note that `lo_tell` will fail if the current read/write location is greater than 2GB.

`lo_tell64` is new as of LightDB 9.3. If this function is run against an older server version, it will fail and return -1.

### 33.3.9. Truncating a Large Object

To truncate a large object to a given length, call

```
int lo_truncate(PGconn *conn, int fd, size_t len);
```

This function truncates the large object descriptor `fd` to length `len`. The `fd` argument must have been returned by a previous `lo_open`. If `len` is greater than the large object's current length, the large object is extended to the specified length with null bytes ('\0'). On success, `lo_truncate` returns zero. On error, the return value is -1.

The read/write location associated with the descriptor `fd` is not changed.

Although the `len` parameter is declared as `size_t`, `lo_truncate` will reject length values larger than `INT_MAX`.

When dealing with large objects that might exceed 2GB in size, instead use

```
int lo_truncate64(PGconn *conn, int fd, pg_int64 len);
```

This function has the same behavior as `lo_truncate`, but it can accept a `len` value exceeding 2GB.

`lo_truncate` is new as of LightDB 8.3; if this function is run against an older server version, it will fail and return -1.

`lo_truncate64` is new as of LightDB 9.3; if this function is run against an older server version, it will fail and return -1.

### 33.3.10. Closing a Large Object Descriptor

A large object descriptor can be closed by calling

```
int lo_close(PGconn *conn, int fd);
```

where `fd` is a large object descriptor returned by `lo_open`. On success, `lo_close` returns zero. On error, the return value is -1.

Any large object descriptors that remain open at the end of a transaction will be closed automatically.

### 33.3.11. Removing a Large Object

To remove a large object from the database, call

```
int lo_unlink(PGconn *conn, Oid lobjId);
```

The `lobjId` argument specifies the OID of the large object to remove. Returns 1 if successful, -1 on failure.

## 33.4. Server-Side Functions

Server-side functions tailored for manipulating large objects from SQL are listed in Table 33.1.

**Table 33.1. SQL-Oriented Large Object Functions**

Function	Description	Example(s)
<code>lo_from_bytea</code>	Creates a large object and stores <i>data</i> in it. If <i>loid</i> is zero then the system will choose a free OID, otherwise that OID is used (with an error if some large object already has that OID). On success, the large object's OID is returned.	<code>lo_from_bytea(loid oid, data bytea) → oid</code> <code>lo_from_bytea(0, '\xffffffff00') → 24528</code>
<code>lo_put</code>	Writes <i>data</i> starting at the given offset within the large object; the large object is enlarged if necessary.	<code>lo_put(loid oid, offset bigint, data bytea) → void</code> <code>lo_put(24528, 1, '\xaa') →</code>
<code>lo_get</code>	Extracts the large object's contents, or a substring thereof.	<code>lo_get(loid oid [, offset bigint, length integer]) → bytea</code> <code>lo_get(24528, 0, 3) → \xffaaff</code>

There are additional server-side functions corresponding to each of the client-side functions described earlier; indeed, for the most part the client-side functions are simply interfaces to the equivalent server-side functions. The ones just as convenient to call via SQL commands are `lo_creat`, `lo_create`, `lo_unlink`, `lo_import`, and `lo_export`. Here are examples of their use:

```
CREATE TABLE image (
    name          text,
    raster        oid
);

SELECT lo_creat(-1);          -- returns OID of new, empty large
object

SELECT lo_create(43213);     -- attempts to create large object with
OID 43213

SELECT lo_unlink(173454);    -- deletes large object with OID 173454

INSERT INTO image (name, raster)
VALUES ('beautiful image', lo_import('/etc/motd'));

INSERT INTO image (name, raster) -- same as above, but specify OID
to use
VALUES ('beautiful image', lo_import('/etc/motd', 68583));

SELECT lo_export(image.raster, '/tmp/motd') FROM image
WHERE name = 'beautiful image';
```

The server-side `lo_import` and `lo_export` functions behave considerably differently from their client-side analogs. These two functions read and write files in the server's file system, using the permissions of the database's owning user. Therefore, by default their use is restricted to superusers. In contrast, the client-side import and export functions read and write files in the client's file system,

using the permissions of the client program. The client-side functions do not require any database privileges, except the privilege to read or write the large object in question.

### Caution

It is possible to GRANT use of the server-side `lo_import` and `lo_export` functions to non-superusers, but careful consideration of the security implications is required. A malicious user of such privileges could easily parlay them into becoming superuser (for example by rewriting server configuration files), or could attack the rest of the server's file system without bothering to obtain database superuser privileges as such. *Access to roles having such privilege must therefore be guarded just as carefully as access to superuser roles.* Nonetheless, if use of server-side `lo_import` or `lo_export` is needed for some routine task, it's safer to use a role with such privileges than one with full superuser privileges, as that helps to reduce the risk of damage from accidental errors.

The functionality of `lo_read` and `lo_write` is also available via server-side calls, but the names of the server-side functions differ from the client side interfaces in that they do not contain underscores. You must call these functions as `loread` and `lowrite`.

## 33.5. Example Program

Example 33.1 is a sample program which shows how the large object interface in `libpq` can be used. Parts of the program are commented out but are left in the source for the reader's benefit. This program can also be found in `src/test/examples/testlo.c` in the source distribution.

### Example 33.1. Large Objects with `libpq` Example Program

```

/*-----
 *
 * testlo.c
 *   test using large objects with libpq
 *
 * Portions Copyright (c) 1996-2020, Hundsun Technologies Inc.
 *
 *
 * IDENTIFICATION
 *   src/test/examples/testlo.c
 *
 *-----
 */
#include <stdio.h>
#include <stdlib.h>

#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>

#include "libpq-fe.h"
#include "libpq/libpq-fs.h"

#define BUFSIZE          1024

```

```
/*
 * importFile -
 *   import file "in_filename" into database as large object
 *   "lobjOid"
 *
 */
static Oid
importFile(PGconn *conn, char *filename)
{
    Oid        lobjId;
    int        lobj_fd;
    char       buf[BUFSIZE];
    int        nbytes,
              tmp;
    int        fd;

    /*
     * open the file to be read in
     */
    fd = open(filename, O_RDONLY, 0666);
    if (fd < 0)
    {
        /* error */
        fprintf(stderr, "cannot open unix file\"%s\"\n", filename);
    }

    /*
     * create the large object
     */
    lobjId = lo_creat(conn, INV_READ | INV_WRITE);
    if (lobjId == 0)
        fprintf(stderr, "cannot create large object");

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);

    /*
     * read in from the Unix file and write to the inversion file
     */
    while ((nbytes = read(fd, buf, BUFSIZE)) > 0)
    {
        tmp = lo_write(conn, lobj_fd, buf, nbytes);
        if (tmp < nbytes)
            fprintf(stderr, "error while reading \"%s\"",
filename);
    }

    close(fd);
    lo_close(conn, lobj_fd);

    return lobjId;
}

static void
pickout(PGconn *conn, Oid lobjId, int start, int len)
{
    int        lobj_fd;
    char       *buf;
    int        nbytes;
    int        nread;
```

```
lobj_fd = lo_open(conn, lobjId, INV_READ);
if (lobj_fd < 0)
    fprintf(stderr, "cannot open large object %u", lobjId);

lo_lseek(conn, lobj_fd, start, SEEK_SET);
buf = malloc(len + 1);

nread = 0;
while (len - nread > 0)
{
    nbytes = lo_read(conn, lobj_fd, buf, len - nread);
    buf[nbytes] = '\\0';
    fprintf(stderr, ">>> %s", buf);
    nread += nbytes;
    if (nbytes <= 0)
        break;           /* no more data? */
}
free(buf);
fprintf(stderr, "\\n");
lo_close(conn, lobj_fd);
}

static void
overwrite(PGconn *conn, Oid lobjId, int start, int len)
{
    int         lobj_fd;
    char        *buf;
    int         nbytes;
    int         nwritten;
    int         i;

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    lo_lseek(conn, lobj_fd, start, SEEK_SET);
    buf = malloc(len + 1);

    for (i = 0; i < len; i++)
        buf[i] = 'X';
    buf[i] = '\\0';

    nwritten = 0;
    while (len - nwritten > 0)
    {
        nbytes = lo_write(conn, lobj_fd, buf + nwritten, len -
nwritten);
        nwritten += nbytes;
        if (nbytes <= 0)
        {
            fprintf(stderr, "\\nWRITE FAILED!\\n");
            break;
        }
    }
    free(buf);
    fprintf(stderr, "\\n");
    lo_close(conn, lobj_fd);
}
```

```
}

/*
 * exportFile -
 *   export large object "lobjOid" to file "out_filename"
 *
 */
static void
exportFile(PGconn *conn, Oid lobjOid, char *filename)
{
    int         lobj_fd;
    char        buf[BUFSIZE];
    int         nbytes,
               tmp;
    int         fd;

    /*
     * open the large object
     */
    lobj_fd = lo_open(conn, lobjOid, INV_READ);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjOid);

    /*
     * open the file to be written to
     */
    fd = open(filename, O_CREAT | O_WRONLY | O_TRUNC, 0666);
    if (fd < 0)
    {
        /* error */
        fprintf(stderr, "cannot open unix file \"%s\"",
                filename);
    }

    /*
     * read in from the inversion file and write to the Unix file
     */
    while ((nbytes = lo_read(conn, lobj_fd, buf, BUFSIZE)) > 0)
    {
        tmp = write(fd, buf, nbytes);
        if (tmp < nbytes)
        {
            fprintf(stderr, "error while writing \"%s\"",
                    filename);
        }
    }

    lo_close(conn, lobj_fd);
    close(fd);

    return;
}

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}
```

```
}

int
main(int argc, char **argv)
{
    char        *in_filename,
               *out_filename;
    char        *database;
    Oid         lobjOid;
    PGconn      *conn;
    PGresult    *res;

    if (argc != 4)
    {
        fprintf(stderr, "Usage: %s database_name in_filename
out_filename\n",
               argv[0]);
        exit(1);
    }

    database = argv[1];
    in_filename = argv[2];
    out_filename = argv[3];

    /*
     * set up the connection
     */
    conn = PQsetdb(NULL, NULL, NULL, NULL, database);

    /* check to see that the backend connection was successfully
made */
    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
               PQerrorMessage(conn));
        exit_nicely(conn);
    }

    /* Set always-secure search path, so malicious users can't take
control. */
    res = PQexec(conn,
                 "SELECT pg_catalog.set_config('search_path', '',
false)");
    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }
    PQclear(res);

    res = PQexec(conn, "begin");
    PQclear(res);
    printf("importing file \"%s\" ... \n", in_filename);
    /* lobjOid = importFile(conn, in_filename); */
    lobjOid = lo_import(conn, in_filename);
    if (lobjOid == 0)
        fprintf(stderr, "%s\n", PQerrorMessage(conn));
}
```

```
    else
    {
        printf("\tas large object %u.\n", lobjOid);

        printf("picking out bytes 1000-2000 of the large object
\n");
        pickout(conn, lobjOid, 1000, 1000);

        printf("overwriting bytes 1000-2000 of the large object
with X's\n");
        overwrite(conn, lobjOid, 1000, 1000);

        printf("exporting large object to file \"%s\" ....\n",
out_filename);
/*      exportFile(conn, lobjOid, out_filename); */
        if (lo_export(conn, lobjOid, out_filename) < 0)
            fprintf(stderr, "%s\n", PQerrorMessage(conn));
    }

    res = PQexec(conn, "end");
    PQclear(res);
    PQfinish(conn);
    return 0;
}
```



---

# Chapter 34. ECPG — Embedded SQL in C

This chapter describes the embedded SQL package for LightDB. It was written by Linus Tolke (<linus@epact.se>) and Michael Meskes (<meskes@postgresql.org>). Originally it was written to work with C. It also works with C++, but it does not recognize all C++ constructs yet.

This documentation is quite incomplete. But since this interface is standardized, additional information can be found in many resources about SQL.

## 34.1. The Concept

An embedded SQL program consists of code written in an ordinary programming language, in this case C, mixed with SQL commands in specially marked sections. To build the program, the source code (\*.pgc) is first passed through the embedded SQL preprocessor, which converts it to an ordinary C program (\*.c), and afterwards it can be processed by a C compiler. (For details about the compiling and linking see Section 34.10). Converted ECPG applications call functions in the libpq library through the embedded SQL library (ecpglib), and communicate with the LightDB server using the normal frontend-backend protocol.

Embedded SQL has advantages over other methods for handling SQL commands from C code. First, it takes care of the tedious passing of information to and from variables in your C program. Second, the SQL code in the program is checked at build time for syntactical correctness. Third, embedded SQL in C is specified in the SQL standard and supported by many other SQL database systems. The LightDB implementation is designed to match this standard as much as possible, and it is usually possible to port embedded SQL programs written for other SQL databases to LightDB with relative ease.

As already stated, programs written for the embedded SQL interface are normal C programs with special code inserted to perform database-related actions. This special code always has the form:

```
EXEC SQL ...;
```

These statements syntactically take the place of a C statement. Depending on the particular statement, they can appear at the global level or within a function. Embedded SQL statements follow the case-sensitivity rules of normal SQL code, and not those of C. Also they allow nested C-style comments that are part of the SQL standard. The C part of the program, however, follows the C standard of not accepting nested comments.

Start with LightDB version 23.3, there are three types of comments that can be used in EXEC SQL: '-- comment', '// comment' and '/\* comment \*/'. Before 23.3, only '/\* comment \*/' is supported.

The '-- comment' and '// comment' comments will be removed after conversion. but the '/\* comment \*/' comment will be moved to the front of ECPGdo as a comment for this call.

The following sections explain all the embedded SQL statements.

## 34.2. Managing Database Connections

This section describes how to open, close, and switch database connections.

### 34.2.1. Connecting to the Database Server

One connects to a database using the following statement:

```
EXEC SQL CONNECT TO target [AS connection-name] [USER user-name];
```

The *target* can be specified in the following ways:

- *dbname*[@*hostname*][:*port*]
- `tcp:postgresql://hostname[:port][/dbname][?options]`
- `unix:postgresql://hostname[:port][/dbname][?options]`
- an SQL string literal containing one of the above forms
- a reference to a character variable containing one of the above forms (see examples)
- DEFAULT

If you specify the connection target literally (that is, not through a variable reference) and you don't quote the value, then the case-insensitivity rules of normal SQL are applied. In that case you can also double-quote the individual parameters separately as needed. In practice, it is probably less error-prone to use a (single-quoted) string literal or a variable reference. The connection target DEFAULT initiates a connection to the default database under the default user name. No separate user name or connection name can be specified in that case.

There are also different ways to specify the user name:

- *username*
- *username/password*
- *username IDENTIFIED BY password*
- *username USING password*

As above, the parameters *username* and *password* can be an SQL identifier, an SQL string literal, or a reference to a character variable.

If the connection target includes any *options*, those consist of *keyword=value* specifications separated by ampersands (&). The allowed key words are the same ones recognized by libpq (see Section 32.1.2). Spaces are ignored before any *keyword* or *value*, though not within or after one. Note that there is no way to write & within a *value*.

The *connection-name* is used to handle multiple connections in one program. It can be omitted if a program uses only one connection. The most recently opened connection becomes the current connection, which is used by default when an SQL statement is to be executed (see later in this chapter).

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from *search\_path*. For example, add `options=-c search_path=` to *options*, or issue `EXEC SQL SELECT pg_catalog.set_config('search_path', '', false);` after connecting. This consideration is not specific to ECPG; it applies to every interface for executing arbitrary SQL commands.

Here are some examples of CONNECT statements:

```
EXEC SQL CONNECT TO mydb@sql.mydomain.com;
```

```
EXEC SQL CONNECT TO unix:postgresql://sql.mydomain.com/mydb AS  
myconnection USER john;
```

```
EXEC SQL BEGIN DECLARE SECTION;
```

```
const char *target = "mydb@sql.mydomain.com";
const char *user = "john";
const char *passwd = "secret";
EXEC SQL END DECLARE SECTION;
...
EXEC SQL CONNECT TO :target USER :user USING :passwd;
/* or EXEC SQL CONNECT TO :target USER :user/:passwd; */
```

The last form makes use of the variant referred to above as character variable reference. You will see in later sections how C variables can be used in SQL statements when you prefix them with a colon.

Be advised that the format of the connection target is not specified in the SQL standard. So if you want to develop portable applications, you might want to use something based on the last example above to encapsulate the connection target string somewhere.

## 34.2.2. Choosing a Connection

SQL statements in embedded SQL programs are by default executed on the current connection, that is, the most recently opened one. If an application needs to manage multiple connections, then there are two ways to handle this.

The first option is to explicitly choose a connection for each SQL statement, for example:

```
EXEC SQL AT connection-name SELECT ...;
```

This option is particularly suitable if the application needs to use several connections in mixed order.

If your application uses multiple threads of execution, they cannot share a connection concurrently. You must either explicitly control access to the connection (using mutexes) or use a connection for each thread.

The second option is to execute a statement to switch the current connection. That statement is:

```
EXEC SQL SET CONNECTION connection-name;
```

This option is particularly convenient if many statements are to be executed on the same connection.

Here is an example program managing multiple database connections:

```
#include <stdio.h>

EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
EXEC SQL END DECLARE SECTION;

int
main()
{
    EXEC SQL CONNECT TO testdb1 AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL CONNECT TO testdb2 AS con2 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL CONNECT TO testdb3 AS con3 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
```

```
    /* This query would be executed in the last opened database
testdb3". */
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb3)\n", dbname);

    /* Using "AT" to run a query in "testdb2" */
    EXEC SQL AT con2 SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb2)\n", dbname);

    /* Switch the current connection to "testdb1". */
    EXEC SQL SET CONNECTION con1;

    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb1)\n", dbname);

    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

This example would produce this output:

```
current=testdb3 (should be testdb3)
current=testdb2 (should be testdb2)
current=testdb1 (should be testdb1)
```

### 34.2.3. Closing a Connection

To close a connection, use the following statement:

```
EXEC SQL DISCONNECT [connection];
```

The *connection* can be specified in the following ways:

- *connection-name*
- DEFAULT
- CURRENT
- ALL

If no connection name is specified, the current connection is closed.

It is good style that an application always explicitly disconnect from every connection it opened.

## 34.3. Running SQL Commands

Any SQL command can be run from within an embedded SQL application. Below are some examples of how to do that.

### 34.3.1. Executing SQL Statements

Creating a table:

```
EXEC SQL CREATE TABLE foo (number integer, ascii char(16));
EXEC SQL CREATE UNIQUE INDEX num1 ON foo(number);
EXEC SQL COMMIT;
```

Inserting rows:

```
EXEC SQL INSERT INTO foo (number, ascii) VALUES (9999, 'doodad');
EXEC SQL COMMIT;
```

Deleting rows:

```
EXEC SQL DELETE FROM foo WHERE number = 9999;
EXEC SQL COMMIT;
```

Updates:

```
EXEC SQL UPDATE foo
    SET ascii = 'foobar'
    WHERE number = 9999;
EXEC SQL COMMIT;
```

SELECT statements that return a single result row can also be executed using EXEC SQL directly. To handle result sets with multiple rows, an application has to use a cursor; see Section 34.3.2 below. (As a special case, an application can fetch multiple rows at once into an array host variable; see Section 34.4.4.3.1.)

Single-row select:

```
EXEC SQL SELECT foo INTO :FooBar FROM table1 WHERE ascii =
    'doodad';
```

Also, a configuration parameter can be retrieved with the SHOW command:

```
EXEC SQL SHOW search_path INTO :var;
```

The tokens of the form *:something* are *host variables*, that is, they refer to variables in the C program. They are explained in Section 34.4.

## 34.3.2. Using Cursors

To retrieve a result set holding multiple rows, an application has to declare a cursor and fetch each row from the cursor. The steps to use a cursor are the following: declare a cursor, open it, fetch a row from the cursor, repeat, and finally close it.

Select using cursors:

```
EXEC SQL DECLARE foo_bar CURSOR FOR
    SELECT number, ascii FROM foo
    ORDER BY ascii;
EXEC SQL OPEN foo_bar;
EXEC SQL FETCH foo_bar INTO :FooBar, DooDad;
...
EXEC SQL CLOSE foo_bar;
EXEC SQL COMMIT;
```

For more details about declaration of the cursor, see `DECLARE`, and see `FETCH` for `FETCH` command details.

### Note

The ECPG `DECLARE` command does not actually cause a statement to be sent to the LightDB backend. The cursor is opened in the backend (using the backend's `DECLARE` command) at the point when the `OPEN` command is executed.

## 34.3.3. Managing Transactions

In the default mode, statements are committed only when `EXEC SQL COMMIT` is issued. The embedded SQL interface also supports autocommit of transactions (similar to `libsql`'s default behavior) via the `-t` command-line option to `ecpg` (see `ecpg`) or via the `EXEC SQL SET AUTOCOMMIT TO ON` statement. In autocommit mode, each command is automatically committed unless it is inside an explicit transaction block. This mode can be explicitly turned off using `EXEC SQL SET AUTOCOMMIT TO OFF`.

The following transaction management commands are available:

```
EXEC SQL COMMIT
```

Commit an in-progress transaction.

```
EXEC SQL ROLLBACK
```

Roll back an in-progress transaction.

```
EXEC SQL PREPARE TRANSACTION transaction_id
```

Prepare the current transaction for two-phase commit.

```
EXEC SQL COMMIT PREPARED transaction_id
```

Commit a transaction that is in prepared state.

```
EXEC SQL ROLLBACK PREPARED transaction_id
```

Roll back a transaction that is in prepared state.

```
EXEC SQL SET AUTOCOMMIT TO ON
```

Enable autocommit mode.

```
EXEC SQL SET AUTOCOMMIT TO OFF
```

Disable autocommit mode. This is the default.

## 34.3.4. Prepared Statements

When the values to be passed to an SQL statement are not known at compile time, or the same statement is going to be used many times, then prepared statements can be useful.

The statement is prepared using the command `PREPARE`. For the values that are not known yet, use the placeholder “?”:

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid, datname FROM pg_database
WHERE oid = ?";
```

If a statement returns a single row, the application can call `EXECUTE` after `PREPARE` to execute the statement, supplying the actual values for the placeholders with a `USING` clause:

```
EXEC SQL EXECUTE stmt1 INTO :dboid, :dbname USING 1;
```

If a statement returns multiple rows, the application can use a cursor declared based on the prepared statement. To bind input parameters, the cursor must be opened with a `USING` clause:

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid,datname FROM pg_database
WHERE oid > ?";
EXEC SQL DECLARE foo_bar CURSOR FOR stmt1;

/* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

EXEC SQL OPEN foo_bar USING 100;
...
while (1)
{
    EXEC SQL FETCH NEXT FROM foo_bar INTO :dboid, :dbname;
    ...
}
EXEC SQL CLOSE foo_bar;
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

For more details about `PREPARE`, see `PREPARE`. Also see Section 34.5 for more details about using placeholders and input parameters.

## 34.4. Using Host Variables

In Section 34.3 you saw how you can execute SQL statements from an embedded SQL program. Some of those statements only used fixed values and did not provide a way to insert user-supplied values into statements or have the program process the values returned by the query. Those kinds of statements are not really useful in real applications. This section explains in detail how you can pass data between your C program and the embedded SQL statements using a simple mechanism called *host variables*. In an embedded SQL program we consider the SQL statements to be *guests* in the C program code which is the *host language*. Therefore the variables of the C program are called *host variables*.

Another way to exchange values between LightDB backends and ECPG applications is the use of SQL descriptors, described in Section 34.7.

### 34.4.1. Overview

Passing data between the C program and the SQL statements is particularly simple in embedded SQL. Instead of having the program paste the data into the statement, which entails various complications, such as properly quoting the value, you can simply write the name of a C variable into the SQL statement, prefixed by a colon. For example:

```
EXEC SQL INSERT INTO sometable VALUES (:v1, 'foo', :v2);
```

This statement refers to two C variables named `v1` and `v2` and also uses a regular SQL string literal, to illustrate that you are not restricted to use one kind of data or the other.

This style of inserting C variables in SQL statements works anywhere a value expression is expected in an SQL statement.

## 34.4.2. Declare Sections

To pass data from the program to the database, for example as parameters in a query, or to pass data from the database back to the program, the C variables that are intended to contain this data need to be declared in specially marked sections, so the embedded SQL preprocessor is made aware of them.

This section starts with:

```
EXEC SQL BEGIN DECLARE SECTION;
```

and ends with:

```
EXEC SQL END DECLARE SECTION;
```

Between those lines, there must be normal C variable declarations, such as:

```
int    x = 4;
char   foo[16], bar[16];
```

As you can see, you can optionally assign an initial value to the variable. The variable's scope is determined by the location of its declaring section within the program. You can also declare variables with the following syntax which implicitly creates a declare section:

```
EXEC SQL int i = 4;
```

You can have as many declare sections in a program as you like.

The declarations are also echoed to the output file as normal C variables, so there's no need to declare them again. Variables that are not intended to be used in SQL commands can be declared normally outside these special sections.

The definition of a structure or union also must be listed inside a DECLARE section. Otherwise the preprocessor cannot handle these types since it does not know the definition.

## 34.4.3. Retrieving Query Results

Now you should be able to pass data generated by your program into an SQL command. But how do you retrieve the results of a query? For that purpose, embedded SQL provides special variants of the usual commands `SELECT` and `FETCH`. These commands have a special `INTO` clause that specifies which host variables the retrieved values are to be stored in. `SELECT` is used for a query that returns only single row, and `FETCH` is used for a query that returns multiple rows, using a cursor.

Here is an example:

```
/*
 * assume this table:
 * CREATE TABLE test1 (a int, b varchar(50));
 */

EXEC SQL BEGIN DECLARE SECTION;
int v1;
VARCHAR v2;
```



```
EXEC SQL END DECLARE SECTION;

...

EXEC SQL SELECT a, b INTO :v1, :v2 FROM test;
```

So the INTO clause appears between the select list and the FROM clause. The number of elements in the select list and the list after INTO (also called the target list) must be equal.

Here is an example using the command FETCH:

```
EXEC SQL BEGIN DECLARE SECTION;
int v1;
VARCHAR v2;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL DECLARE foo CURSOR FOR SELECT a, b FROM test;

...

do
{
    ...
    EXEC SQL FETCH NEXT FROM foo INTO :v1, :v2;
    ...
} while (...);
```

Here the INTO clause appears after all the normal clauses.

### 34.4.4. Type Mapping

When ECPG applications exchange values between the LightDB server and the C application, such as when retrieving query results from the server or executing SQL statements with input parameters, the values need to be converted between LightDB data types and host language variable types (C language data types, concretely). One of the main points of ECPG is that it takes care of this automatically in most cases.

In this respect, there are two kinds of data types: Some simple LightDB data types, such as `integer` and `text`, can be read and written by the application directly. Other LightDB data types, such as `timestamp` and `numeric` can only be accessed through special library functions; see Section 34.4.4.2.

Table 34.1 shows which LightDB data types correspond to which C data types. When you wish to send or receive a value of a given LightDB data type, you should declare a C variable of the corresponding C data type in the declare section.

**Table 34.1. Mapping Between LightDB Data Types and C Variable Types**

LightDB data type	Host variable type
<code>smallint</code>	<code>short</code>
<code>integer</code>	<code>int</code>
<code>bigint</code>	<code>long long int</code>
<code>decimal</code>	<code>decimal<sup>a</sup></code>
<code>numeric</code>	<code>numeric<sup>a</sup></code>

LightDB data type	Host variable type
real	float
double precision	double
smallserial	short
serial	int
bigserial	long long int
oid	unsigned int
character( <i>n</i> ), varchar( <i>n</i> ), text	char[ <i>n</i> +1], VARCHAR[ <i>n</i> +1]
name	char[NAMEDATALEN]
timestamp	timestamp <sup>a</sup>
interval	interval <sup>a</sup>
date	date <sup>a</sup>
boolean	bool <sup>b</sup>
bytea	char *, bytea[ <i>n</i> ]

<sup>a</sup>This type can only be accessed through special library functions; see Section 34.4.4.2.

<sup>b</sup>declared in `ecpglib.h` if not native

### 34.4.4.1. Handling Character Strings

To handle SQL character string data types, such as `varchar` and `text`, there are two possible ways to declare the host variables.

One way is using `char[ ]`, an array of `char`, which is the most common way to handle character data in C.

```
EXEC SQL BEGIN DECLARE SECTION;
    char str[50];
EXEC SQL END DECLARE SECTION;
```

Note that you have to take care of the length yourself. If you use this host variable as the target variable of a query which returns a string with more than 49 characters, a buffer overflow occurs.

The other way is using the `VARCHAR` type, which is a special type provided by ECPG. The definition on an array of type `VARCHAR` is converted into a named `struct` for every variable. A declaration like:

```
VARCHAR var[180];
```

is converted into:

```
struct varchar_var { int len; char arr[180]; } var;
```

The member `arr` hosts the string including a terminating zero byte. Thus, to store a string in a `VARCHAR` host variable, the host variable has to be declared with the length including the zero byte terminator. The member `len` holds the length of the string stored in the `arr` without the terminating zero byte. When a host variable is used as input for a query, if `strlen(arr)` and `len` are different, the shorter one is used.

`VARCHAR` can be written in upper or lower case, but not in mixed case.

`char` and `VARCHAR` host variables can also hold values of other SQL types, which will be stored in their string forms.

### 34.4.4.2. Accessing Special Data Types

ECPG contains some special types that help you to interact easily with some special data types from the LightDB server. In particular, it has implemented support for the `numeric`, `decimal`, `date`, `timestamp`, and `interval` types. These data types cannot usefully be mapped to primitive host variable types (such as `int`, `long`, `long int`, or `char[ ]`), because they have a complex internal structure. Applications deal with these types by declaring host variables in special types and accessing them using functions in the `pgtypes` library. The `pgtypes` library, described in detail in Section 34.6 contains basic functions to deal with those types, such that you do not need to send a query to the SQL server just for adding an interval to a time stamp for example.

The follow subsections describe these special data types. For more details about `pgtypes` library functions, see Section 34.6.

#### 34.4.4.2.1. timestamp, date

Here is a pattern for handling `timestamp` variables in the ECPG host application.

First, the program has to include the header file for the `timestamp` type:

```
#include <pgtypes_timestamp.h>
```

Next, declare a host variable as type `timestamp` in the declare section:

```
EXEC SQL BEGIN DECLARE SECTION;
timestamp ts;
EXEC SQL END DECLARE SECTION;
```

And after reading a value into the host variable, process it using `pgtypes` library functions. In following example, the `timestamp` value is converted into text (ASCII) form with the `PGTYPEStimestamp_to_asc()` function:

```
EXEC SQL SELECT now()::timestamp INTO :ts;

printf("ts = %s\n", PGTYPEStimestamp_to_asc(ts));
```

This example will show some result like following:

```
ts = 2010-06-27 18:03:56.949343
```

In addition, the `DATE` type can be handled in the same way. The program has to include `pgtypes_date.h`, declare a host variable as the date type and convert a `DATE` value into a text form using `PGTYPESdate_to_asc()` function. For more details about the `pgtypes` library functions, see Section 34.6.

#### 34.4.4.2.2. interval

The handling of the `interval` type is also similar to the `timestamp` and `date` types. It is required, however, to allocate memory for an `interval` type value explicitly. In other words, the memory space for the variable has to be allocated in the heap memory, not in the stack memory.

Here is an example program:

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_interval.h>
```

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    interval *in;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    in = PGTYPESEinterval_new();
EXEC SQL SELECT '1 min'::interval INTO :in;
printf("interval = %s\n", PGTYPESEinterval_to_asc(in));
PGTYPESEinterval_free(in);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

#### 34.4.4.2.3. numeric, decimal

The handling of the `numeric` and `decimal` types is similar to the `interval` type: It requires defining a pointer, allocating some memory space on the heap, and accessing the variable using the `pgtypes` library functions. For more details about the `pgtypes` library functions, see Section 34.6.

No functions are provided specifically for the `decimal` type. An application has to convert it to a `numeric` variable using a `pgtypes` library function to do further processing.

Here is an example program handling `numeric` and `decimal` type variables.

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_numeric.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    numeric *num;
    numeric *num2;
    decimal *dec;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    num = PGTYPESEnumeric_new();
    dec = PGTYPESEdecimal_new();

    EXEC SQL SELECT 12.345::numeric(4,2), 23.456::decimal(4,2)
INTO :num, :dec;
```

```

printf("numeric = %s\n", PGTYPEStoasc(num, 0));
printf("numeric = %s\n", PGTYPEStoasc(num, 1));
printf("numeric = %s\n", PGTYPEStoasc(num, 2));

/* Convert decimal to numeric to show a decimal value. */
num2 = PGTYPEStoasc_new();
PGTYPEStoasc_from_decimal(dec, num2);

printf("decimal = %s\n", PGTYPEStoasc(num2, 0));
printf("decimal = %s\n", PGTYPEStoasc(num2, 1));
printf("decimal = %s\n", PGTYPEStoasc(num2, 2));

PGTYPEStoasc_free(num2);
PGTYPEStoasc_free(dec);
PGTYPEStoasc_free(num);

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
return 0;
}

```

#### 34.4.4.2.4. bytea

The handling of the `bytea` type is similar to that of `VARCHAR`. The definition on an array of type `bytea` is converted into a named struct for every variable. A declaration like:

```
bytea var[180];
```

is converted into:

```
struct bytea_var { int len; char arr[180]; } var;
```

The member `arr` hosts binary format data. It can also handle `'\0'` as part of data, unlike `VARCHAR`. The data is converted from/to hex format and sent/received by `ecpglib`.

#### Note

`bytea` variable can be used only when `bytea_output` is set to `hex`.

### 34.4.4.3. Host Variables with Nonprimitive Types

As a host variable you can also use arrays, typedefs, structs, and pointers.

#### 34.4.4.3.1. Arrays

There are two use cases for arrays as host variables. The first is a way to store some text string in `char[]` or `VARCHAR[]`, as explained in Section 34.4.4.1. The second use case is to retrieve multiple rows from a query result without using a cursor. Without an array, to process a query result consisting of multiple rows, it is required to use a cursor and the `FETCH` command. But with array host variables, multiple rows can be received at once. The length of the array has to be defined to be able to accommodate all rows, otherwise a buffer overflow will likely occur.

Following example scans the `pg_database` system table and shows all OIDs and names of the available databases:

```

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int dbid[8];
    char dbname[8][16];
    int i;
EXEC SQL END DECLARE SECTION;

    memset(dbname, 0, sizeof(char)* 16 * 8);
    memset(dbid, 0, sizeof(int) * 8);

    EXEC SQL CONNECT TO testdb;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    /* Retrieve multiple rows into arrays at once. */
    EXEC SQL SELECT oid,datname INTO :dbid, :dbname FROM
pg_database;

    for (i = 0; i < 8; i++)
        printf("oid=%d, dbname=%s\n", dbid[i], dbname[i]);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}

```

This example shows following result. (The exact values depend on local circumstances.)

```

oid=1, dbname=template1
oid=11510, dbname=template0
oid=11511, dbname=postgres
oid=313780, dbname=testdb
oid=0, dbname=
oid=0, dbname=
oid=0, dbname=

```

### 34.4.4.3.2. Structures

A structure whose member names match the column names of a query result, can be used to retrieve multiple columns at once. The structure enables handling multiple column values in a single host variable.

The following example retrieves OIDs, names, and sizes of the available databases from the `pg_database` system table and using the `pg_database_size()` function. In this example, a structure variable `dbinfo_t` with members whose names match each column in the `SELECT` result is used to retrieve one result row without putting multiple host variables in the `FETCH` statement.

```

EXEC SQL BEGIN DECLARE SECTION;
    typedef struct
    {
        int oid;
        char datname[65];
        long long int size;
    } dbinfo_t;

```

```
    dbinfo_t dbval;
EXEC SQL END DECLARE SECTION;

    memset(&dbval, 0, sizeof(dbinfo_t));

    EXEC SQL DECLARE curl CURSOR FOR SELECT oid, datname,
pg_database_size(oid) AS size FROM pg_database;
    EXEC SQL OPEN curl;

    /* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch multiple columns into one structure. */
    EXEC SQL FETCH FROM curl INTO :dbval;

    /* Print members of the structure. */
    printf("oid=%d, datname=%s, size=%lld\n", dbval.oid,
dbval.datname, dbval.size);
}

EXEC SQL CLOSE curl;
```

This example shows following result. (The exact values depend on local circumstances.)

```
oid=1, datname=template1, size=4324580
oid=11510, datname=template0, size=4243460
oid=11511, datname=postgres, size=4324580
oid=313780, datname=testdb, size=8183012
```

Structure host variables “absorb” as many columns as the structure as fields. Additional columns can be assigned to other host variables. For example, the above program could also be restructured like this, with the size variable outside the structure:

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef struct
    {
        int oid;
        char datname[65];
    } dbinfo_t;

    dbinfo_t dbval;
    long long int size;
EXEC SQL END DECLARE SECTION;

    memset(&dbval, 0, sizeof(dbinfo_t));

    EXEC SQL DECLARE curl CURSOR FOR SELECT oid, datname,
pg_database_size(oid) AS size FROM pg_database;
    EXEC SQL OPEN curl;

    /* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
```

```
    /* Fetch multiple columns into one structure. */
    EXEC SQL FETCH FROM curl INTO :dbval, :size;

    /* Print members of the structure. */
    printf("oid=%d, datname=%s, size=%lld\n", dbval.oid,
dbval.datname, size);
}

EXEC SQL CLOSE curl;
```

### 34.4.4.3.3. Typedefs

Use the `typedef` keyword to map new types to already existing types.

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef char mychartype[40];
    typedef long serial_t;
EXEC SQL END DECLARE SECTION;
```

Note that you could also use:

```
EXEC SQL TYPE serial_t IS long;
```

This declaration does not need to be part of a declare section.

### 34.4.4.3.4. Pointers

You can declare pointers to the most common types. Note however that you cannot use pointers as target variables of queries without auto-allocation. See Section 34.7 for more information on auto-allocation.

```
EXEC SQL BEGIN DECLARE SECTION;
    int *intp;
    char **charp;
EXEC SQL END DECLARE SECTION;
```

## 34.4.5. Handling Nonprimitive SQL Data Types

This section contains information on how to handle nonscalar and user-defined SQL-level data types in ECPG applications. Note that this is distinct from the handling of host variables of nonprimitive types, described in the previous section.

### 34.4.5.1. Arrays

Multi-dimensional SQL-level arrays are not directly supported in ECPG. One-dimensional SQL-level arrays can be mapped into C array host variables and vice-versa. However, when creating a statement `ecpg` does not know the types of the columns, so that it cannot check if a C array is input into a corresponding SQL-level array. When processing the output of a SQL statement, `ecpg` has the necessary information and thus checks if both are arrays.

If a query accesses *elements* of an array separately, then this avoids the use of arrays in ECPG. Then, a host variable with a type that can be mapped to the element type should be used. For example, if a column type is array of `integer`, a host variable of type `int` can be used. Also if the element type is `varchar` or `text`, a host variable of type `char[ ]` or `VARCHAR[ ]` can be used.

Here is an example. Assume the following table:



```

CREATE TABLE t3 (
    ii integer[]
);

testdb=> SELECT * FROM t3;
        ii
-----
    {1,2,3,4,5}
(1 row)

```

The following example program retrieves the 4th element of the array and stores it into a host variable of type int:

```

EXEC SQL BEGIN DECLARE SECTION;
int ii;
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[4] FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :ii ;
    printf("ii=%d\n", ii);
}

EXEC SQL CLOSE cur1;

```

This example shows the following result:

```
ii=4
```

To map multiple array elements to the multiple elements in an array type host variables each element of array column and each element of the host variable array have to be managed separately, for example:

```

EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[1], ii[2], ii[3], ii[4]
FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1
    INTO :ii_a[0], :ii_a[1], :ii_a[2], :ii_a[3];
    ...
}

```

Note again that

```

EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* WRONG */
    EXEC SQL FETCH FROM cur1 INTO :ii_a;
    ...
}

```

would not work correctly in this case, because you cannot map an array type column to an array host variable directly.

Another workaround is to store arrays in their external string representation in host variables of type `char[]` or `VARCHAR[]`. For more details about this representation, see Section 8.15.2. Note that this means that the array cannot be accessed naturally as an array in the host program (without further processing that parses the text representation).

### 34.4.5.2. Composite Types

Composite types are not directly supported in ECPG, but an easy workaround is possible. The available workarounds are similar to the ones described for arrays above: Either access each attribute separately or use the external string representation.

For the following examples, assume the following type and table:

```

CREATE TYPE comp_t AS (intval integer, textval varchar(32));
CREATE TABLE t4 (compval comp_t);
INSERT INTO t4 VALUES ( (256, 'LightDB') );

```

The most obvious solution is to access each attribute separately. The following program retrieves data from the example table by selecting each attribute of the type `comp_t` separately:

```

EXEC SQL BEGIN DECLARE SECTION;
int intval;
varchar textval[33];
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT
list. */
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).intval,
(compval).textval FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch each element of the composite type column into host
variables. */

```

```

EXEC SQL FETCH FROM cur1 INTO :intval, :textval;

printf("intval=%d, textval=%s\n", intval, textval.arr);
}

EXEC SQL CLOSE cur1;

```

To enhance this example, the host variables to store values in the `FETCH` command can be gathered into one structure. For more details about the host variable in the structure form, see Section 34.4.4.3.2. To switch to the structure, the example can be modified as below. The two host variables, `intval` and `textval`, become members of the `comp_t` structure, and the structure is specified on the `FETCH` command.

```

EXEC SQL BEGIN DECLARE SECTION;
typedef struct
{
    int intval;
    varchar textval[33];
} comp_t;

comp_t compval;
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT
list. */
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).intval,
(compval).textval FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM cur1 INTO :compval;

    printf("intval=%d, textval=%s\n", compval.intval,
compval.textval.arr);
}

EXEC SQL CLOSE cur1;

```

Although a structure is used in the `FETCH` command, the attribute names in the `SELECT` clause are specified one by one. This can be enhanced by using a `*` to ask for all attributes of the composite type value.

```

...
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).* FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM cur1 INTO :compval;

```

```

    printf("intval=%d, textval=%s\n", compval.intval,
    compval.textval.arr);
}
...

```

This way, composite types can be mapped into structures almost seamlessly, even though ECPG does not understand the composite type itself.

Finally, it is also possible to store composite type values in their external string representation in host variables of type `char [ ]` or `VARCHAR[ ]`. But that way, it is not easily possible to access the fields of the value from the host program.

### 34.4.5.3. User-Defined Base Types

New user-defined base types are not directly supported by ECPG. You can use the external string representation and host variables of type `char[ ]` or `VARCHAR[ ]`, and this solution is indeed appropriate and sufficient for many types.

Here is an example using the data type `complex` from the example in Section 36.13. The external string representation of that type is `(%f,%f)`, which is defined in the functions `complex_in()` and `complex_out()` functions in Section 36.13. The following example inserts the complex type values `(1,1)` and `(3,3)` into the columns `a` and `b`, and select them from the table after that.

```

EXEC SQL BEGIN DECLARE SECTION;
    varchar a[64];
    varchar b[64];
EXEC SQL END DECLARE SECTION;

EXEC SQL INSERT INTO test_complex VALUES ('(1,1)', '(3,3)');

EXEC SQL DECLARE cur1 CURSOR FOR SELECT a, b FROM test_complex;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :a, :b;
    printf("a=%s, b=%s\n", a.arr, b.arr);
}

EXEC SQL CLOSE cur1;

```

This example shows following result:

```
a=(1,1), b=(3,3)
```

Another workaround is avoiding the direct use of the user-defined types in ECPG and instead create a function or cast that converts between the user-defined type and a primitive type that ECPG can handle. Note, however, that type casts, especially implicit ones, should be introduced into the type system very carefully.

For example,

```

CREATE FUNCTION create_complex(r double, i double) RETURNS complex
LANGUAGE SQL
IMMUTABLE

```

```
AS $$ SELECT $1 * complex '(1,0)' + $2 * complex '(0,1)' $$;
```

After this definition, the following

```
EXEC SQL BEGIN DECLARE SECTION;
double a, b, c, d;
EXEC SQL END DECLARE SECTION;
```

```
a = 1;
b = 2;
c = 3;
d = 4;
```

```
EXEC SQL INSERT INTO test_complex VALUES (create_complex(:a, :b),
create_complex(:c, :d));
```

has the same effect as

```
EXEC SQL INSERT INTO test_complex VALUES ('(1,2)', '(3,4)');
```

## 34.4.6. Indicators

The examples above do not handle null values. In fact, the retrieval examples will raise an error if they fetch a null value from the database. To be able to pass null values to the database or retrieve null values from the database, you need to append a second host variable specification to each host variable that contains data. This second host variable is called the *indicator* and contains a flag that tells whether the datum is null, in which case the value of the real host variable is ignored. Here is an example that handles the retrieval of null values correctly:

```
EXEC SQL BEGIN DECLARE SECTION;
VARCHAR val;
int val_ind;
EXEC SQL END DECLARE SECTION;
```

...

```
EXEC SQL SELECT b INTO :val :val_ind FROM test1;
```

The indicator variable `val_ind` will be zero if the value was not null, and it will be negative if the value was null. (See Section 34.16 to enable Oracle-specific behavior.)

The indicator has another function: if the indicator value is positive, it means that the value is not null, but it was truncated when it was stored in the host variable.

If the argument `-r no_indicator` is passed to the preprocessor `ecpg`, it works in “no-indicator” mode. In no-indicator mode, if no indicator variable is specified, null values are signaled (on input and output) for character string types as empty string and for integer types as the lowest possible value for type (for example, `INT_MIN` for `int`).

## 34.5. Dynamic SQL

In many cases, the particular SQL statements that an application has to execute are known at the time the application is written. In some cases, however, the SQL statements are composed at run time or provided by an external source. In these cases you cannot embed the SQL statements directly into the C source code, but there is a facility that allows you to call arbitrary SQL statements that you provide in a string variable.

### 34.5.1. Executing Statements without a Result Set

The simplest way to execute an arbitrary SQL statement is to use the command EXECUTE IMMEDIATE. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "CREATE TABLE test1 (...);";
EXEC SQL END DECLARE SECTION;

EXEC SQL EXECUTE IMMEDIATE :stmt;
```

EXECUTE IMMEDIATE can be used for SQL statements that do not return a result set (e.g., DDL, INSERT, UPDATE, DELETE). You cannot execute statements that retrieve data (e.g., SELECT) this way. The next section describes how to do that.

### 34.5.2. Executing a Statement with Input Parameters

A more powerful way to execute arbitrary SQL statements is to prepare them once and execute the prepared statement as often as you like. It is also possible to prepare a generalized version of a statement and then execute specific versions of it by substituting parameters. When preparing the statement, write question marks where you want to substitute parameters later. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "INSERT INTO test1 VALUES(?, ?);";
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
...
EXEC SQL EXECUTE mystmt USING 42, 'foobar';
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

### 34.5.3. Executing a Statement with a Result Set

To execute an SQL statement with a single result row, EXECUTE can be used. To save the result, add an INTO clause.

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "SELECT a, b, c FROM test1 WHERE a > ?";
int v1, v2;
VARCHAR v3[50];
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
...
EXEC SQL EXECUTE mystmt INTO :v1, :v2, :v3 USING 37;
```

An EXECUTE command can have an INTO clause, a USING clause, both, or neither.

If a query is expected to return more than one result row, a cursor should be used, as in the following example. (See Section 34.3.2 for more details about the cursor.)

```
EXEC SQL BEGIN DECLARE SECTION;
char dbaname[128];
char datname[128];
char *stmt = "SELECT u.username as dbaname, d.datname "
             " FROM pg_database d, pg_user u "
             " WHERE d.datdba = u.usesysid";
EXEC SQL END DECLARE SECTION;

EXEC SQL CONNECT TO testdb AS con1 USER testuser;
EXEC SQL SELECT pg_catalog.set_config('search_path', '', false);
EXEC SQL COMMIT;

EXEC SQL PREPARE stmt1 FROM :stmt;

EXEC SQL DECLARE cursor1 CURSOR FOR stmt1;
EXEC SQL OPEN cursor1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH cursor1 INTO :dbaname,:datname;
    printf("dbaname=%s, datname=%s\n", dbaname, datname);
}

EXEC SQL CLOSE cursor1;

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
```

## 34.5.4. Executing a Do Statement with Input and Output Parameters

The do statement must be in language plorasql.

```
EXEC SQL BEGIN DECLARE SECTION;
int id = 1;
int iReturnCode = -1;
EXEC SQL END DECLARE SECTION;

EXEC SQL create table t1(
    id integer,
    val text);

EXEC SQL insert into t1 values
    (1, 'a'),
    (2, null),
    (4, 'd');

EXEC SQL
Do $$
begin
    begin
        update t1 set val = 'C' where id = :id;
```

```
:iReturnCode = 0;
:id = :id + 1;

if SQL%NOTFOUND then
    :iReturnCode = 123;
end if;

exception
    when others then
        :iReturnCode = 456;
end;
end;
$$ Language plorasql;
```

Every variable with ':' is recognized as a parameter, and the parameter's mode is inout.

## 34.6. pgtypes Library

The pgtypes library maps LightDB database types to C equivalents that can be used in C programs. It also offers functions to do basic calculations with those types within C, i.e., without the help of the LightDB server. See the following example:

```
EXEC SQL BEGIN DECLARE SECTION;
    date datel;
    timestamp ts1, tsout;
    interval iv1;
    char *out;
EXEC SQL END DECLARE SECTION;

PGTYPESdate_today(&datel);
EXEC SQL SELECT started, duration INTO :ts1, :iv1 FROM datetbl
    WHERE d=:datel;
PGTYPEStimestamp_add_interval(&ts1, &iv1, &tsout);
out = PGTYPEStimestamp_to_asc(&tsout);
printf("Started + duration: %s\n", out);
PGTYPESchar_free(out);
```

### 34.6.1. Character Strings

Some functions such as `PGTYPESnumeric_to_asc` return a pointer to a freshly allocated character string. These results should be freed with `PGTYPESchar_free` instead of `free`. (This is important only on Windows, where memory allocation and release sometimes need to be done by the same library.)

### 34.6.2. The numeric Type

The numeric type offers to do calculations with arbitrary precision. See Section 8.1 for the equivalent type in the LightDB server. Because of the arbitrary precision this variable needs to be able to expand and shrink dynamically. That's why you can only create numeric variables on the heap, by means of the `PGTYPESnumeric_new` and `PGTYPESnumeric_free` functions. The decimal type, which is similar but limited in precision, can be created on the stack as well as on the heap.

The following functions can be used to work with the numeric type:



**PGTYPEStnumeric\_new**

Request a pointer to a newly allocated numeric variable.

```
numeric *PGTYPEStnumeric_new(void);
```

**PGTYPEStnumeric\_free**

Free a numeric type, release all of its memory.

```
void PGTYPEStnumeric_free(numeric *var);
```

**PGTYPEStnumeric\_from\_asc**

Parse a numeric type from its string notation.

```
numeric *PGTYPEStnumeric_from_asc(char *str, char **endptr);
```

Valid formats are for example: -2, .794, +3.44, 592.49E07 or -32.84e-4. If the value could be parsed successfully, a valid pointer is returned, else the NULL pointer. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in *endptr*. You can safely set *endptr* to NULL.

**PGTYPEStnumeric\_to\_asc**

Returns a pointer to a string allocated by `malloc` that contains the string representation of the numeric type `num`.

```
char *PGTYPEStnumeric_to_asc(numeric *num, int dscale);
```

The numeric value will be printed with `dscale` decimal digits, with rounding applied if necessary. The result must be freed with `PGTYPEStchar_free()`.

**PGTYPEStnumeric\_add**

Add two numeric variables into a third one.

```
int PGTYPEStnumeric_add(numeric *var1, numeric *var2, numeric *result);
```

The function adds the variables `var1` and `var2` into the result variable `result`. The function returns 0 on success and -1 in case of error.

**PGTYPEStnumeric\_sub**

Subtract two numeric variables and return the result in a third one.

```
int PGTYPEStnumeric_sub(numeric *var1, numeric *var2, numeric *result);
```

The function subtracts the variable `var2` from the variable `var1`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

**PGTYPEStnumeric\_mul**

Multiply two numeric variables and return the result in a third one.

```
int PGTYPEsnumeric_mul(numeric *var1, numeric *var2, numeric
    *result);
```

The function multiplies the variables `var1` and `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPEsnumeric_div`

Divide two numeric variables and return the result in a third one.

```
int PGTYPEsnumeric_div(numeric *var1, numeric *var2, numeric
    *result);
```

The function divides the variables `var1` by `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPEsnumeric_cmp`

Compare two numeric variables.

```
int PGTYPEsnumeric_cmp(numeric *var1, numeric *var2)
```

This function compares two numeric variables. In case of error, `INT_MAX` is returned. On success, the function returns one of three possible results:

- 1, if `var1` is bigger than `var2`
- -1, if `var1` is smaller than `var2`
- 0, if `var1` and `var2` are equal

`PGTYPEsnumeric_from_int`

Convert an int variable to a numeric variable.

```
int PGTYPEsnumeric_from_int(signed int int_val, numeric *var);
```

This function accepts a variable of type `signed int` and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

`PGTYPEsnumeric_from_long`

Convert a long int variable to a numeric variable.

```
int PGTYPEsnumeric_from_long(signed long int long_val, numeric
    *var);
```

This function accepts a variable of type `signed long int` and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

`PGTYPEsnumeric_copy`

Copy over one numeric variable into another one.

```
int PGTYPEsnumeric_copy(numeric *src, numeric *dst);
```

This function copies over the value of the variable that `src` points to into the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

`PGTYPESnumeric_from_double`

Convert a variable of type double to a numeric.

```
int PGTYPESnumeric_from_double(double d, numeric *dst);
```

This function accepts a variable of type double and stores the result in the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

`PGTYPESnumeric_to_double`

Convert a variable of type numeric to double.

```
int PGTYPESnumeric_to_double(numeric *nv, double *dp)
```

The function converts the numeric value from the variable that `nv` points to into the double variable that `dp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_int`

Convert a variable of type numeric to int.

```
int PGTYPESnumeric_to_int(numeric *nv, int *ip);
```

The function converts the numeric value from the variable that `nv` points to into the integer variable that `ip` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_long`

Convert a variable of type numeric to long.

```
int PGTYPESnumeric_to_long(numeric *nv, long *lp);
```

The function converts the numeric value from the variable that `nv` points to into the long integer variable that `lp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_decimal`

Convert a variable of type numeric to decimal.

```
int PGTYPESnumeric_to_decimal(numeric *src, decimal *dst);
```

The function converts the numeric value from the variable that `src` points to into the decimal variable that `dst` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_from_decimal`

Convert a variable of type decimal to numeric.

```
int PGTYPESnumeric_from_decimal(decimal *src, numeric *dst);
```

The function converts the decimal value from the variable that `src` points to into the numeric variable that `dst` points to. It returns 0 on success and -1 if an error occurs. Since the decimal type is implemented as a limited version of the numeric type, overflow cannot occur with this conversion.

### 34.6.3. The date Type

The date type in C enables your programs to deal with data of the SQL type date. See Section 8.5 for the equivalent type in the LightDB server.

The following functions can be used to work with the date type:

`PGTYPESdate_from_timestamp`

Extract the date part from a timestamp.

```
date PGTYPESdate_from_timestamp(timestamp dt);
```

The function receives a timestamp as its only argument and returns the extracted date part from this timestamp.

`PGTYPESdate_from_asc`

Parse a date from its textual representation.

```
date PGTYPESdate_from_asc(char *str, char **endptr);
```

The function receives a C char\* string `str` and a pointer to a C char\* string `endptr`. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

Note that the function always assumes MDY-formatted dates and there is currently no variable to change that within ECPG.

Table 34.2 shows the allowed input formats.

**Table 34.2. Valid Input Formats for `PGTYPESdate_from_asc`**

Input	Result
January 8, 1999	January 8, 1999
1999-01-08	January 8, 1999
1/8/1999	January 8, 1999
1/18/1999	January 18, 1999
01/02/03	February 1, 2003
1999-Jan-08	January 8, 1999
Jan-08-1999	January 8, 1999
08-Jan-1999	January 8, 1999
99-Jan-08	January 8, 1999
08-Jan-99	January 8, 1999
08-Jan-06	January 8, 2006
Jan-08-99	January 8, 1999
19990108	ISO 8601; January 8, 1999

Input	Result
990108	ISO 8601; January 8, 1999
1999.008	year and day of year
J2451187	Julian day
January 8, 99 BC	year 99 before the Common Era

**PGTYPESdate\_to\_asc**

Return the textual representation of a date variable.

```
char *PGTYPESdate_to_asc(date dDate);
```

The function receives the date `dDate` as its only parameter. It will output the date in the form 1999-01-18, i.e., in the YYYY-MM-DD format. The result must be freed with `PGTYPESchar_free()`.

**PGTYPESdate\_julmdy**

Extract the values for the day, the month and the year from a variable of type date.

```
void PGTYPESdate_julmdy(date d, int *mdy);
```

The function receives the date `d` and a pointer to an array of 3 integer values `mdy`. The variable name indicates the sequential order: `mdy[0]` will be set to contain the number of the month, `mdy[1]` will be set to the value of the day and `mdy[2]` will contain the year.

**PGTYPESdate\_mdyjul**

Create a date value from an array of 3 integers that specify the day, the month and the year of the date.

```
void PGTYPESdate_mdyjul(int *mdy, date *jdate);
```

The function receives the array of the 3 integers (`mdy`) as its first argument and as its second argument a pointer to a variable of type date that should hold the result of the operation.

**PGTYPESdate\_dayofweek**

Return a number representing the day of the week for a date value.

```
int PGTYPESdate_dayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday
- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday

- 6 - Saturday

`PGTYPESdate_today`

Get the current date.

```
void PGTYPESdate_today(date *d);
```

The function receives a pointer to a date variable (`d`) that it sets to the current date.

`PGTYPESdate_fmt_asc`

Convert a variable of type `date` to its textual representation using a format mask.

```
int PGTYPESdate_fmt_asc(date dDate, char *fmtstring, char
    *outbuf);
```

The function receives the date to convert (`dDate`), the format mask (`fmtstring`) and the string that will hold the textual representation of the date (`outbuf`).

On success, 0 is returned and a negative value if an error occurred.

The following literals are the field specifiers you can use:

- `dd` - The number of the day of the month.
- `mm` - The number of the month of the year.
- `yy` - The number of the year as a two digit number.
- `yyyy` - The number of the year as a four digit number.
- `ddd` - The name of the day (abbreviated).
- `mmm` - The name of the month (abbreviated).

All other characters are copied 1:1 to the output string.

Table 34.3 indicates a few possible formats. This will give you an idea of how to use this function. All output lines are based on the same date: November 23, 1959.

**Table 34.3. Valid Input Formats for `PGTYPESdate_fmt_asc`**

Format	Result
<code>mmdyy</code>	112359
<code>ddmmyy</code>	231159
<code>yyymmdd</code>	591123
<code>yy/mm/dd</code>	59/11/23
<code>yy mm dd</code>	59 11 23
<code>yy.mm.dd</code>	59.11.23
<code>.mm.yyyy.dd.</code>	.11.1959.23.
<code>mmm. dd, yyyy</code>	Nov. 23, 1959
<code>mmm dd yyyy</code>	Nov 23 1959
<code>yyyy dd mm</code>	1959 23 11
<code>ddd, mmm. dd, yyyy</code>	Mon, Nov. 23, 1959

Format	Result
(ddd) mmm. dd, yyyy	(Mon) Nov. 23, 1959

`PGTYPESdate_defmt_asc`

Use a format mask to convert a C `char*` string to a value of type `date`.

```
int PGTYPESdate_defmt_asc(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (`d`), the format mask to use for parsing the date (`fmt`) and the C `char*` string containing the textual representation of the date (`str`). The textual representation is expected to match the format mask. However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals `yy` or `yyyy` that indicate the position of the year, `mm` to indicate the position of the month and `dd` to indicate the position of the day.

Table 34.4 indicates a few possible formats. This will give you an idea of how to use this function.

**Table 34.4. Valid Input Formats for `rdefmtdate`**

Format	String	Result
<code>ddmmyy</code>	21-2-54	1954-02-21
<code>ddmmyy</code>	2-12-54	1954-12-02
<code>ddmmyy</code>	20111954	1954-11-20
<code>ddmmyy</code>	130464	1964-04-13
<code>mmm.dd.yyyy</code>	MAR-12-1967	1967-03-12
<code>yy/mm/dd</code>	1954, February 3rd	1954-02-03
<code>mmm.dd.yyyy</code>	041269	1969-04-12
<code>yy/mm/dd</code>	In the year 2525, in the month of July, mankind will be alive on the 28th day	2525-07-28
<code>dd-mm-yy</code>	I said on the 28th of July in the year 2525	2525-07-28
<code>mmm.dd.yyyy</code>	9/14/58	1958-09-14
<code>yy/mm/dd</code>	47/03/29	1947-03-29
<code>mmm.dd.yyyy</code>	oct 28 1975	1975-10-28
<code>mmddy</code>	Nov 14th, 1985	1985-11-14

## 34.6.4. The timestamp Type

The timestamp type in C enables your programs to deal with data of the SQL type timestamp. See Section 8.5 for the equivalent type in the LightDB server.

The following functions can be used to work with the timestamp type:

`PGTYPEStimestamp_from_asc`

Parse a timestamp from its textual representation into a timestamp variable.

```
timestamp PGTYPEStimestamp_from_asc(char *str, char **endptr);
```

The function receives the string to parse (*str*) and a pointer to a C `char*` (*endptr*). At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in *\*endptr*. You can safely set *endptr* to `NULL`.

The function returns the parsed timestamp on success. On error, `PGTYPEStimestamp_invalid` is returned and `errno` is set to `PGTYPEStimestamp_TS_BAD_TIMESTAMP`. See `PGTYPEStimestamp_invalid` for important notes on this value.

In general, the input string can contain any combination of an allowed date specification, a whitespace character and an allowed time specification. Note that time zones are not supported by ECPG. It can parse them but does not apply any calculation as the LightDB server does for example. Timezone specifiers are silently discarded.

Table 34.5 contains a few examples for input strings.

**Table 34.5. Valid Input Formats for `PGTYPEStimestamp_from_asc`**

Input	Result
1999-01-08 04:05:06	1999-01-08 04:05:06
January 8 04:05:06 1999 PST	1999-01-08 04:05:06
1999-Jan-08 04:05:06.789-8	1999-01-08 04:05:06.789 (time zone specifier ignored)
J2451187 04:05-08:00	1999-01-08 04:05:00 (time zone specifier ignored)

```
PGTYPEStimestamp_to_asc
```

Converts a date to a C `char*` string.

```
char *PGTYPEStimestamp_to_asc(timestamp tstamp);
```

The function receives the timestamp *tstamp* as its only argument and returns an allocated string that contains the textual representation of the timestamp. The result must be freed with `PGTYPEStimestamp_free()`.

```
PGTYPEStimestamp_current
```

Retrieve the current timestamp.

```
void PGTYPEStimestamp_current(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that *ts* points to.

```
PGTYPEStimestamp_fmt_asc
```

Convert a timestamp variable to a C `char*` using a format mask.

```
int PGTYPEStimestamp_fmt_asc(timestamp *ts, char *output, int
    str_len, char *fmtstr);
```

The function receives a pointer to the timestamp to convert as its first argument (*ts*), a pointer to the output buffer (*output*), the maximal length that has been allocated for the output buffer (*str\_len*) and the format mask to use for the conversion (*fmtstr*).



Upon success, the function returns 0 and a negative value if an error occurred.

You can use the following format specifiers for the format mask. The format specifiers are the same ones that are used in the `strftime` function in `libc`. Any non-format specifier will be copied into the output buffer.

- `%A` - is replaced by national representation of the full weekday name.
- `%a` - is replaced by national representation of the abbreviated weekday name.
- `%B` - is replaced by national representation of the full month name.
- `%b` - is replaced by national representation of the abbreviated month name.
- `%C` - is replaced by (year / 100) as decimal number; single digits are preceded by a zero.
- `%c` - is replaced by national representation of time and date.
- `%D` - is equivalent to `%m/%d/%y`.
- `%d` - is replaced by the day of the month as a decimal number (01–31).
- `%E*` `%O*` - POSIX locale extensions. The sequences `%Ec %EC %Ex %EX %Ey %EY %Od %Oe %OH %OI %Om %OM %OS %Ou %OU %OV %Ow %OW %Oy` are supposed to provide alternative representations.

Additionally `%OB` implemented to represent alternative months names (used standalone, without day mentioned).

- `%e` - is replaced by the day of month as a decimal number (1–31); single digits are preceded by a blank.
- `%F` - is equivalent to `%Y-%m-%d`.
- `%G` - is replaced by a year as a decimal number with century. This year is the one that contains the greater part of the week (Monday as the first day of the week).
- `%g` - is replaced by the same year as in `%G`, but as a decimal number without century (00–99).
- `%H` - is replaced by the hour (24-hour clock) as a decimal number (00–23).
- `%h` - the same as `%b`.
- `%I` - is replaced by the hour (12-hour clock) as a decimal number (01–12).
- `%j` - is replaced by the day of the year as a decimal number (001–366).
- `%k` - is replaced by the hour (24-hour clock) as a decimal number (0–23); single digits are preceded by a blank.
- `%l` - is replaced by the hour (12-hour clock) as a decimal number (1–12); single digits are preceded by a blank.
- `%M` - is replaced by the minute as a decimal number (00–59).
- `%m` - is replaced by the month as a decimal number (01–12).
- `%n` - is replaced by a newline.
- `%O*` - the same as `%E*`.
- `%p` - is replaced by national representation of either “ante meridiem” or “post meridiem” as appropriate.

- %R - is equivalent to %H:%M.
- %r - is equivalent to %I:%M:%S %p.
- %S - is replaced by the second as a decimal number (00–60).
- %s - is replaced by the number of seconds since the Epoch, UTC.
- %T - is equivalent to %H:%M:%S
- %t - is replaced by a tab.
- %U - is replaced by the week number of the year (Sunday as the first day of the week) as a decimal number (00–53).
- %u - is replaced by the weekday (Monday as the first day of the week) as a decimal number (1–7).
- %V - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (01–53). If the week containing January 1 has four or more days in the new year, then it is week 1; otherwise it is the last week of the previous year, and the next week is week 1.
- %v - is equivalent to %e-%b-%Y.
- %W - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (00–53).
- %w - is replaced by the weekday (Sunday as the first day of the week) as a decimal number (0–6).
- %X - is replaced by national representation of the time.
- %x - is replaced by national representation of the date.
- %Y - is replaced by the year with century as a decimal number.
- %y - is replaced by the year without century as a decimal number (00–99).
- %Z - is replaced by the time zone name.
- %z - is replaced by the time zone offset from UTC; a leading plus sign stands for east of UTC, a minus sign for west of UTC, hours and minutes follow with two digits each and no delimiter between them (common form for RFC 822 date headers).
- %+ - is replaced by national representation of the date and time.
- %-\* - GNU libc extension. Do not do any padding when performing numerical outputs.
- \$\_\* - GNU libc extension. Explicitly specify space for padding.
- %0\* - GNU libc extension. Explicitly specify zero for padding.
- %% - is replaced by %.

#### PGTYPEStimestamp\_sub

Subtract one timestamp from another one and save the result in a variable of type interval.

```
int PGTYPEStimestamp_sub(timestamp *ts1, timestamp *ts2,
                          interval *iv);
```

The function will subtract the timestamp variable that `ts2` points to from the timestamp variable that `ts1` points to and will store the result in the interval variable that `iv` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

#### PGTYPEStimestamp\_defmt\_asc

Parse a timestamp value from its textual representation using a formatting mask.

```
int PGTYPEStimestamp_defmt_asc(char *str, char *fmt, timestamp
*d);
```

The function receives the textual representation of a timestamp in the variable `str` as well as the formatting mask to use in the variable `fmt`. The result will be stored in the variable that `d` points to.

If the formatting mask `fmt` is NULL, the function will fall back to the default formatting mask which is `%Y-%m-%d %H:%M:%S`.

This is the reverse function to `PGTYPEStimestamp_fmt_asc`. See the documentation there in order to find out about the possible formatting mask entries.

#### PGTYPEStimestamp\_add\_interval

Add an interval variable to a timestamp variable.

```
int PGTYPEStimestamp_add_interval(timestamp *tin, interval
*span, timestamp *tout);
```

The function receives a pointer to a timestamp variable `tin` and a pointer to an interval variable `span`. It adds the interval to the timestamp and saves the resulting timestamp in the variable that `tout` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

#### PGTYPEStimestamp\_sub\_interval

Subtract an interval variable from a timestamp variable.

```
int PGTYPEStimestamp_sub_interval(timestamp *tin, interval
*span, timestamp *tout);
```

The function subtracts the interval variable that `span` points to from the timestamp variable that `tin` points to and saves the result into the variable that `tout` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

## 34.6.5. The interval Type

The interval type in C enables your programs to deal with data of the SQL type interval. See Section 8.5 for the equivalent type in the LightDB server.

The following functions can be used to work with the interval type:

#### PGTYPEStinterval\_new

Return a pointer to a newly allocated interval variable.

```
interval *PGTYPESinterval_new(void);
```

PGTYPESinterval\_free

Release the memory of a previously allocated interval variable.

```
void PGTYPESinterval_free(interval *intvl);
```

PGTYPESinterval\_from\_asc

Parse an interval from its textual representation.

```
interval *PGTYPESinterval_from_asc(char *str, char **endptr);
```

The function parses the input string `str` and returns a pointer to an allocated interval variable. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to `NULL`.

PGTYPESinterval\_to\_asc

Convert a variable of type interval to its textual representation.

```
char *PGTYPESinterval_to_asc(interval *span);
```

The function converts the interval variable that `span` points to into a C `char*`. The output looks like this example: `@ 1 day 12 hours 59 mins 10 secs`. The result must be freed with `PGTYPESchar_free()`.

PGTYPESinterval\_copy

Copy a variable of type interval.

```
int PGTYPESinterval_copy(interval *intvlsrc, interval *intvldest);
```

The function copies the interval variable that `intvlsrc` points to into the variable that `intvldest` points to. Note that you need to allocate the memory for the destination variable before.

## 34.6.6. The decimal Type

The decimal type is similar to the numeric type. However it is limited to a maximum precision of 30 significant digits. In contrast to the numeric type which can be created on the heap only, the decimal type can be created either on the stack or on the heap (by means of the functions `PGTYPESdecimal_new` and `PGTYPESdecimal_free`). There are a lot of other functions that deal with the decimal type in the Informix compatibility mode described in Section 34.15.

The following functions can be used to work with the decimal type and are not only contained in the `libcompat` library.

PGTYPESdecimal\_new

Request a pointer to a newly allocated decimal variable.

```
decimal *PGTYPESdecimal_new(void);
```

PGTYPESdecimal\_free

Free a decimal type, release all of its memory.

```
void PGTYPESdecimal_free(decimal *var);
```

## 34.6.7. errno Values of pgtypeslib

PGTYPES\_NUM\_BAD\_NUMERIC

An argument should contain a numeric variable (or point to a numeric variable) but in fact its in-memory representation was invalid.

PGTYPES\_NUM\_OVERFLOW

An overflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause overflow.

PGTYPES\_NUM\_UNDERFLOW

An underflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause underflow.

PGTYPES\_NUM\_DIVIDE\_ZERO

A division by zero has been attempted.

PGTYPES\_DATE\_BAD\_DATE

An invalid date string was passed to the PGTYPESdate\_from\_asc function.

PGTYPES\_DATE\_ERR\_EARGS

Invalid arguments were passed to the PGTYPESdate\_defmt\_asc function.

PGTYPES\_DATE\_ERR\_ENOSHORTDATE

An invalid token in the input string was found by the PGTYPESdate\_defmt\_asc function.

PGTYPES\_INTVL\_BAD\_INTERVAL

An invalid interval string was passed to the PGTYPESinterval\_from\_asc function, or an invalid interval value was passed to the PGTYPESinterval\_to\_asc function.

PGTYPES\_DATE\_ERR\_ENOTDMY

There was a mismatch in the day/month/year assignment in the PGTYPESdate\_defmt\_asc function.

PGTYPES\_DATE\_BAD\_DAY

An invalid day of the month value was found by the PGTYPESdate\_defmt\_asc function.

PGTYPES\_DATE\_BAD\_MONTH

An invalid month value was found by the PGTYPESdate\_defmt\_asc function.

PGTYPES\_TS\_BAD\_TIMESTAMP

An invalid timestamp string pass passed to the PGTYPEStimestamp\_from\_asc function, or an invalid timestamp value was passed to the PGTYPEStimestamp\_to\_asc function.

PGTYPES\_TS\_ERR\_EINFTIME

An infinite timestamp value was encountered in a context that cannot handle it.

## 34.6.8. Special Constants of pgtypeslib

PGTYPESInvalidTimestamp

A value of type timestamp representing an invalid time stamp. This is returned by the function `PGTYPEStimestamp_from_asc` on parse error. Note that due to the internal representation of the `timestamp` data type, `PGTYPESInvalidTimestamp` is also a valid timestamp at the same time. It is set to `1899-12-31 23:59:59`. In order to detect errors, make sure that your application does not only test for `PGTYPESInvalidTimestamp` but also for `errno != 0` after each call to `PGTYPEStimestamp_from_asc`.

## 34.7. Using Descriptor Areas

An SQL descriptor area is a more sophisticated method for processing the result of a `SELECT`, `FETCH` or a `DESCRIBE` statement. An SQL descriptor area groups the data of one row of data together with metadata items into one data structure. The metadata is particularly useful when executing dynamic SQL statements, where the nature of the result columns might not be known ahead of time. LightDB provides two ways to use Descriptor Areas: the named SQL Descriptor Areas and the C-structure SQLDAs.

### 34.7.1. Named SQL Descriptor Areas

A named SQL descriptor area consists of a header, which contains information concerning the entire descriptor, and one or more item descriptor areas, which basically each describe one column in the result row.

Before you can use an SQL descriptor area, you need to allocate one:

```
EXEC SQL ALLOCATE DESCRIPTOR identifier;
```

The identifier serves as the “variable name” of the descriptor area. When you don't need the descriptor anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE DESCRIPTOR identifier;
```

To use a descriptor area, specify it as the storage target in an `INTO` clause, instead of listing host variables:

```
EXEC SQL FETCH NEXT FROM mycursor INTO SQL DESCRIPTOR mydesc;
```

If the result set is empty, the Descriptor Area will still contain the metadata from the query, i.e., the field names.

For not yet executed prepared queries, the `DESCRIBE` statement can be used to get the metadata of the result set:

```
EXEC SQL BEGIN DECLARE SECTION;  
char *sql_stmt = "SELECT * FROM table1";  
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL PREPARE stmt1 FROM :sql_stmt;
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;
```

Before LightDB 9.0, the `SQL` keyword was optional, so using `DESCRIPTOR` and `SQL DESCRIPTOR` produced named SQL Descriptor Areas. Now it is mandatory, omitting the `SQL` keyword produces SQLDA Descriptor Areas, see Section 34.7.2.

In `DESCRIBE` and `FETCH` statements, the `INTO` and `USING` keywords can be used to similarly: they produce the result set and the metadata in a Descriptor Area.

Now how do you get the data out of the descriptor area? You can think of the descriptor area as a structure with named fields. To retrieve the value of a field from the header and store it into a host variable, use the following command:

```
EXEC SQL GET DESCRIPTOR name :hostvar = field;
```

Currently, there is only one header field defined: `COUNT`, which tells how many item descriptor areas exist (that is, how many columns are contained in the result). The host variable needs to be of an integer type. To get a field from the item descriptor area, use the following command:

```
EXEC SQL GET DESCRIPTOR name VALUE num :hostvar = field;
```

`num` can be a literal integer or a host variable containing an integer. Possible fields are:

`CARDINALITY` (integer)

number of rows in the result set

`DATA`

actual data item (therefore, the data type of this field depends on the query)

`DATETIME_INTERVAL_CODE` (integer)

When `TYPE` is 9, `DATETIME_INTERVAL_CODE` will have a value of 1 for `DATE`, 2 for `TIME`, 3 for `TIMESTAMP`, 4 for `TIME WITH TIME ZONE`, or 5 for `TIMESTAMP WITH TIME ZONE`.

`DATETIME_INTERVAL_PRECISION` (integer)

not implemented

`INDICATOR` (integer)

the indicator (indicating a null value or a value truncation)

`KEY_MEMBER` (integer)

not implemented

`LENGTH` (integer)

length of the datum in characters

`NAME` (string)

name of the column

`NULLABLE` (integer)

not implemented

OCTET\_LENGTH (integer)

length of the character representation of the datum in bytes

PRECISION (integer)

precision (for type numeric)

RETURNED\_LENGTH (integer)

length of the datum in characters

RETURNED\_OCTET\_LENGTH (integer)

length of the character representation of the datum in bytes

SCALE (integer)

scale (for type numeric)

TYPE (integer)

numeric code of the data type of the column

In EXECUTE, DECLARE and OPEN statements, the effect of the INTO and USING keywords are different. A Descriptor Area can also be manually built to provide the input parameters for a query or a cursor and USING SQL DESCRIPTOR *name* is the way to pass the input parameters into a parameterized query. The statement to build a named SQL Descriptor Area is below:

```
EXEC SQL SET DESCRIPTOR name VALUE num field = :hostvar;
```

LightDB supports retrieving more than one record in one FETCH statement and storing the data in host variables in this case assumes that the variable is an array. E.g.:

```
EXEC SQL BEGIN DECLARE SECTION;
int id[5];
EXEC SQL END DECLARE SECTION;

EXEC SQL FETCH 5 FROM mycursor INTO SQL DESCRIPTOR mydesc;

EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :id = DATA;
```

## 34.7.2. SQLDA Descriptor Areas

An SQLDA Descriptor Area is a C language structure which can be also used to get the result set and the metadata of a query. One structure stores one record from the result set.

```
EXEC SQL include sqllda.h;
sqllda_t      *mysqlda;

EXEC SQL FETCH 3 FROM mycursor INTO DESCRIPTOR mysqlda;
```

Note that the SQL keyword is omitted. The paragraphs about the use cases of the INTO and USING keywords in Section 34.7.1 also apply here with an addition. In a DESCRIBE statement the DESCRIPTOR keyword can be completely omitted if the INTO keyword is used:

```
EXEC SQL DESCRIBE prepared_statement INTO mysqlda;
```



The general flow of a program that uses SQLDA is:

1. Prepare a query, and declare a cursor for it.
2. Declare an SQLDA for the result rows.
3. Declare an SQLDA for the input parameters, and initialize them (memory allocation, parameter settings).
4. Open a cursor with the input SQLDA.
5. Fetch rows from the cursor, and store them into an output SQLDA.
6. Read values from the output SQLDA into the host variables (with conversion if necessary).
7. Close the cursor.
8. Free the memory area allocated for the input SQLDA.

### 34.7.2.1. SQLDA Data Structure

SQLDA uses three data structure types: `sqllda_t`, `sqlvar_t`, and `struct sqlname`.

#### Tip

LightDB's SQLDA has a similar data structure to the one in IBM DB2 Universal Database, so some technical information on DB2's SQLDA could help understanding LightDB's one better.

#### 34.7.2.1.1. `sqllda_t` Structure

The structure type `sqllda_t` is the type of the actual SQLDA. It holds one record. And two or more `sqllda_t` structures can be connected in a linked list with the pointer in the `desc_next` field, thus representing an ordered collection of rows. So, when two or more rows are fetched, the application can read them by following the `desc_next` pointer in each `sqllda_t` node.

The definition of `sqllda_t` is:

```
struct sqllda_struct
{
    char          sqldaid[8];
    long         sqldabc;
    short        sqln;
    short        sqld;
    struct sqllda_struct *desc_next;
    struct sqlvar_struct sqlvar[1];
};

typedef struct sqllda_struct sqllda_t;
```

The meaning of the fields is:

`sqldaid`

It contains the literal string "SQLDA ".

`sqldabc`

It contains the size of the allocated space in bytes.

`sqln`

It contains the number of input parameters for a parameterized query in case it's passed into `OPEN`, `DECLARE` or `EXECUTE` statements using the `USING` keyword. In case it's used as output of `SELECT`, `EXECUTE` or `FETCH` statements, its value is the same as `sqld` statement

`sqld`

It contains the number of fields in a result set.

`desc_next`

If the query returns more than one record, multiple linked `SQLDA` structures are returned, and `desc_next` holds a pointer to the next entry in the list.

`sqlvar`

This is the array of the columns in the result set.

### 34.7.2.1.2. `sqlvar_t` Structure

The structure type `sqlvar_t` holds a column value and metadata such as type and length. The definition of the type is:

```
struct sqlvar_struct
{
    short          sqltype;
    short          sqllen;
    char           *sqldata;
    short          *sqlind;
    struct sqlname sqlname;
};

typedef struct sqlvar_struct sqlvar_t;
```

The meaning of the fields is:

`sqltype`

Contains the type identifier of the field. For values, see enum `ECPGttype` in `ecpgtype.h`.

`sqllen`

Contains the binary length of the field. e.g., 4 bytes for `ECPGt_int`.

`sqldata`

Points to the data. The format of the data is described in Section 34.4.4.

`sqlind`

Points to the null indicator. 0 means not null, -1 means null.

`sqlname`

The name of the field.

### 34.7.2.1.3. `struct sqlname` Structure

A `struct sqlname` structure holds a column name. It is used as a member of the `sqlvar_t` structure. The definition of the structure is:

```
#define NAMEDATALEN 64

struct sqlname
{
    short      length;
    char      data[NAMEDATALEN];
};
```

The meaning of the fields is:

`length`

Contains the length of the field name.

`data`

Contains the actual field name.

### 34.7.2.2. Retrieving a Result Set Using an SQLDA

The general steps to retrieve a query result set through an SQLDA are:

1. Declare an `sqlda_t` structure to receive the result set.
2. Execute `FETCH/EXECUTE/DESCRIBE` commands to process a query specifying the declared SQLDA.
3. Check the number of records in the result set by looking at `sqln`, a member of the `sqlda_t` structure.
4. Get the values of each column from `sqlvar[0]`, `sqlvar[1]`, etc., members of the `sqlda_t` structure.
5. Go to next row (`sqlda_t` structure) by following the `desc_next` pointer, a member of the `sqlda_t` structure.
6. Repeat above as you need.

Here is an example retrieving a result set through an SQLDA.

First, declare a `sqlda_t` structure to receive the result set.

```
sqlda_t *sqlda1;
```

Next, specify the SQLDA in a command. This is a `FETCH` command example.

```
EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;
```

Run a loop following the linked list to retrieve the rows.

```
sqlda_t *cur_sqlda;

for (cur_sqlda = sqlda1;
     cur_sqlda != NULL;
     cur_sqlda = cur_sqlda->desc_next)
{
    ...
}
```

```
}

```

Inside the loop, run another loop to retrieve each column data (`sqlvar_t` structure) of the row.

```
for (i = 0; i < cur_sqlda->sqlld; i++)
{
    sqlvar_t v = cur_sqlda->sqlvar[i];
    char *sqldata = v.sqldata;
    short sqlllen = v.sqlllen;
    ...
}
```

To get a column value, check the `sqltype` value, a member of the `sqlvar_t` structure. Then, switch to an appropriate way, depending on the column type, to copy data from the `sqlvar` field to a host variable.

```
char var_buf[1024];

switch (v.sqltype)
{
    case ECPGt_char:
        memset(&var_buf, 0, sizeof(var_buf));
        memcpy(&var_buf, sqldata, (sizeof(var_buf) <= sqlllen ?
sizeof(var_buf) - 1 : sqlllen));
        break;

    case ECPGt_int: /* integer */
        memcpy(&intval, sqldata, sqlllen);
        snprintf(var_buf, sizeof(var_buf), "%d", intval);
        break;

    ...
}
```

### 34.7.2.3. Passing Query Parameters Using an SQLDA

The general steps to use an SQLDA to pass input parameters to a prepared query are:

1. Create a prepared query (prepared statement)
2. Declare a `sqlda_t` structure as an input SQLDA.
3. Allocate memory area (as `sqlda_t` structure) for the input SQLDA.
4. Set (copy) input values in the allocated memory.
5. Open a cursor with specifying the input SQLDA.

Here is an example.

First, create a prepared statement.

```
EXEC SQL BEGIN DECLARE SECTION;
char query[1024] = "SELECT d.oid, * FROM pg_database d,
pg_stat_database s WHERE d.oid = s.datid AND (d.datname = ? OR
d.oid = ?)";
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL PREPARE stmt1 FROM :query;
```

Next, allocate memory for an SQLDA, and set the number of input parameters in `sqln`, a member variable of the `sqlda_t` structure. When two or more input parameters are required for the prepared query, the application has to allocate additional memory space which is calculated by  $(nr. \text{ of params} - 1) * \text{sizeof}(\text{sqlvar\_t})$ . The example shown here allocates memory space for two input parameters.

```
sqlda_t *sqlda2;
```

```
sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
```

```
sqlda2->sqln = 2; /* number of input variables */
```

After memory allocation, store the parameter values into the `sqlvar[]` array. (This is same array used for retrieving column values when the SQLDA is receiving a result set.) In this example, the input parameters are "postgres", having a string type, and 1, having an integer type.

```
sqlda2->sqlvar[0].sqltype = ECPGt_char;
sqlda2->sqlvar[0].sqldata = "postgres";
sqlda2->sqlvar[0].sqlllen = 8;
```

```
int intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *) &intval;
sqlda2->sqlvar[1].sqlllen = sizeof(intval);
```

By opening a cursor and specifying the SQLDA that was set up beforehand, the input parameters are passed to the prepared statement.

```
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;
```

Finally, after using input SQLDAs, the allocated memory space must be freed explicitly, unlike SQLDAs used for receiving query results.

```
free(sqlda2);
```

### 34.7.2.4. A Sample Application Using SQLDA

Here is an example program, which describes how to fetch access statistics of the databases, specified by the input parameters, from the system catalogs.

This application joins two system tables, `pg_database` and `pg_stat_database` on the database OID, and also fetches and shows the database statistics which are retrieved by two input parameters (a database `postgres`, and OID 1).

First, declare an SQLDA for input and an SQLDA for output.

```
EXEC SQL include sqlda.h;
```

```
sqlda_t *sqlda1; /* an output descriptor */
sqlda_t *sqlda2; /* an input descriptor */
```

Next, connect to the database, prepare a statement, and declare a cursor for the prepared statement.

```

int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d,
pg_stat_database s WHERE d.oid=s.datid AND ( d.datname=? OR
d.oid=? )";
    EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    EXEC SQL PREPARE stmt1 FROM :query;
    EXEC SQL DECLARE cur1 CURSOR FOR stmt1;

```

Next, put some values in the input SQLDA for the input parameters. Allocate memory for the input SQLDA, and set the number of input parameters to `sqln`. Store type, value, and value length into `sqltype`, `sqldata`, and `sqlllen` in the `sqlvar` structure.

```

/* Create SQLDA structure for input parameters. */
sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) +
sizeof(sqlvar_t));
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
sqlda2->sqln = 2; /* number of input variables */

sqlda2->sqlvar[0].sqltype = ECPGt_char;
sqlda2->sqlvar[0].sqldata = "postgres";
sqlda2->sqlvar[0].sqlllen = 8;

intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *)&intval;
sqlda2->sqlvar[1].sqlllen = sizeof(intval);

```

After setting up the input SQLDA, open a cursor with the input SQLDA.

```

/* Open a cursor with input parameters. */
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;

```

Fetch rows into the output SQLDA from the opened cursor. (Generally, you have to call `FETCH` repeatedly in the loop, to fetch all rows in the result set.)

```

while (1)
{
    sqlda_t *cur_sqlda;

    /* Assign descriptor to the cursor */
    EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;

```

Next, retrieve the fetched records from the SQLDA, by following the linked list of the `sqlda_t` structure.

```

for (cur_sqlda = sqlda1 ;

```

```

    cur_sqlda != NULL ;
    cur_sqlda = cur_sqlda->desc_next)
{
    ...

```

Read each columns in the first record. The number of columns is stored in `sqld`, the actual data of the first column is stored in `sqlvar[0]`, both members of the `sqlda_t` structure.

```

/* Print every column in a row. */
for (i = 0; i < sqlda1->sqld; i++)
{
    sqlvar_t v = sqlda1->sqlvar[i];
    char *sqldata = v.sqldata;
    short sqllen = v.sqlllen;

    strncpy(name_buf, v.sqlname.data, v.sqlname.length);
    name_buf[v.sqlname.length] = '\0';

```

Now, the column data is stored in the variable `v`. Copy every datum into host variables, looking at `v.sqltype` for the type of the column.

```

    switch (v.sqltype) {
        int intval;
        double doubleval;
        unsigned long long int longlongval;

        case ECPGt_char:
            memset(&var_buf, 0, sizeof(var_buf));
            memcpy(&var_buf, sqldata, (sizeof(var_buf) <=
sqlllen ? sizeof(var_buf)-1 : sqllen));
            break;

        case ECPGt_int: /* integer */
            memcpy(&intval, sqldata, sqllen);
            snprintf(var_buf, sizeof(var_buf), "%d",
intval);
            break;

        ...

        default:
            ...
    }

    printf("%s = %s (type: %d)\n", name_buf, var_buf,
v.sqltype);
}

```

Close the cursor after processing all of records, and disconnect from the database.

```

EXEC SQL CLOSE cur1;
EXEC SQL COMMIT;

EXEC SQL DISCONNECT ALL;

```

The whole program is shown in Example 34.1.

**Example 34.1. Example SQLDA Program**

```

#include <stdlib.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>
#include <unistd.h>

EXEC SQL include sqlda.h;

sqlda_t *sqlda1; /* descriptor for output */
sqlda_t *sqlda2; /* descriptor for input */

EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d,
pg_stat_database s WHERE d.oid=s.datid AND ( d.datname=? OR
d.oid=? )";

    int intval;
    unsigned long long int longlongval;
    EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO uptimedb AS con1 USER uptime;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    EXEC SQL PREPARE stmt1 FROM :query;
    EXEC SQL DECLARE cur1 CURSOR FOR stmt1;

    /* Create a SQLDA structure for an input parameter */
    sqlda2 = (sqlda_t *)malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
    memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
    sqlda2->sqln = 2; /* a number of input variables */

    sqlda2->sqlvar[0].sqltype = ECPGt_char;
    sqlda2->sqlvar[0].sqldata = "postgres";
    sqlda2->sqlvar[0].sqlllen = 8;

    intval = 1;
    sqlda2->sqlvar[1].sqltype = ECPGt_int;
    sqlda2->sqlvar[1].sqldata = (char *) &intval;
    sqlda2->sqlvar[1].sqlllen = sizeof(intval);

    /* Open a cursor with input parameters. */
    EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;

    while (1)
    {
        sqlda_t *cur_sqlda;

        /* Assign descriptor to the cursor */

```



```

EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;

for (cur_sqlda = sqlda1 ;
     cur_sqlda != NULL ;
     cur_sqlda = cur_sqlda->desc_next)
{
    int i;
    char name_buf[1024];
    char var_buf[1024];

    /* Print every column in a row. */
    for (i=0 ; i<cur_sqlda->sqld ; i++)
    {
        sqlvar_t v = cur_sqlda->sqlvar[i];
        char *sqldata = v.sqldata;
        short sqllen = v.sqllen;

        strncpy(name_buf, v.sqlname.data,
v.sqlname.length);
        name_buf[v.sqlname.length] = '\0';

        switch (v.sqltype)
        {
            case ECPGt_char:
                memset(&var_buf, 0, sizeof(var_buf));
                memcpy(&var_buf, sqldata,
(sizeof(var_buf)<=sqllen ? sizeof(var_buf)-1 : sqllen) );
                break;

            case ECPGt_int: /* integer */
                memcpy(&intval, sqldata, sqllen);
                sprintf(var_buf, sizeof(var_buf), "%d",
intval);
                break;

            case ECPGt_long_long: /* bigint */
                memcpy(&longlongval, sqldata, sqllen);
                sprintf(var_buf, sizeof(var_buf), "%lld",
longlongval);
                break;

            default:
                {
                    int i;
                    memset(var_buf, 0, sizeof(var_buf));
                    for (i = 0; i < sqllen; i++)
                    {
                        char tmpbuf[16];
                        sprintf(tmpbuf, sizeof(tmpbuf), "%02x",
(unsigned char) sqldata[i]);
                        strcat(var_buf, tmpbuf,
sizeof(var_buf));
                    }
                }
                break;
        }
    }
}

```

```

        printf("%s = %s (type: %d)\n", name_buf, var_buf,
v.sqltype);
    }

    printf("\n");
}

EXEC SQL CLOSE curl;
EXEC SQL COMMIT;

EXEC SQL DISCONNECT ALL;

return 0;
}

```

The output of this example should look something like the following (some numbers will vary).

```

oid = 1 (type: 1)
datname = templatel (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = t (type: 1)
datallowconn = t (type: 1)
datconlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig = (type: 1)
datacl = {=c/uptime,uptime=CTc/uptime} (type: 1)
datid = 1 (type: 1)
datname = templatel (type: 1)
numbackends = 0 (type: 5)
xact_commit = 113606 (type: 9)
xact_rollback = 0 (type: 9)
blks_read = 130 (type: 9)
blks_hit = 7341714 (type: 9)
tup_returned = 38262679 (type: 9)
tup_fetched = 1836281 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)

oid = 11511 (type: 1)
datname = postgres (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = f (type: 1)
datallowconn = t (type: 1)
datconlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig = (type: 1)
datacl = (type: 1)
datid = 11511 (type: 1)
datname = postgres (type: 1)

```

```
numbackends = 0 (type: 5)
xact_commit = 221069 (type: 9)
xact_rollback = 18 (type: 9)
blks_read = 1176 (type: 9)
blks_hit = 13943750 (type: 9)
tup_returned = 77410091 (type: 9)
tup_fetched = 3253694 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)
```

## 34.8. Error Handling

This section describes how you can handle exceptional conditions and warnings in an embedded SQL program. There are two nonexclusive facilities for this.

- Callbacks can be configured to handle warning and error conditions using the `WHENEVER` command.
- Detailed information about the error or warning can be obtained from the `sqlca` variable.

### 34.8.1. Setting Callbacks

One simple method to catch errors and warnings is to set a specific action to be executed whenever a particular condition occurs. In general:

```
EXEC SQL WHENEVER condition action;
```

*condition* can be one of the following:

SQLERROR

The specified action is called whenever an error occurs during the execution of an SQL statement.

SQLWARNING

The specified action is called whenever a warning occurs during the execution of an SQL statement.

NOT FOUND

The specified action is called whenever an SQL statement retrieves or affects zero rows. (This condition is not an error, but you might be interested in handling it specially.)

*action* can be one of the following:

CONTINUE

This effectively means that the condition is ignored. This is the default.

GOTO *label*

GO TO *label*

Jump to the specified label (using a C `goto` statement).

SQLPRINT

Print a message to standard error. This is useful for simple programs or during prototyping. The details of the message cannot be configured.

STOP

Call `exit(1)`, which will terminate the program.

DO BREAK

Execute the C statement `break`. This should only be used in loops or `switch` statements.

DO CONTINUE

Execute the C statement `continue`. This should only be used in loops statements. If executed, will cause the flow of control to return to the top of the loop.

CALL *name* (*args*)

DO *name* (*args*)

Call the specified C functions with the specified arguments. (This use is different from the meaning of `CALL` and `DO` in the normal LightDB grammar.)

The SQL standard only provides for the actions `CONTINUE` and `GOTO` (and `GO TO`).

Here is an example that you might want to use in a simple program. It prints a simple message when a warning occurs and aborts the program when an error happens:

```
EXEC SQL WHENEVER SQLWARNING SQLPRINT;  
EXEC SQL WHENEVER SQLERROR STOP;
```

The statement `EXEC SQL WHENEVER` is a directive of the SQL preprocessor, not a C statement. The error or warning actions that it sets apply to all embedded SQL statements that appear below the point where the handler is set, unless a different action was set for the same condition between the first `EXEC SQL WHENEVER` and the SQL statement causing the condition, regardless of the flow of control in the C program. So neither of the two following C program excerpts will have the desired effect:

```
/*  
 * WRONG  
 */  
int main(int argc, char *argv[])  
{  
    ...  
    if (verbose) {  
        EXEC SQL WHENEVER SQLWARNING SQLPRINT;  
    }  
    ...  
    EXEC SQL SELECT ...;  
    ...  
}
```

```
/*  
 * WRONG  
 */  
int main(int argc, char *argv[])  
{  
    ...  
    set_error_handler();  
    ...  
    EXEC SQL SELECT ...;  
}
```

```

    ...
}

static void set_error_handler(void)
{
    EXEC SQL WHENEVER SQLERROR STOP;
}

```

### 34.8.2. sqlca

For more powerful error handling, the embedded SQL interface provides a global variable with the name `sqlca` (SQL communication area) that has the following structure:

```

struct
{
    char sqlcaid[8];
    long sqlabc;
    long sqlcode;
    struct
    {
        int sqlerrml;
        char sqlerrmc[SQLERRMC_LEN];
    } sqlerrm;
    char sqlerrp[8];
    long sqlerrd[6];
    char sqlwarn[8];
    char sqlstate[5];
} sqlca;

```

(In a multithreaded program, every thread automatically gets its own copy of `sqlca`. This works similarly to the handling of the standard C global variable `errno`.)

`sqlca` covers both warnings and errors. If multiple warnings or errors occur during the execution of a statement, then `sqlca` will only contain information about the last one.

If no error occurred in the last SQL statement, `sqlca.sqlcode` will be 0 and `sqlca.sqlstate` will be "00000". If a warning or error occurred, then `sqlca.sqlcode` will be negative and `sqlca.sqlstate` will be different from "00000". A positive `sqlca.sqlcode` indicates a harmless condition, such as that the last query returned zero rows. `sqlcode` and `sqlstate` are two different error code schemes; details appear below.

If the last SQL statement was successful, then `sqlca.sqlerrd[1]` contains the OID of the processed row, if applicable, and `sqlca.sqlerrd[2]` contains the number of processed or returned rows, if applicable to the command.

In case of an error or warning, `sqlca.sqlerrm.sqlerrmc` will contain a string that describes the error. The field `sqlca.sqlerrm.sqlerrml` contains the length of the error message that is stored in `sqlca.sqlerrm.sqlerrmc` (the result of `strlen()`, not really interesting for a C programmer). Note that some messages are too long to fit in the fixed-size `sqlerrmc` array; they will be truncated.

In case of a warning, `sqlca.sqlwarn[2]` is set to W. (In all other cases, it is set to something different from W.) If `sqlca.sqlwarn[1]` is set to W, then a value was truncated when it was stored in a host variable. `sqlca.sqlwarn[0]` is set to W if any of the other elements are set to indicate a warning.

The fields `sqlcaid`, `sqlabc`, `sqlerrp`, and the remaining elements of `sqlerrd` and `sqlwarn` currently contain no useful information.

The structure `sqlca` is not defined in the SQL standard, but is implemented in several other SQL database systems. The definitions are similar at the core, but if you want to write portable applications, then you should investigate the different implementations carefully.

Here is one example that combines the use of `WHENEVER` and `sqlca`, printing out the contents of `sqlca` when an error occurs. This is perhaps useful for debugging or prototyping applications, before installing a more “user-friendly” error handler.

```
EXEC SQL WHENEVER SQLERROR CALL print_sqlca();

void
print_sqlca()
{
    fprintf(stderr, "==== sqlca ====\n");
    fprintf(stderr, "sqlcode: %ld\n", sqlca.sqlcode);
    fprintf(stderr, "sqlerrm.sqlerrml: %d\n",
sqlca.sqlerrm.sqlerrml);
    fprintf(stderr, "sqlerrm.sqlerrmc: %s\n",
sqlca.sqlerrm.sqlerrmc);
    fprintf(stderr, "sqlerrd: %ld %ld %ld %ld %ld %ld\n",
sqlca.sqlerrd[0], sqlca.sqlerrd[1], sqlca.sqlerrd[2],

sqlca.sqlerrd[3], sqlca.sqlerrd[4], sqlca.sqlerrd[5]);
    fprintf(stderr, "sqlwarn: %d %d %d %d %d %d %d %d\n",
sqlca.sqlwarn[0], sqlca.sqlwarn[1], sqlca.sqlwarn[2],

sqlca.sqlwarn[3], sqlca.sqlwarn[4], sqlca.sqlwarn[5],

sqlca.sqlwarn[6], sqlca.sqlwarn[7]);
    fprintf(stderr, "sqlstate: %5s\n", sqlca.sqlstate);
    fprintf(stderr, "=====\n");
}
```

The result could look as follows (here an error due to a misspelled table name):

```
==== sqlca ====
sqlcode: -400
sqlerrm.sqlerrml: 49
sqlerrm.sqlerrmc: relation "pg_databasep" does not exist on line 38
sqlerrd: 0 0 0 0 0 0
sqlwarn: 0 0 0 0 0 0 0 0
sqlstate: 42P01
=====
```

### 34.8.3. SQLSTATE VS. SQLCODE

The fields `sqlca.sqlstate` and `sqlca.sqlcode` are two different schemes that provide error codes. Both are derived from the SQL standard, but `SQLCODE` has been marked deprecated in the SQL-92 edition of the standard and has been dropped in later editions. Therefore, new applications are strongly encouraged to use `SQLSTATE`.

`SQLSTATE` is a five-character array. The five characters contain digits or upper-case letters that represent codes of various error and warning conditions. `SQLSTATE` has a hierarchical scheme: the first two characters indicate the general class of the condition, the last three characters indicate a subclass of the general condition. A successful state is indicated by the code `00000`. The `SQLSTATE` codes are for the most part defined in the SQL standard. The LightDB server natively supports

SQLSTATE error codes; therefore a high degree of consistency can be achieved by using this error code scheme throughout all applications. For further information see Appendix A.

SQLCODE, the deprecated error code scheme, is a simple integer. A value of 0 indicates success, a positive value indicates success with additional information, a negative value indicates an error. The SQL standard only defines the positive value +100, which indicates that the last command returned or affected zero rows, and no specific negative values. Therefore, this scheme can only achieve poor portability and does not have a hierarchical code assignment. Historically, the embedded SQL processor for LightDB has assigned some specific SQLCODE values for its use, which are listed below with their numeric value and their symbolic name. Remember that these are not portable to other SQL implementations. To simplify the porting of applications to the SQLSTATE scheme, the corresponding SQLSTATE is also listed. There is, however, no one-to-one or one-to-many mapping between the two schemes (indeed it is many-to-many), so you should consult the global SQLSTATE listing in Appendix A in each case.

These are the assigned SQLCODE values:

0 (ECPG\_NO\_ERROR)

Indicates no error. (SQLSTATE 00000)

100 (ECPG\_NOT\_FOUND)

This is a harmless condition indicating that the last command retrieved or processed zero rows, or that you are at the end of the cursor. (SQLSTATE 02000)

When processing a cursor in a loop, you could use this code as a way to detect when to abort the loop, like this:

```
while (1)
{
    EXEC SQL FETCH ... ;
    if (sqlca.sqlcode == ECPG_NOT_FOUND)
        break;
}
```

But `WHENEVER NOT FOUND DO BREAK` effectively does this internally, so there is usually no advantage in writing this out explicitly.

-12 (ECPG\_OUT\_OF\_MEMORY)

Indicates that your virtual memory is exhausted. The numeric value is defined as `-ENOMEM`. (SQLSTATE YE001)

-200 (ECPG\_UNSUPPORTED)

Indicates the preprocessor has generated something that the library does not know about. Perhaps you are running incompatible versions of the preprocessor and the library. (SQLSTATE YE002)

-201 (ECPG\_TOO\_MANY\_ARGUMENTS)

This means that the command specified more host variables than the command expected. (SQLSTATE 07001 or 07002)

-202 (ECPG\_TOO\_FEW\_ARGUMENTS)

This means that the command specified fewer host variables than the command expected. (SQLSTATE 07001 or 07002)

-203 (ECPG\_TOO\_MANY\_MATCHES)

This means a query has returned multiple rows but the statement was only prepared to store one result row (for example, because the specified variables are not arrays). (SQLSTATE 21000)

-204 (ECPG\_INT\_FORMAT)

The host variable is of type `int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `int`. The library uses `strtol()` for this conversion. (SQLSTATE 42804)

-205 (ECPG\_UINT\_FORMAT)

The host variable is of type `unsigned int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `unsigned int`. The library uses `strtoul()` for this conversion. (SQLSTATE 42804)

-206 (ECPG\_FLOAT\_FORMAT)

The host variable is of type `float` and the datum in the database is of another type and contains a value that cannot be interpreted as a `float`. The library uses `strtod()` for this conversion. (SQLSTATE 42804)

-207 (ECPG\_NUMERIC\_FORMAT)

The host variable is of type `numeric` and the datum in the database is of another type and contains a value that cannot be interpreted as a `numeric` value. (SQLSTATE 42804)

-208 (ECPG\_INTERVAL\_FORMAT)

The host variable is of type `interval` and the datum in the database is of another type and contains a value that cannot be interpreted as an `interval` value. (SQLSTATE 42804)

-209 (ECPG\_DATE\_FORMAT)

The host variable is of type `date` and the datum in the database is of another type and contains a value that cannot be interpreted as a `date` value. (SQLSTATE 42804)

-210 (ECPG\_TIMESTAMP\_FORMAT)

The host variable is of type `timestamp` and the datum in the database is of another type and contains a value that cannot be interpreted as a `timestamp` value. (SQLSTATE 42804)

-211 (ECPG\_CONVERT\_BOOL)

This means the host variable is of type `bool` and the datum in the database is neither `'t'` nor `'f'`. (SQLSTATE 42804)

-212 (ECPG\_EMPTY)

The statement sent to the LightDB server was empty. (This cannot normally happen in an embedded SQL program, so it might point to an internal error.) (SQLSTATE YE002)

-213 (ECPG\_MISSING\_INDICATOR)

A null value was returned and no null indicator variable was supplied. (SQLSTATE 22002)

-214 (ECPG\_NO\_ARRAY)

An ordinary variable was used in a place that requires an array. (SQLSTATE 42804)

-215 (ECPG\_DATA\_NOT\_ARRAY)

The database returned an ordinary variable in a place that requires array value. (SQLSTATE 42804)



-216 (ECPG\_ARRAY\_INSERT)

The value could not be inserted into the array. (SQLSTATE 42804)

-220 (ECPG\_NO\_CONN)

The program tried to access a connection that does not exist. (SQLSTATE 08003)

-221 (ECPG\_NOT\_CONN)

The program tried to access a connection that does exist but is not open. (This is an internal error.) (SQLSTATE YE002)

-230 (ECPG\_INVALID\_STMT)

The statement you are trying to use has not been prepared. (SQLSTATE 26000)

-239 (ECPG\_INFORMIX\_DUPLICATE\_KEY)

Duplicate key error, violation of unique constraint (Informix compatibility mode). (SQLSTATE 23505)

-240 (ECPG\_UNKNOWN\_DESCRIPTOR)

The descriptor specified was not found. The statement you are trying to use has not been prepared. (SQLSTATE 33000)

-241 (ECPG\_INVALID\_DESCRIPTOR\_INDEX)

The descriptor index specified was out of range. (SQLSTATE 07009)

-242 (ECPG\_UNKNOWN\_DESCRIPTOR\_ITEM)

An invalid descriptor item was requested. (This is an internal error.) (SQLSTATE YE002)

-243 (ECPG\_VAR\_NOT\_NUMERIC)

During the execution of a dynamic statement, the database returned a numeric value and the host variable was not numeric. (SQLSTATE 07006)

-244 (ECPG\_VAR\_NOT\_CHAR)

During the execution of a dynamic statement, the database returned a non-numeric value and the host variable was numeric. (SQLSTATE 07006)

-284 (ECPG\_INFORMIX\_SUBSELECT\_NOT\_ONE)

A result of the subquery is not single row (Informix compatibility mode). (SQLSTATE 21000)

-400 (ECPG\_PGSQL)

Some error caused by the LightDB server. The message contains the error message from the LightDB server.

-401 (ECPG\_TRANS)

The LightDB server signaled that we cannot start, commit, or rollback the transaction. (SQLSTATE 08007)

-402 (ECPG\_CONNECT)

The connection attempt to the database did not succeed. (SQLSTATE 08001)

-403 (ECPG\_DUPLICATE\_KEY)

Duplicate key error, violation of unique constraint. (SQLSTATE 23505)

-404 (ECPG\_SUBSELECT\_NOT\_ONE)

A result for the subquery is not single row. (SQLSTATE 21000)

-602 (ECPG\_WARNING\_UNKNOWN\_PORTAL)

An invalid cursor name was specified. (SQLSTATE 34000)

-603 (ECPG\_WARNING\_IN\_TRANSACTION)

Transaction is in progress. (SQLSTATE 25001)

-604 (ECPG\_WARNING\_NO\_TRANSACTION)

There is no active (in-progress) transaction. (SQLSTATE 25P01)

-605 (ECPG\_WARNING\_PORTAL\_EXISTS)

An existing cursor name was specified. (SQLSTATE 42P03)

## 34.9. Preprocessor Directives

Several preprocessor directives are available that modify how the `ecpg` preprocessor parses and processes a file.

### 34.9.1. Including Files

To include an external file into your embedded SQL program, use:

```
EXEC SQL INCLUDE filename;  
EXEC SQL INCLUDE <filename>;  
EXEC SQL INCLUDE "filename";
```

The embedded SQL preprocessor will look for a file named *filename*.h, preprocess it, and include it in the resulting C output. Thus, embedded SQL statements in the included file are handled correctly.

The `ecpg` preprocessor will search a file at several directories in following order:

- current directory
- /usr/local/include
- LightDB include directory, defined at build time (e.g., /usr/local/lightdb-x/include)
- /usr/include

But when `EXEC SQL INCLUDE "filename"` is used, only the current directory is searched.

In each directory, the preprocessor will first look for the file name as given, and if not found will append `.h` to the file name and try again (unless the specified file name already has that suffix).

Note that `EXEC SQL INCLUDE` is *not* the same as:

```
#include <filename.h>
```

because this file would not be subject to SQL command preprocessing. Naturally, you can continue to use the C `#include` directive to include other header files.

### Note

The include file name is case-sensitive, even though the rest of the EXEC SQL INCLUDE command follows the normal SQL case-sensitivity rules.

## 34.9.2. The define and undef Directives

Similar to the directive `#define` that is known from C, embedded SQL has a similar concept:

```
EXEC SQL DEFINE name ;
EXEC SQL DEFINE name value ;
```

So you can define a name:

```
EXEC SQL DEFINE HAVE_FEATURE ;
```

And you can also define constants:

```
EXEC SQL DEFINE MYNUMBER 12 ;
EXEC SQL DEFINE MYSTRING 'abc' ;
```

Use `undef` to remove a previous definition:

```
EXEC SQL UNDEF MYNUMBER ;
```

Of course you can continue to use the C versions `#define` and `#undef` in your embedded SQL program. The difference is where your defined values get evaluated. If you use EXEC SQL DEFINE then the `ecpg` preprocessor evaluates the defines and substitutes the values. For example if you write:

```
EXEC SQL DEFINE MYNUMBER 12 ;
...
EXEC SQL UPDATE Tbl SET col = MYNUMBER ;
```

then `ecpg` will already do the substitution and your C compiler will never see any name or identifier MYNUMBER. Note that you cannot use `#define` for a constant that you are going to use in an embedded SQL query because in this case the embedded SQL precompiler is not able to see this declaration.

## 34.9.3. ifdef, ifndef, elif, else, and endif Directives

You can use the following directives to compile code sections conditionally:

```
EXEC SQL ifdef name ;
```

Checks a *name* and processes subsequent lines if *name* has been defined via EXEC SQL define *name*.

```
EXEC SQL ifndef name ;
```

Checks a *name* and processes subsequent lines if *name* has *not* been defined via EXEC SQL define *name*.

```
EXEC SQL elif name;
```

Begins an optional alternative section after an EXEC SQL `ifdef name` or EXEC SQL `ifndef name` directive. Any number of `elif` sections can appear. Lines following an `elif` will be processed if *name* has been defined *and* no previous section of the same `ifdef/ifndef...endif` construct has been processed.

```
EXEC SQL else;
```

Begins an optional, final alternative section after an EXEC SQL `ifdef name` or EXEC SQL `ifndef name` directive. Subsequent lines will be processed if no previous section of the same `ifdef/ifndef...endif` construct has been processed.

```
EXEC SQL endif;
```

Ends an `ifdef/ifndef...endif` construct. Subsequent lines are processed normally.

`ifdef/ifndef...endif` constructs can be nested, up to 127 levels deep.

This example will compile exactly one of the three SET TIMEZONE commands:

```
EXEC SQL ifdef TZVAR;
EXEC SQL SET TIMEZONE TO TZVAR;
EXEC SQL elif TZNAME;
EXEC SQL SET TIMEZONE TO TZNAME;
EXEC SQL else;
EXEC SQL SET TIMEZONE TO 'GMT';
EXEC SQL endif;
```

## 34.10. Processing Embedded SQL Programs

Now that you have an idea how to form embedded SQL C programs, you probably want to know how to compile them. Before compiling you run the file through the embedded SQL C preprocessor, which converts the SQL statements you used to special function calls. After compiling, you must link with a special library that contains the needed functions. These functions fetch information from the arguments, perform the SQL command using the libpq interface, and put the result in the arguments specified for output.

The preprocessor program is called `ecpg` and is included in a normal LightDB installation. Embedded SQL programs are typically named with an extension `.pgc`. If you have a program file called `prog1.pgc`, you can preprocess it by simply calling:

```
ecpg prog1.pgc
```

This will create a file called `prog1.c`. If your input files do not follow the suggested naming pattern, you can specify the output file explicitly using the `-o` option.

The preprocessed file can be compiled normally, for example:

```
cc -c prog1.c
```

The generated C source files include header files from the LightDB installation, so if you installed LightDB in a location that is not searched by default, you have to add an option such as `-I/usr/local/lightdb-x/include` to the compilation command line.

To link an embedded SQL program, you need to include the `libecpg` library, like so:

```
cc -o myprog prog1.o prog2.o ... -lecpg
```

Again, you might have to add an option like `-L/usr/local/lightdb-x/lib` to that command line.

You can use `lt_config` or `pkg-config` with package name `libecpg` to get the paths for your installation.

If you manage the build process of a larger project using `make`, it might be convenient to include the following implicit rule to your makefiles:

```
ECPG = ecpg

%.c: %.pgc
    $(ECPG) $<
```

The complete syntax of the `ecpg` command is detailed in `ecpg`.

The `ecpg` library is thread-safe by default. However, you might need to use some threading command-line options to compile your client code.

## 34.11. Library Functions

The `libecpg` library primarily contains “hidden” functions that are used to implement the functionality expressed by the embedded SQL commands. But there are some functions that can usefully be called directly. Note that this makes your code unportable.

- `ECPGdebug(int on, FILE *stream)` turns on debug logging if called with the first argument non-zero. Debug logging is done on `stream`. The log contains all SQL statements with all the input variables inserted, and the results from the LightDB server. This can be very useful when searching for errors in your SQL statements.

### Note

On Windows, if the `ecpg` libraries and an application are compiled with different flags, this function call will crash the application because the internal representation of the `FILE` pointers differ. Specifically, `multithreaded/single-threaded`, `release/debug`, and `static/dynamic` flags should be the same for the library and all applications using that library.

- `ECPGget_PGconn(const char *connection_name)` returns the library database connection handle identified by the given name. If `connection_name` is set to `NULL`, the current connection handle is returned. If no connection handle can be identified, the function returns `NULL`. The returned connection handle can be used to call any other functions from `libpq`, if necessary.

### Note

It is a bad idea to manipulate database connection handles made from `ecpg` directly with `libpq` routines.

- `ECPGtransactionStatus(const char *connection_name)` returns the current transaction status of the given connection identified by `connection_name`. See Section 32.2 and `libpq`'s `PQtransactionStatus` for details about the returned status codes.
- `ECPGstatus(int lineno, const char* connection_name)` returns true if you are connected to a database and false if not. `connection_name` can be `NULL` if a single connection is being used.

## 34.12. Large Objects

Large objects are not directly supported by ECPG, but ECPG application can manipulate large objects through the libpq large object functions, obtaining the necessary PGconn object by calling the ECPGget\_PGconn() function. (However, use of the ECPGget\_PGconn() function and touching PGconn objects directly should be done very carefully and ideally not mixed with other ECPG database access calls.)

For more details about the ECPGget\_PGconn(), see Section 34.11. For information about the large object function interface, see Chapter 33.

Large object functions have to be called in a transaction block, so when autocommit is off, BEGIN commands have to be issued explicitly.

Example 34.2 shows an example program that illustrates how to create, write, and read a large object in an ECPG application.

### Example 34.2. ECPG Program Accessing Large Objects

```
#include <stdio.h>
#include <stdlib.h>
#include <libpq-fe.h>
#include <libpq/libpq-fs.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    PGconn      *conn;
    Oid          loid;
    int          fd;
    char         buf[256];
    int          buflen = 256;
    char         buf2[256];
    int          rc;

    memset(buf, 1, buflen);

    EXEC SQL CONNECT TO testdb AS con1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    conn = ECPGget_PGconn("con1");
    printf("conn = %p\n", conn);

    /* create */
    loid = lo_create(conn, 0);
    if (loid < 0)
        printf("lo_create() failed: %s", PQerrorMessage(conn));

    printf("loid = %d\n", loid);

    /* write test */
    fd = lo_open(conn, loid, INV_READ|INV_WRITE);
    if (fd < 0)
        printf("lo_open() failed: %s", PQerrorMessage(conn));
```

```

printf("fd = %d\n", fd);

rc = lo_write(conn, fd, buf, buflen);
if (rc < 0)
    printf("lo_write() failed\n");

rc = lo_close(conn, fd);
if (rc < 0)
    printf("lo_close() failed: %s", PQerrorMessage(conn));

/* read test */
fd = lo_open(conn, loid, INV_READ);
if (fd < 0)
    printf("lo_open() failed: %s", PQerrorMessage(conn));

printf("fd = %d\n", fd);

rc = lo_read(conn, fd, buf2, buflen);
if (rc < 0)
    printf("lo_read() failed\n");

rc = lo_close(conn, fd);
if (rc < 0)
    printf("lo_close() failed: %s", PQerrorMessage(conn));

/* check */
rc = memcmp(buf, buf2, buflen);
printf("memcmp() = %d\n", rc);

/* cleanup */
rc = lo_unlink(conn, loid);
if (rc < 0)
    printf("lo_unlink() failed: %s", PQerrorMessage(conn));

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
return 0;
}

```

## 34.13. C++ Applications

ECPG has some limited support for C++ applications. This section describes some caveats.

The `ecpg` preprocessor takes an input file written in C (or something like C) and embedded SQL commands, converts the embedded SQL commands into C language chunks, and finally generates a `.c` file. The header file declarations of the library functions used by the C language chunks that `ecpg` generates are wrapped in `extern "C" { ... }` blocks when used under C++, so they should work seamlessly in C++.

In general, however, the `ecpg` preprocessor only understands C; it does not handle the special syntax and reserved words of the C++ language. So, some embedded SQL code written in C++ application code that uses complicated features specific to C++ might fail to be preprocessed correctly or might not work as expected.

A safe way to use the embedded SQL code in a C++ application is hiding the ECPG calls in a C module, which the C++ application code calls into to access the database, and linking that together with the rest of the C++ code. See Section 34.13.2 about that.

### 34.13.1. Scope for Host Variables

The `ecpg` preprocessor understands the scope of variables in C. In the C language, this is rather simple because the scopes of variables is based on their code blocks. In C++, however, the class member variables are referenced in a different code block from the declared position, so the `ecpg` preprocessor will not understand the scope of the class member variables.

For example, in the following case, the `ecpg` preprocessor cannot find any declaration for the variable `dbname` in the `test` method, so an error will occur.

```
class TestCpp
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    EXEC SQL CONNECT TO testdb1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
}

void Test::test()
{
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

TestCpp::~TestCpp()
{
    EXEC SQL DISCONNECT ALL;
}
```

This code will result in an error like this:

**ecpg test\_cpp.pgc**

```
test_cpp.pgc:28: ERROR: variable "dbname" is not declared
```

To avoid this scope issue, the `test` method could be modified to use a local variable as intermediate storage. But this approach is only a poor workaround, because it uglifies the code and reduces performance.

```
void TestCpp::test()
{
    EXEC SQL BEGIN DECLARE SECTION;
    char tmp[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :tmp;
```



```

    strcpy(dbname, tmp, sizeof(tmp));

    printf("current_database = %s\n", dbname);
}

```

## 34.13.2. C++ Application Development with External C Module

If you understand these technical limitations of the `ecpg` preprocessor in C++, you might come to the conclusion that linking C objects and C++ objects at the link stage to enable C++ applications to use ECPG features could be better than writing some embedded SQL commands in C++ code directly. This section describes a way to separate some embedded SQL commands from C++ application code with a simple example. In this example, the application is implemented in C++, while C and ECPG is used to connect to the LightDB server.

Three kinds of files have to be created: a C file (`*.pgc`), a header file, and a C++ file:

`test_mod.pgc`

A sub-routine module to execute SQL commands embedded in C. It is going to be converted into `test_mod.c` by the preprocessor.

```

#include "test_mod.h"
#include <stdio.h>

void
db_connect()
{
    EXEC SQL CONNECT TO testdb1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
}

void
db_test()
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

void
db_disconnect()
{
    EXEC SQL DISCONNECT ALL;
}

```

`test_mod.h`

A header file with declarations of the functions in the C module (`test_mod.pgc`). It is included by `test_cpp.cpp`. This file has to have an `extern "C"` block around the declarations, because it will be linked from the C++ module.

```

#ifdef __cplusplus

```

```
extern "C" {
#endif

void db_connect();
void db_test();
void db_disconnect();

#ifdef __cplusplus
}
#endif
```

test\_cpp.cpp

The main code for the application, including the main routine, and in this example a C++ class.

```
#include "test_mod.h"

class TestCpp
{
public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    db_connect();
}

void
TestCpp::test()
{
    db_test();
}

TestCpp::~TestCpp()
{
    db_disconnect();
}

int
main(void)
{
    TestCpp *t = new TestCpp();

    t->test();
    return 0;
}
```

To build the application, proceed as follows. Convert `test_mod.pgc` into `test_mod.c` by running `ecpg`, and generate `test_mod.o` by compiling `test_mod.c` with the C compiler:

```
ecpg -o test_mod.c test_mod.pgc
cc -c test_mod.c -o test_mod.o
```

Next, generate `test_cpp.o` by compiling `test_cpp.cpp` with the C++ compiler:

```
c++ -c test_cpp.cpp -o test_cpp.o
```

Finally, link these object files, `test_cpp.o` and `test_mod.o`, into one executable, using the C++ compiler driver:

```
c++ test_cpp.o test_mod.o -lecpG -o test_cpp
```

## 34.14. Embedded SQL Commands

This section describes all SQL commands that are specific to embedded SQL. Also refer to the SQL commands listed in SQL Commands, which can also be used in embedded SQL, unless stated otherwise.

# ALLOCATE DESCRIPTOR

ALLOCATE DESCRIPTOR — allocate an SQL descriptor area

## Synopsis

```
ALLOCATE DESCRIPTOR name
```

## Description

ALLOCATE DESCRIPTOR allocates a new named SQL descriptor area, which can be used to exchange data between the LightDB server and the host program.

Descriptor areas should be freed after use using the DEALLOCATE DESCRIPTOR command.

## Parameters

*name*

A name of SQL descriptor, case sensitive. This can be an SQL identifier or a host variable.

## Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;
```

## Compatibility

ALLOCATE DESCRIPTOR is specified in the SQL standard.

## See Also

DEALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR

# CONNECT

CONNECT — establish a database connection

## Synopsis

```
CONNECT TO connection_target [ AS connection_name ]
  [ USER connection_user ]
CONNECT TO DEFAULT
CONNECT connection_user
DATABASE connection_target
```

## Description

The CONNECT command establishes a connection between the client and the LightDB server.

## Parameters

*connection\_target*

*connection\_target* specifies the target server of the connection on one of several forms.

[ *database\_name* ] [ @*host* ] [ :*port* ]

Connect over TCP/IP

unix:postgresql://*host* [ :*port* ] / [ *database\_name* ] [ ?*connection\_option* ]

Connect over Unix-domain sockets

tcp:postgresql://*host* [ :*port* ] / [ *database\_name* ] [ ?*connection\_option* ]

Connect over TCP/IP

SQL string constant

containing a value in one of the above forms

host variable

host variable of type `char [ ]` or `VARCHAR [ ]` containing a value in one of the above forms

*connection\_name*

An optional identifier for the connection, so that it can be referred to in other commands. This can be an SQL identifier or a host variable.

*connection\_user*

The user name for the database connection.

This parameter can also specify user name and password, using one the forms *user\_name* / *password*, *user\_name* IDENTIFIED BY *password*, or *user\_name* USING *password*.

User name and password can be SQL identifiers, string constants, or host variables.

## DEFAULT

Use all default connection parameters, as defined by libpq.

## Examples

Here are several variants for specifying connection parameters:

```
EXEC SQL CONNECT TO "connectdb" AS main;
EXEC SQL CONNECT TO "connectdb" AS second;
EXEC SQL CONNECT TO "unix:postgresql://200.46.204.71/connectdb" AS
  main USER connectuser;
EXEC SQL CONNECT TO "unix:postgresql://localhost/connectdb" AS main
  USER connectuser;
EXEC SQL CONNECT TO 'connectdb' AS main;
EXEC SQL CONNECT TO 'unix:postgresql://localhost/connectdb' AS main
  USER :user;
EXEC SQL CONNECT TO :db AS :id;
EXEC SQL CONNECT TO :db USER connectuser USING :pw;
EXEC SQL CONNECT TO @localhost AS main USER connectdb;
EXEC SQL CONNECT TO REGRESSDB1 as main;
EXEC SQL CONNECT TO AS main USER connectdb;
EXEC SQL CONNECT TO connectdb AS :id;
EXEC SQL CONNECT TO connectdb AS main USER connectuser/connectdb;
EXEC SQL CONNECT TO connectdb AS main;
EXEC SQL CONNECT TO connectdb@localhost AS main;
EXEC SQL CONNECT TO tcp:postgresql://localhost/ USER connectdb;
EXEC SQL CONNECT TO tcp:postgresql://localhost/connectdb USER
  connectuser IDENTIFIED BY connectpw;
EXEC SQL CONNECT TO tcp:postgresql://localhost:20/connectdb USER
  connectuser IDENTIFIED BY connectpw;
EXEC SQL CONNECT TO unix:postgresql://localhost/ AS main USER
  connectdb;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb AS main
  USER connectuser;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER
  connectuser IDENTIFIED BY "connectpw";
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER
  connectuser USING "connectpw";
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb?
  connect_timeout=14 USER connectuser;
```

Here is an example program that illustrates the use of host variables to specify connection parameters:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
  char *dbname      = "testdb";      /* database name */
  char *user        = "testuser";    /* connection user name */
  char *connection  = "tcp:postgresql://localhost:5432/testdb";
                                      /* connection string */
  char ver[256];      /* buffer to store the version
  string */
EXEC SQL END DECLARE SECTION;

  ECPGdebug(1, stderr);
```

```
EXEC SQL CONNECT TO :dbname USER :user;
EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
EXEC SQL SELECT version() INTO :ver;
EXEC SQL DISCONNECT;

printf("version: %s\n", ver);

EXEC SQL CONNECT TO :connection USER :user;
EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
EXEC SQL SELECT version() INTO :ver;
EXEC SQL DISCONNECT;

printf("version: %s\n", ver);

return 0;
}
```

## Compatibility

CONNECT is specified in the SQL standard, but the format of the connection parameters is implementation-specific.

## See Also

DISCONNECT, SET CONNECTION

# DEALLOCATE DESCRIPTOR

DEALLOCATE DESCRIPTOR — deallocate an SQL descriptor area

## Synopsis

```
DEALLOCATE DESCRIPTOR name
```

## Description

DEALLOCATE DESCRIPTOR deallocates a named SQL descriptor area.

## Parameters

*name*

The name of the descriptor which is going to be deallocated. It is case sensitive. This can be an SQL identifier or a host variable.

## Examples

```
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

## Compatibility

DEALLOCATE DESCRIPTOR is specified in the SQL standard.

## See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR



## DECLARE

DECLARE — define a cursor

### Synopsis

```
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
  CURSOR [ { WITH | WITHOUT } HOLD ] FOR prepared_name  
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
  CURSOR [ { WITH | WITHOUT } HOLD ] FOR query
```

### Description

DECLARE declares a cursor for iterating over the result set of a prepared statement. This command has slightly different semantics from the direct SQL command DECLARE: Whereas the latter executes a query and prepares the result set for retrieval, this embedded SQL command merely declares a name as a “loop variable” for iterating over the result set of a query; the actual execution happens when the cursor is opened with the OPEN command.

### Parameters

*cursor\_name*

A cursor name, case sensitive. This can be an SQL identifier or a host variable.

*prepared\_name*

The name of a prepared query, either as an SQL identifier or a host variable.

*query*

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

For the meaning of the cursor options, see DECLARE.

### Examples

Examples declaring a cursor for a query:

```
EXEC SQL DECLARE C CURSOR FOR SELECT * FROM My_Table;  
EXEC SQL DECLARE C CURSOR FOR SELECT Item1 FROM T;  
EXEC SQL DECLARE cur1 CURSOR FOR SELECT version();
```

An example declaring a cursor for a prepared statement:

```
EXEC SQL PREPARE stmt1 AS SELECT version();  
EXEC SQL DECLARE cur1 CURSOR FOR stmt1;
```

### Compatibility

DECLARE is specified in the SQL standard.

### See Also

OPEN, CLOSE, DECLARE

## DESCRIBE

DESCRIBE — obtain information about a prepared statement or result set

### Synopsis

```
DESCRIBE [ OUTPUT ] prepared_name USING [ SQL ]  
    DESCRIPTOR descriptor_name  
DESCRIBE [ OUTPUT ] prepared_name INTO [ SQL ]  
    DESCRIPTOR descriptor_name  
DESCRIBE [ OUTPUT ] prepared_name INTO slda_name
```

### Description

DESCRIBE retrieves metadata information about the result columns contained in a prepared statement, without actually fetching a row.

### Parameters

*prepared\_name*

The name of a prepared statement. This can be an SQL identifier or a host variable.

*descriptor\_name*

A descriptor name. It is case sensitive. It can be an SQL identifier or a host variable.

*slda\_name*

The name of an SQLDA variable.

### Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;  
EXEC SQL PREPARE stmt1 FROM :sql_stmt;  
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;  
EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :charvar = NAME;  
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

### Compatibility

DESCRIBE is specified in the SQL standard.

### See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

# DISCONNECT

DISCONNECT — terminate a database connection

## Synopsis

```
DISCONNECT connection_name
DISCONNECT [ CURRENT ]
DISCONNECT DEFAULT
DISCONNECT ALL
```

## Description

DISCONNECT closes a connection (or all connections) to the database.

## Parameters

*connection\_name*

A database connection name established by the CONNECT command.

CURRENT

Close the “current” connection, which is either the most recently opened connection, or the connection set by the SET CONNECTION command. This is also the default if no argument is given to the DISCONNECT command.

DEFAULT

Close the default connection.

ALL

Close all open connections.

## Examples

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS DEFAULT USER testuser;
    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL CONNECT TO testdb AS con2 USER testuser;
    EXEC SQL CONNECT TO testdb AS con3 USER testuser;

    EXEC SQL DISCONNECT CURRENT; /* close con3          */
    EXEC SQL DISCONNECT DEFAULT; /* close DEFAULT  */
    EXEC SQL DISCONNECT ALL;     /* close con2 and con1 */

    return 0;
}
```

## Compatibility

DISCONNECT is specified in the SQL standard.

## **See Also**

CONNECT, SET CONNECTION

## EXECUTE IMMEDIATE

EXECUTE IMMEDIATE — dynamically prepare and execute a statement

### Synopsis

```
EXECUTE IMMEDIATE string
```

### Description

EXECUTE IMMEDIATE immediately prepares and executes a dynamically specified SQL statement, without retrieving result rows.

### Parameters

*string*

A literal C string or a host variable containing the SQL statement to be executed.

### Examples

Here is an example that executes an INSERT statement using EXECUTE IMMEDIATE and a host variable named `command`:

```
printf(command, "INSERT INTO test (name, amount, letter) VALUES  
( 'db: 'r1''', 1, 'f' )");  
EXEC SQL EXECUTE IMMEDIATE :command;
```

### Compatibility

EXECUTE IMMEDIATE is specified in the SQL standard.

## GET DESCRIPTOR

GET DESCRIPTOR — get information from an SQL descriptor area

### Synopsis

```
GET DESCRIPTOR descriptor_name :cvariable = descriptor_header_item
[ , ... ]
GET DESCRIPTOR descriptor_name VALUE column_number :cvariable
= descriptor_item [ , ... ]
```

### Description

GET DESCRIPTOR retrieves information about a query result set from an SQL descriptor area and stores it into host variables. A descriptor area is typically populated using FETCH or SELECT before using this command to transfer the information into host language variables.

This command has two forms: The first form retrieves descriptor “header” items, which apply to the result set in its entirety. One example is the row count. The second form, which requires the column number as additional parameter, retrieves information about a particular column. Examples are the column name and the actual column value.

### Parameters

*descriptor\_name*

A descriptor name.

*descriptor\_header\_item*

A token identifying which header information item to retrieve. Only COUNT, to get the number of columns in the result set, is currently supported.

*column\_number*

The number of the column about which information is to be retrieved. The count starts at 1.

*descriptor\_item*

A token identifying which item of information about a column to retrieve. See Section 34.7.1 for a list of supported items.

*cvariable*

A host variable that will receive the data retrieved from the descriptor area.

### Examples

An example to retrieve the number of columns in a result set:

```
EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
```

An example to retrieve a data length in the first column:

```
EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length =
RETURNED_OCTET_LENGTH;
```

An example to retrieve the data body of the second column as a string:

```
EXEC SQL GET DESCRIPTOR d VALUE 2 :d_data = DATA;
```

Here is an example for a whole procedure of executing `SELECT current_database();` and showing the number of columns, the column data length, and the column data:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int d_count;
    char d_data[1024];
    int d_returned_octet_length;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL ALLOCATE DESCRIPTOR d;

    /* Declare, open a cursor, and assign a descriptor to the
cursor */
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database();
    EXEC SQL OPEN cur;
    EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;

    /* Get a number of total columns */
    EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
    printf("d_count          = %d\n", d_count);

    /* Get length of a returned column */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length =
RETURNED_OCTET_LENGTH;
    printf("d_returned_octet_length = %d\n",
d_returned_octet_length);

    /* Fetch the returned column as a string */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_data = DATA;
    printf("d_data          = %s\n", d_data);

    /* Closing */
    EXEC SQL CLOSE cur;
    EXEC SQL COMMIT;

    EXEC SQL DEALLOCATE DESCRIPTOR d;
    EXEC SQL DISCONNECT ALL;

    return 0;
}
```

When the example is executed, the result will look like this:

```
d_count          = 1
d_returned_octet_length = 6
d_data          = testdb
```

## Compatibility

GET DESCRIPTOR is specified in the SQL standard.

## See Also

ALLOCATE DESCRIPTOR, SET DESCRIPTOR



## OPEN

OPEN — open a dynamic cursor

## Synopsis

```
OPEN cursor_name
OPEN cursor_name USING value [, ... ]
OPEN cursor_name USING SQL DESCRIPTOR descriptor_name
```

## Description

OPEN opens a cursor and optionally binds actual values to the placeholders in the cursor's declaration. The cursor must previously have been declared with the DECLARE command. The execution of OPEN causes the query to start executing on the server.

## Parameters

*cursor\_name*

The name of the cursor to be opened. This can be an SQL identifier or a host variable.

*value*

A value to be bound to a placeholder in the cursor. This can be an SQL constant, a host variable, or a host variable with indicator.

*descriptor\_name*

The name of a descriptor containing values to be bound to the placeholders in the cursor. This can be an SQL identifier or a host variable.

## Examples

```
EXEC SQL OPEN a;
EXEC SQL OPEN d USING 1, 'test';
EXEC SQL OPEN c1 USING SQL DESCRIPTOR mydesc;
EXEC SQL OPEN :curname1;
```

## Compatibility

OPEN is specified in the SQL standard.

## See Also

DECLARE, CLOSE

# PREPARE

PREPARE — prepare a statement for execution

## Synopsis

```
PREPARE name FROM string
```

## Description

PREPARE prepares a statement dynamically specified as a string for execution. This is different from the direct SQL statement PREPARE, which can also be used in embedded programs. The EXECUTE command is used to execute either kind of prepared statement.

## Parameters

*prepared\_name*

An identifier for the prepared query.

*string*

A literal C string or a host variable containing a preparable statement, one of the SELECT, INSERT, UPDATE, or DELETE.

## Examples

```
char *stmt = "SELECT * FROM test1 WHERE a = ? AND b = ?";

EXEC SQL ALLOCATE DESCRIPTOR outdesc;
EXEC SQL PREPARE foo FROM :stmt;

EXEC SQL EXECUTE foo USING SQL DESCRIPTOR indesc INTO SQL
DESCRIPTOR outdesc;
```

## Compatibility

PREPARE is specified in the SQL standard.

## See Also

EXECUTE

## SET AUTOCOMMIT

SET AUTOCOMMIT — set the autocommit behavior of the current session

### Synopsis

```
SET AUTOCOMMIT { = | TO } { ON | OFF }
```

### Description

SET AUTOCOMMIT sets the autocommit behavior of the current database session. By default, embedded SQL programs are *not* in autocommit mode, so COMMIT needs to be issued explicitly when desired. This command can change the session to autocommit mode, where each individual statement is committed implicitly.

### Compatibility

SET AUTOCOMMIT is an extension of LightDB ECPG.

## SET CONNECTION

SET CONNECTION — select a database connection

### Synopsis

```
SET CONNECTION [ TO | = ] connection_name
```

### Description

SET CONNECTION sets the “current” database connection, which is the one that all commands use unless overridden.

### Parameters

*connection\_name*

A database connection name established by the CONNECT command.

DEFAULT

Set the connection to the default connection.

### Examples

```
EXEC SQL SET CONNECTION TO con2;  
EXEC SQL SET CONNECTION = con1;
```

### Compatibility

SET CONNECTION is specified in the SQL standard.

### See Also

CONNECT, DISCONNECT

# SET DESCRIPTOR

SET DESCRIPTOR — set information in an SQL descriptor area

## Synopsis

```
SET DESCRIPTOR descriptor_name descriptor_header_item = value
[ , ... ]
SET DESCRIPTOR descriptor_name VALUE number descriptor_item = value
[ , ... ]
```

## Description

SET DESCRIPTOR populates an SQL descriptor area with values. The descriptor area is then typically used to bind parameters in a prepared query execution.

This command has two forms: The first form applies to the descriptor “header”, which is independent of a particular datum. The second form assigns values to particular datums, identified by number.

## Parameters

*descriptor\_name*

A descriptor name.

*descriptor\_header\_item*

A token identifying which header information item to set. Only COUNT, to set the number of descriptor items, is currently supported.

*number*

The number of the descriptor item to set. The count starts at 1.

*descriptor\_item*

A token identifying which item of information to set in the descriptor. See Section 34.7.1 for a list of supported items.

*value*

A value to store into the descriptor item. This can be an SQL constant or a host variable.

## Examples

```
EXEC SQL SET DESCRIPTOR indesc COUNT = 1;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = 2;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = :val1;
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val1, DATA =
'some string';
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val2null, DATA
= :val2;
```

## Compatibility

SET DESCRIPTOR is specified in the SQL standard.

## **See Also**

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

## TYPE

TYPE — define a new data type

## Synopsis

```
TYPE type_name IS ctype
```

## Description

The TYPE command defines a new C type. It is equivalent to putting a typedef into a declare section.

This command is only recognized when `ecpg` is run with the `-c` option.

## Parameters

*type\_name*

The name for the new type. It must be a valid C type name.

*ctype*

A C type specification.

## Examples

```
EXEC SQL TYPE customer IS
  struct
  {
    varchar name[50];
    int     phone;
  };
```

```
EXEC SQL TYPE cust_ind IS
  struct ind
  {
    short  name_ind;
    short  phone_ind;
  };
```

```
EXEC SQL TYPE c IS char reference;
EXEC SQL TYPE ind IS union { int integer; short smallint; };
EXEC SQL TYPE intarray IS int[AMOUNT];
EXEC SQL TYPE str IS varchar[BUFFERSIZ];
EXEC SQL TYPE string IS char[11];
```

Here is an example program that uses EXEC SQL TYPE:

```
EXEC SQL WHENEVER SQLERROR SQLPRINT;

EXEC SQL TYPE tt IS
  struct
  {
    varchar v[256];
    int     i;
```

```
};

EXEC SQL TYPE tt_ind IS
  struct ind {
    short  v_ind;
    short  i_ind;
  };

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
  tt t;
  tt_ind t_ind;
EXEC SQL END DECLARE SECTION;

  EXEC SQL CONNECT TO testdb AS con1;
  EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

  EXEC SQL SELECT current_database(), 256 INTO :t:t_ind LIMIT 1;

  printf("t.v = %s\n", t.v.arr);
  printf("t.i = %d\n", t.i);

  printf("t_ind.v_ind = %d\n", t_ind.v_ind);
  printf("t_ind.i_ind = %d\n", t_ind.i_ind);

  EXEC SQL DISCONNECT con1;

  return 0;
}
```

The output from this program looks like this:

```
t.v = testdb
t.i = 256
t_ind.v_ind = 0
t_ind.i_ind = 0
```

## Compatibility

The TYPE command is a LightDB extension.



## VAR

VAR — define a variable

## Synopsis

```
VAR varname IS ctype
```

## Description

The VAR command assigns a new C data type to a host variable. The host variable must be previously declared in a declare section.

## Parameters

*varname*

A C variable name.

*ctype*

A C type specification.

## Examples

```
Exec sql begin declare section;  
short a;  
exec sql end declare section;  
EXEC SQL VAR a IS int;
```

## Compatibility

The VAR command is a LightDB extension.

## WHENEVER

WHENEVER — specify the action to be taken when an SQL statement causes a specific class condition to be raised

## Synopsis

```
WHENEVER { NOT FOUND | SQLERROR | SQLWARNING } action
```

## Description

Define a behavior which is called on the special cases (Rows not found, SQL warnings or errors) in the result of SQL execution.

## Parameters

See Section 34.8.1 for a description of the parameters.

## Examples

```
EXEC SQL WHENEVER NOT FOUND CONTINUE;
EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER NOT FOUND DO CONTINUE;
EXEC SQL WHENEVER SQLWARNING SQLPRINT;
EXEC SQL WHENEVER SQLWARNING DO warn();
EXEC SQL WHENEVER SQLERROR sqlprint;
EXEC SQL WHENEVER SQLERROR CALL print2();
EXEC SQL WHENEVER SQLERROR DO handle_error("select");
EXEC SQL WHENEVER SQLERROR DO sqlnotice(NULL, NONO);
EXEC SQL WHENEVER SQLERROR DO sqlprint();
EXEC SQL WHENEVER SQLERROR GOTO error_label;
EXEC SQL WHENEVER SQLERROR STOP;
```

A typical application is the use of `WHENEVER NOT FOUND BREAK` to handle looping through result sets:

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS con1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL ALLOCATE DESCRIPTOR d;
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database(),
'hoge', 256;
    EXEC SQL OPEN cur;

    /* when end of result set reached, break out of while loop */
    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
        EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;
        ...
    }
}
```

```

EXEC SQL CLOSE cur;
EXEC SQL COMMIT;

EXEC SQL DEALLOCATE DESCRIPTOR d;
EXEC SQL DISCONNECT ALL;

return 0;
}

```

## Compatibility

WHENEVER is specified in the SQL standard, but most of the actions are LightDB extensions.

## 34.15. Informix Compatibility Mode

`ecpg` can be run in a so-called *Informix compatibility mode*. If this mode is active, it tries to behave as if it were the Informix precompiler for Informix E/SQL. Generally spoken this will allow you to use the dollar sign instead of the `EXEC SQL` primitive to introduce embedded SQL commands:

```

$int j = 3;
$CONNECT TO :dbname;
$CREATE TABLE test(i INT PRIMARY KEY, j INT);
$INSERT INTO test(i, j) VALUES (7, :j);
$COMMIT;

```

### Note

There must not be any white space between the `$` and a following preprocessor directive, that is, `include`, `define`, `ifdef`, etc. Otherwise, the preprocessor will parse the token as a host variable.

There are two compatibility modes: `INFORMIX`, `INFORMIX_SE`

When linking programs that use this compatibility mode, remember to link against `libcompat` that is shipped with ECPG.

Besides the previously explained syntactic sugar, the Informix compatibility mode ports some functions for input, output and transformation of data as well as embedded SQL statements known from E/SQL to ECPG.

Informix compatibility mode is closely connected to the `pgtypeslib` library of ECPG. `pgtypeslib` maps SQL data types to data types within the C host program and most of the additional functions of the Informix compatibility mode allow you to operate on those C host program types. Note however that the extent of the compatibility is limited. It does not try to copy Informix behavior; it allows you to do more or less the same operations and gives you functions that have the same name and the same basic behavior but it is no drop-in replacement if you are using Informix at the moment. Moreover, some of the data types are different. For example, LightDB's datetime and interval types do not know about ranges like for example `YEAR TO MINUTE` so you won't find support in ECPG for that either.

### 34.15.1. Additional Types

The Informix-special "string" pseudo-type for storing right-trimmed character string data is now supported in Informix-mode without using `typedef`. In fact, in Informix-mode, ECPG refuses to process source files that contain `typedef sometype string;`

```
EXEC SQL BEGIN DECLARE SECTION;
string userid; /* this variable will contain trimmed data */
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL FETCH MYCUR INTO :userid;
```

## 34.15.2. Additional/Missing Embedded SQL Statements

`CLOSE DATABASE`

This statement closes the current connection. In fact, this is a synonym for ECPG's `DISCONNECT CURRENT`:

```
$CLOSE DATABASE;           /* close the current connection
*/
EXEC SQL CLOSE DATABASE;
```

`FREE cursor_name`

Due to the differences how ECPG works compared to Informix's ESQL/C (i.e., which steps are purely grammar transformations and which steps rely on the underlying run-time library) there is no `FREE cursor_name` statement in ECPG. This is because in ECPG, `DECLARE CURSOR` doesn't translate to a function call into the run-time library that uses to the cursor name. This means that there's no run-time bookkeeping of SQL cursors in the ECPG run-time library, only in the LightDB server.

`FREE statement_name`

`FREE statement_name` is a synonym for `DEALLOCATE PREPARE statement_name`.

## 34.15.3. Informix-compatible SQLDA Descriptor Areas

Informix-compatible mode supports a different structure than the one described in Section 34.7.2. See below:

```
struct sqlvar_compat
{
    short    sqltype;
    int      sqllen;
    char     *sqldata;
    short    *sqlind;
    char     *sqlname;
    char     *sqlformat;
    short    sqlitype;
    short    sqlilen;
    char     *sqlidata;
    int      sqlxid;
    char     *sqltypename;
    short    sqltypelen;
    short    sqlownerlen;
    short    sqlsourcetype;
    char     *sqlownername;
    int      sqlsourceid;
    char     *sqlilongdata;
```

```
    int    sqlflags;
    void   *sqlreserved;
};

struct sqlda_compat
{
    short  sqld;
    struct sqlvar_compat *sqlvar;
    char   desc_name[19];
    short  desc_occ;
    struct sqlda_compat *desc_next;
    void   *reserved;
};

typedef struct sqlvar_compat    sqlvar_t;
typedef struct sqlda_compat    sqlda_t;
```

The global properties are:

`sqld`

The number of fields in the SQLDA descriptor.

`sqlvar`

Pointer to the per-field properties.

`desc_name`

Unused, filled with zero-bytes.

`desc_occ`

Size of the allocated structure.

`desc_next`

Pointer to the next SQLDA structure if the result set contains more than one record.

`reserved`

Unused pointer, contains NULL. Kept for Informix-compatibility.

The per-field properties are below, they are stored in the `sqlvar` array:

`sqltype`

Type of the field. Constants are in `sqltypes.h`

`sqllen`

Length of the field data.

`sqldata`

Pointer to the field data. The pointer is of `char *` type, the data pointed by it is in a binary format. Example:

```
int intval;
```

```
switch (sqldata->sqlvar[i].sqltype)
```

```

    {
        case SQLINTEGER:
            intval = *(int *)sqldata->sqlvar[i].sqldata;
            break;
        ...
    }

```

`sqlind`

Pointer to the NULL indicator. If returned by DESCRIBE or FETCH then it's always a valid pointer. If used as input for EXECUTE ... USING `sqlda`; then NULL-pointer value means that the value for this field is non-NULL. Otherwise a valid pointer and `sqlitype` has to be properly set. Example:

```

if (*(int2 *)sqldata->sqlvar[i].sqlind != 0)
    printf("value is NULL\n");

```

`sqlname`

Name of the field. 0-terminated string.

`sqlformat`

Reserved in Informix, value of `PQfformat` for the field.

`sqlitype`

Type of the NULL indicator data. It's always `SQLSMINT` when returning data from the server. When the `SQLDA` is used for a parameterized query, the data is treated according to the set type.

`sqlilen`

Length of the NULL indicator data.

`sqlxid`

Extended type of the field, result of `PQftype`.

```

sqltypename
sqltypelen
sqlownerlen
sqlsourcetype
sqlownername
sqlsourceid
sqlflags
sqlreserved

```

Unused.

`sqlilongdata`

It equals to `sqldata` if `sqlilen` is larger than 32kB.

Example:

```
EXEC SQL INCLUDE sqlda.h;
```

```

    sqlda_t      *sqlda; /* This doesn't need to be under
embedded DECLARE SECTION */

```

```
EXEC SQL BEGIN DECLARE SECTION;
char *prep_stmt = "select * from table1";
int i;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL PREPARE mystmt FROM :prep_stmt;

EXEC SQL DESCRIBE mystmt INTO sqlda;

printf("# of fields: %d\n", sqlda->sqld);
for (i = 0; i < sqlda->sqld; i++)
    printf("field %d: \"%s\"\n", sqlda->sqlvar[i]->sqlname);

EXEC SQL DECLARE mycursor CURSOR FOR mystmt;
EXEC SQL OPEN mycursor;
EXEC SQL WHENEVER NOT FOUND GOTO out;

while (1)
{
    EXEC SQL FETCH mycursor USING sqlda;
}

EXEC SQL CLOSE mycursor;

free(sqlda); /* The main structure is all to be free(),
              * sqlda and sqlda->sqlvar is in one allocated
area */
```

For more information, see the `sqlda.h` header and the `src/interfaces/ecpg/test/compat_informix/sqlda.pgc` regression test.

## 34.15.4. Additional Functions

`decadd`

Add two decimal type values.

```
int decadd(decimal *arg1, decimal *arg2, decimal *sum);
```

The function receives a pointer to the first operand of type `decimal` (`arg1`), a pointer to the second operand of type `decimal` (`arg2`) and a pointer to a value of type `decimal` that will contain the sum (`sum`). On success, the function returns 0. `ECPG_INFORMIX_NUM_OVERFLOW` is returned in case of overflow and `ECPG_INFORMIX_NUM_UNDERFLOW` in case of underflow. -1 is returned for other failures and `errno` is set to the respective `errno` number of the `pgtypeslib`.

`deccmp`

Compare two variables of type `decimal`.

```
int deccmp(decimal *arg1, decimal *arg2);
```

The function receives a pointer to the first decimal value (`arg1`), a pointer to the second decimal value (`arg2`) and returns an integer value that indicates which is the bigger value.

- 1, if the value that `arg1` points to is bigger than the value that `var2` points to

- -1, if the value that `arg1` points to is smaller than the value that `arg2` points to
- 0, if the value that `arg1` points to and the value that `arg2` points to are equal

`deccopy`

Copy a decimal value.

```
void deccopy(decimal *src, decimal *target);
```

The function receives a pointer to the decimal value that should be copied as the first argument (`src`) and a pointer to the target structure of type `decimal` (`target`) as the second argument.

`deccvasc`

Convert a value from its ASCII representation into a decimal type.

```
int deccvasc(char *cp, int len, decimal *np);
```

The function receives a pointer to string that contains the string representation of the number to be converted (`cp`) as well as its length `len`. `np` is a pointer to the decimal value that saves the result of the operation.

Valid formats are for example: `-2`, `.794`, `+3.44`, `592.49E07` or `-32.84e-4`.

The function returns 0 on success. If overflow or underflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` is returned. If the ASCII representation could not be parsed, `ECPG_INFORMIX_BAD_NUMERIC` is returned or `ECPG_INFORMIX_BAD_EXPONENT` if this problem occurred while parsing the exponent.

`deccvdbl`

Convert a value of type double to a value of type decimal.

```
int deccvdbl(double dbl, decimal *np);
```

The function receives the variable of type double that should be converted as its first argument (`dbl`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvint`

Convert a value of type int to a value of type decimal.

```
int deccvint(int in, decimal *np);
```

The function receives the variable of type int that should be converted as its first argument (`in`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvlong`

Convert a value of type long to a value of type decimal.



```
int deccvlong(long lng, decimal *np);
```

The function receives the variable of type long that should be converted as its first argument (`lng`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`decdiv`

Divide two variables of type decimal.

```
int decdiv(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1/n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the division fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively. If an attempt to divide by zero is observed, the function returns `ECPG_INFORMIX_DIVIDE_ZERO`.

`decmul`

Multiply two decimal values.

```
int decmul(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1*n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the multiplication fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`decsub`

Subtract one decimal value from another.

```
int decsub(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1-n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the subtraction fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`dectoasc`

Convert a variable of type decimal to its ASCII representation in a C char\* string.

```
int dectoasc(decimal *np, char *cp, int len, int right)
```

The function receives a pointer to a variable of type decimal (`np`) that it converts to its textual representation. `cp` is the buffer that should hold the result of the operation. The parameter `right` specifies, how many digits right of the decimal point should be included in the output. The result will be rounded to this number of decimal digits. Setting `right` to -1 indicates that all available decimal digits should be included in the output. If the length of the output buffer, which is indicated by `len` is not sufficient to hold the textual representation including the trailing zero byte, only a single `*` character is stored in the result and -1 is returned.

The function returns either -1 if the buffer `cp` was too small or `ECPG_INFORMIX_OUT_OF_MEMORY` if memory was exhausted.

#### `dectodbl`

Convert a variable of type decimal to a double.

```
int dectodbl(decimal *np, double *dblp);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the double variable that should hold the result of the operation (`dblp`).

On success, 0 is returned and a negative value if the conversion failed.

#### `dectoint`

Convert a variable to type decimal to an integer.

```
int dectoint(decimal *np, int *ip);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the integer variable that should hold the result of the operation (`ip`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits an integer to the range from -32767 to 32767, while the limits in the ECPG implementation depend on the architecture (`INT_MIN` .. `INT_MAX`).

#### `dectolong`

Convert a variable to type decimal to a long integer.

```
int dectolong(decimal *np, long *lngp);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the long variable that should hold the result of the operation (`lngp`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits a long integer to the range from -2,147,483,647 to 2,147,483,647, while the limits in the ECPG implementation depend on the architecture (`-LONG_MAX` .. `LONG_MAX`).

#### `rdatestr`

Converts a date to a C char\* string.

```
int rdatestr(date d, char *str);
```

The function receives two arguments, the first one is the date to convert (*d*) and the second one is a pointer to the target string. The output format is always *yyyy-mm-dd*, so you need to allocate at least 11 bytes (including the zero-byte terminator) for the string.

The function returns 0 on success and a negative value in case of error.

Note that ECPG's implementation differs from the Informix implementation. In Informix the format can be influenced by setting environment variables. In ECPG however, you cannot change the output format.

#### `rstrdate`

Parse the textual representation of a date.

```
int rstrdate(char *str, date *d);
```

The function receives the textual representation of the date to convert (*str*) and a pointer to a variable of type `date` (*d*). This function does not allow you to specify a format mask. It uses the default format mask of Informix which is *mm/dd/yyyy*. Internally, this function is implemented by means of `rdefmtdate`. Therefore, `rstrdate` is not faster and if you have the choice you should opt for `rdefmtdate` which allows you to specify the format mask explicitly.

The function returns the same values as `rdefmtdate`.

#### `rtoday`

Get the current date.

```
void rtoday(date *d);
```

The function receives a pointer to a date variable (*d*) that it sets to the current date.

Internally this function uses the `PGTYPESdate_today` function.

#### `rjulmdy`

Extract the values for the day, the month and the year from a variable of type `date`.

```
int rjulmdy(date d, short mdy[3]);
```

The function receives the date *d* and a pointer to an array of 3 short integer values *mdy*. The variable name indicates the sequential order: *mdy*[0] will be set to contain the number of the month, *mdy*[1] will be set to the value of the day and *mdy*[2] will contain the year.

The function always returns 0 at the moment.

Internally the function uses the `PGTYPESdate_julmdy` function.

#### `rdefmtdate`

Use a format mask to convert a character string to a value of type `date`.

```
int rdefmtdate(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (*d*), the format mask to use for parsing the date (*fmt*) and the C `char*` string containing the textual

representation of the date (`str`). The textual representation is expected to match the format mask. However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals `yy` or `yyyy` that indicate the position of the year, `mm` to indicate the position of the month and `dd` to indicate the position of the day.

The function returns the following values:

- 0 - The function terminated successfully.
- `ECPG_INFORMIX_ENOSHORTDATE` - The date does not contain delimiters between day, month and year. In this case the input string must be exactly 6 or 8 bytes long but isn't.
- `ECPG_INFORMIX_ENOTDMY` - The format string did not correctly indicate the sequential order of year, month and day.
- `ECPG_INFORMIX_BAD_DAY` - The input string does not contain a valid day.
- `ECPG_INFORMIX_BAD_MONTH` - The input string does not contain a valid month.
- `ECPG_INFORMIX_BAD_YEAR` - The input string does not contain a valid year.

Internally this function is implemented to use the `PGTYPESdate_defmt_asc` function. See the reference there for a table of example input.

#### `rfmtdate`

Convert a variable of type `date` to its textual representation using a format mask.

```
int rfmtdate(date d, char *fmt, char *str);
```

The function receives the date to convert (`d`), the format mask (`fmt`) and the string that will hold the textual representation of the date (`str`).

On success, 0 is returned and a negative value if an error occurred.

Internally this function uses the `PGTYPESdate_fmt_asc` function, see the reference there for examples.

#### `rmdyjul`

Create a date value from an array of 3 short integers that specify the day, the month and the year of the date.

```
int rmdyjul(short mdy[3], date *d);
```

The function receives the array of the 3 short integers (`mdy`) and a pointer to a variable of type `date` that should hold the result of the operation.

Currently the function returns always 0.

Internally the function is implemented to use the function `PGTYPESdate_mdyjul`.

#### `rdayofweek`

Return a number representing the day of the week for a date value.

```
int rdayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday
- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday
- 6 - Saturday

Internally the function is implemented to use the function `PGTYPESdate_dayofweek`.

#### `dtcurrent`

Retrieve the current timestamp.

```
void dtcurrent(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that `ts` points to.

#### `dtcvasc`

Parses a timestamp from its textual representation into a timestamp variable.

```
int dtcvasc(char *str, timestamp *ts);
```

The function receives the string to parse (`str`) and a pointer to the timestamp variable that should hold the result of the operation (`ts`).

The function returns 0 on success and a negative value in case of error.

Internally this function uses the `PGTYPEStimestamp_from_asc` function. See the reference there for a table with example inputs.

#### `dtcvfmtasc`

Parses a timestamp from its textual representation using a format mask into a timestamp variable.

```
dtcvfmtasc(char *inbuf, char *fmtstr, timestamp *dtvalue)
```

The function receives the string to parse (`inbuf`), the format mask to use (`fmtstr`) and a pointer to the timestamp variable that should hold the result of the operation (`dtvalue`).

This function is implemented by means of the `PGTYPEStimestamp_defmt_asc` function. See the documentation there for a list of format specifiers that can be used.

The function returns 0 on success and a negative value in case of error.

#### `dtsub`

Subtract one timestamp from another and return a variable of type interval.

```
int dtsub(timestamp *ts1, timestamp *ts2, interval *iv);
```

The function will subtract the timestamp variable that `ts2` points to from the timestamp variable that `ts1` points to and will store the result in the interval variable that `iv` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

#### `dttoasc`

Convert a timestamp variable to a C `char*` string.

```
int dttoasc(timestamp *ts, char *output);
```

The function receives a pointer to the timestamp variable to convert (`ts`) and the string that should hold the result of the operation (`output`). It converts `ts` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

#### `dttofmtasc`

Convert a timestamp variable to a C `char*` using a format mask.

```
int dttofmtasc(timestamp *ts, char *output, int str_len, char *fmtstr);
```

The function receives a pointer to the timestamp to convert as its first argument (`ts`), a pointer to the output buffer (`output`), the maximal length that has been allocated for the output buffer (`str_len`) and the format mask to use for the conversion (`fmtstr`).

Upon success, the function returns 0 and a negative value if an error occurred.

Internally, this function uses the `PGTYPEStimestamp_fmt_asc` function. See the reference there for information on what format mask specifiers can be used.

#### `intoasc`

Convert an interval variable to a C `char*` string.

```
int intoasc(interval *i, char *str);
```

The function receives a pointer to the interval variable to convert (`i`) and the string that should hold the result of the operation (`str`). It converts `i` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

#### `rfmtlong`

Convert a long integer value to its textual representation using a format mask.

```
int rfmtlong(long lng_val, char *fmt, char *outbuf);
```

The function receives the long value `lng_val`, the format mask `fmt` and a pointer to the output buffer `outbuf`. It converts the long value according to the format mask to its textual representation.

The format mask can be composed of the following format specifying characters:

- \* (asterisk) - if this position would be blank otherwise, fill it with an asterisk.

- & (ampersand) - if this position would be blank otherwise, fill it with a zero.
- # - turn leading zeroes into blanks.
- < - left-justify the number in the string.
- , (comma) - group numbers of four or more digits into groups of three digits separated by a comma.
- . (period) - this character separates the whole-number part of the number from the fractional part.
- - (minus) - the minus sign appears if the number is a negative value.
- + (plus) - the plus sign appears if the number is a positive value.
- ( - this replaces the minus sign in front of the negative number. The minus sign will not appear.
- ) - this character replaces the minus and is printed behind the negative value.
- \$ - the currency symbol.

#### rupshift

Convert a string to upper case.

```
void rupshift(char *str);
```

The function receives a pointer to the string and transforms every lower case character to upper case.

#### byleng

Return the number of characters in a string without counting trailing blanks.

```
int byleng(char *str, int len);
```

The function expects a fixed-length string as its first argument (`str`) and its length as its second argument (`len`). It returns the number of significant characters, that is the length of the string without trailing blanks.

#### ldchar

Copy a fixed-length string into a null-terminated string.

```
void ldchar(char *src, int len, char *dest);
```

The function receives the fixed-length string to copy (`src`), its length (`len`) and a pointer to the destination memory (`dest`). Note that you need to reserve at least `len+1` bytes for the string that `dest` points to. The function copies at most `len` bytes to the new location (less if the source string has trailing blanks) and adds the null-terminator.

#### rgetmsg

```
int rgetmsg(int msgnum, char *s, int maxsize);
```

This function exists but is not implemented at the moment!

**rtyalign**

```
int rtyalign(int offset, int type);
```

This function exists but is not implemented at the moment!

**rtypmsize**

```
int rtypmsize(int type, int len);
```

This function exists but is not implemented at the moment!

**rtypwidth**

```
int rtypwidth(int sqltype, int sqllen);
```

This function exists but is not implemented at the moment!

**rsetnull**

Set a variable to NULL.

```
int rsetnull(int t, char *ptr);
```

The function receives an integer that indicates the type of the variable and a pointer to the variable itself that is cast to a C char\* pointer.

The following types exist:

- CCHARTYPE - For a variable of type char or char\*
- CSHORTTYPE - For a variable of type short int
- CINTTYPE - For a variable of type int
- CBOOLTYPE - For a variable of type boolean
- CFLOATTYPE - For a variable of type float
- CLONGTYPE - For a variable of type long
- CDOUBLETYPE - For a variable of type double
- CDECIMALTYPE - For a variable of type decimal
- CDATETYPE - For a variable of type date
- CDTIMETYPE - For a variable of type timestamp

Here is an example of a call to this function:

```
$char c[] = "abc          ";
$short s = 17;
$int i = -74874;

rsetnull(CCHARTYPE, (char *) c);
rsetnull(CSHORTTYPE, (char *) &s);
rsetnull(CINTTYPE, (char *) &i);
```



`risnull`

Test if a variable is NULL.

```
int risnull(int t, char *ptr);
```

The function receives the type of the variable to test (`t`) as well a pointer to this variable (`ptr`). Note that the latter needs to be cast to a `char*`. See the function `rsetnull` for a list of possible variable types.

Here is an example of how to use this function:

```
$char c[] = "abc          ";
$short s = 17;
$int i = -74874;

risnull(CCHARTYPE, (char *) c);
risnull(CSHORTTYPE, (char *) &s);
risnull(CINTTYPE, (char *) &i);
```

## 34.15.5. Additional Constants

Note that all constants here describe errors and all of them are defined to represent negative values. In the descriptions of the different constants you can also find the value that the constants represent in the current implementation. However you should not rely on this number. You can however rely on the fact all of them are defined to represent negative values.

`ECPG_INFORMIX_NUM_OVERFLOW`

Functions return this value if an overflow occurred in a calculation. Internally it is defined as -1200 (the Informix definition).

`ECPG_INFORMIX_NUM_UNDERFLOW`

Functions return this value if an underflow occurred in a calculation. Internally it is defined as -1201 (the Informix definition).

`ECPG_INFORMIX_DIVIDE_ZERO`

Functions return this value if an attempt to divide by zero is observed. Internally it is defined as -1202 (the Informix definition).

`ECPG_INFORMIX_BAD_YEAR`

Functions return this value if a bad value for a year was found while parsing a date. Internally it is defined as -1204 (the Informix definition).

`ECPG_INFORMIX_BAD_MONTH`

Functions return this value if a bad value for a month was found while parsing a date. Internally it is defined as -1205 (the Informix definition).

`ECPG_INFORMIX_BAD_DAY`

Functions return this value if a bad value for a day was found while parsing a date. Internally it is defined as -1206 (the Informix definition).

ECPG\_INFORMIX\_ENOSHORTDATE

Functions return this value if a parsing routine needs a short date representation but did not get the date string in the right length. Internally it is defined as -1209 (the Informix definition).

ECPG\_INFORMIX\_DATE\_CONVERT

Functions return this value if an error occurred during date formatting. Internally it is defined as -1210 (the Informix definition).

ECPG\_INFORMIX\_OUT\_OF\_MEMORY

Functions return this value if memory was exhausted during their operation. Internally it is defined as -1211 (the Informix definition).

ECPG\_INFORMIX\_ENOTDMY

Functions return this value if a parsing routine was supposed to get a format mask (like `mmddy`) but not all fields were listed correctly. Internally it is defined as -1212 (the Informix definition).

ECPG\_INFORMIX\_BAD\_NUMERIC

Functions return this value either if a parsing routine cannot parse the textual representation for a numeric value because it contains errors or if a routine cannot complete a calculation involving numeric variables because at least one of the numeric variables is invalid. Internally it is defined as -1213 (the Informix definition).

ECPG\_INFORMIX\_BAD\_EXPONENT

Functions return this value if a parsing routine cannot parse an exponent. Internally it is defined as -1216 (the Informix definition).

ECPG\_INFORMIX\_BAD\_DATE

Functions return this value if a parsing routine cannot parse a date. Internally it is defined as -1218 (the Informix definition).

ECPG\_INFORMIX\_EXTRA\_CHARS

Functions return this value if a parsing routine is passed extra characters it cannot parse. Internally it is defined as -1264 (the Informix definition).

## 34.16. Oracle Compatibility Mode

`ecpg` can be run in a so-called *Oracle compatibility mode*. If this mode is active, it tries to behave as if it were Oracle Pro\*C.

Specifically, this mode changes `ecpg` in three ways:

- Pad character arrays receiving character string types with trailing spaces to the specified length
- Zero byte terminate these character arrays, and set the indicator variable if truncation occurs
- Set the null indicator to -1 when character arrays receive empty character string types

## 34.17. Internals

This section explains how ECPG works internally. This information can occasionally be useful to help users understand how to use ECPG.

The first four lines written by `ecpg` to the output are fixed lines. Two are comments and two are include lines necessary to interface to the library. Then the preprocessor reads through the file and writes output. Normally it just echoes everything to the output.

When it sees an `EXEC SQL` statement, it intervenes and changes it. The command starts with `EXEC SQL` and ends with `;`. Everything in between is treated as an `SQL` statement and parsed for variable substitution.

Variable substitution occurs when a symbol starts with a colon (`:`). The variable with that name is looked up among the variables that were previously declared within a `EXEC SQL DECLARE` section.

The most important function in the library is `ECPGdo`, which takes care of executing most commands. It takes a variable number of arguments. This can easily add up to 50 or so arguments, and we hope this will not be a problem on any platform.

The arguments are:

A line number

This is the line number of the original line; used in error messages only.

A string

This is the `SQL` command that is to be issued. It is modified by the input variables, i.e., the variables that were not known at compile time but are to be entered in the command. Where the variables should go the string contains `?`.

Input variables

Every input variable causes ten arguments to be created. (See below.)

`ECPGt_EOIT`

An `enum` telling that there are no more input variables.

Output variables

Every output variable causes ten arguments to be created. (See below.) These variables are filled by the function.

`ECPGt_EORT`

An `enum` telling that there are no more variables.

For every variable that is part of the `SQL` command, the function gets ten arguments:

1. The type as a special symbol.
2. A pointer to the value or a pointer to the pointer.
3. The size of the variable if it is a `char` or `varchar`.
4. The number of elements in the array (for array fetches).
5. The offset to the next element in the array (for array fetches).
6. The type of the indicator variable as a special symbol.
7. A pointer to the indicator variable.
8. 0
9. The number of elements in the indicator array (for array fetches).

10. The offset to the next element in the indicator array (for array fetches).

Note that not all SQL commands are treated in this way. For instance, an open cursor statement like:

```
EXEC SQL OPEN cursor;
```

is not copied to the output. Instead, the cursor's DECLARE command is used at the position of the OPEN command because it indeed opens the cursor.

Here is a complete example describing the output of the preprocessor of a file `foo.pgc` (details might change with each particular version of the preprocessor):

```
EXEC SQL BEGIN DECLARE SECTION;
int index;
int result;
EXEC SQL END DECLARE SECTION;
...
EXEC SQL SELECT res INTO :result FROM mytable WHERE index = :index;
```

is translated into:

```
/* Processed by ecpg (2.6.0) */
/* These two include files are added by the preprocessor */
#include <ecpgtype.h>;
#include <ecpglib.h>;

/* exec sql begin declare section */

#line 1 "foo.pgc"

    int index;
    int result;
/* exec sql end declare section */
...
ECPGdo(__LINE__, NULL, "SELECT res FROM mytable WHERE index = ?
",
        ECPGt_int,&(index),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EOIT,
        ECPGt_int,&(result),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EORT);
#line 147 "foo.pgc"
```

(The indentation here is added for readability and not something the preprocessor does.)

## 34.18. Comment

Start with `lightdb` version 23.3, there are three types of comments that can be used in EXEC SQL: '-- comment', '// comment' and '/\* comment \*/'. Before 23.3, only '/\* comment \*/' is supported.

---

# Chapter 35. The Information Schema

The information schema consists of a set of views that contain information about the objects defined in the current database. The information schema is defined in the SQL standard and can therefore be expected to be portable and remain stable — unlike the system catalogs, which are specific to LightDB and are modeled after implementation concerns. The information schema views do not, however, contain information about LightDB-specific features; to inquire about those you need to query the system catalogs or other LightDB-specific views.

## Note

When querying the database for constraint information, it is possible for a standard-compliant query that expects to return one row to return several. This is because the SQL standard requires constraint names to be unique within a schema, but LightDB does not enforce this restriction. LightDB automatically-generated constraint names avoid duplicates in the same schema, but users can specify such duplicate names.

This problem can appear when querying information schema views such as `check_constraint_routine_usage`, `check_constraints`, `domain_constraints`, and `referential_constraints`. Some other views have similar issues but contain the table name to help distinguish duplicate rows, e.g., `constraint_column_usage`, `constraint_table_usage`, `table_constraints`.

## 35.1. The Schema

The information schema itself is a schema named `information_schema`. This schema automatically exists in all databases. The owner of this schema is the initial database user in the cluster, and that user naturally has all the privileges on this schema, including the ability to drop it (but the space savings achieved by that are minuscule).

By default, the information schema is not in the schema search path, so you need to access all objects in it through qualified names. Since the names of some of the objects in the information schema are generic names that might occur in user applications, you should be careful if you want to put the information schema in the path.

## 35.2. Data Types

The columns of the information schema views use special data types that are defined in the information schema. These are defined as simple domains over ordinary built-in types. You should not use these types for work outside the information schema, but your applications must be prepared for them if they select from the information schema.

These types are:

`cardinal_number`

A nonnegative integer.

`character_data`

A character string (without specific maximum length).

`sql_identifier`

A character string. This type is used for SQL identifiers, the type `character_data` is used for any other kind of text data.

time\_stamp

A domain over the type timestamp with time zone

yes\_or\_no

A character string domain that contains either YES or NO. This is used to represent Boolean (true/false) data in the information schema. (The information schema was invented before the type boolean was added to the SQL standard, so this convention is necessary to keep the information schema backward compatible.)

Every column in the information schema has one of these five types.

### 35.3. information\_schema\_catalog\_name

information\_schema\_catalog\_name is a table that always contains one row and one column containing the name of the current database (current catalog, in SQL terminology).

**Table 35.1. information\_schema\_catalog\_name Columns**

Column Type	Description
catalog_name sql_identifier	Name of the database that contains this information schema

### 35.4. administrable\_role\_authorized\_role

The view administrable\_role\_authorized\_role identifies all roles that the current user has the admin option for.

**Table 35.2. administrable\_role\_authorized\_role Columns**

Column Type	Description
grantee sql_identifier	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
role_name sql_identifier	Name of a role
is_grantable yes_or_no	Always YES

### 35.5. applicable\_roles

The view applicable\_roles identifies all roles whose privileges the current user can use. This means there is some chain of role grants from the current user to the role in question. The current user itself is also an applicable role. The set of applicable roles is generally used for permission checking.

**Table 35.3. applicable\_roles Columns**

Column Type	Description
grantee sql_identifier	

Column Type	Description
	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
role_name sql_identifier	Name of a role
is_grantable yes_or_no	YES if the grantee has the admin option on the role, NO if not

## 35.6. attributes

The view `attributes` contains information about the attributes of composite data types defined in the database. (Note that the view does not give information about table columns, which are sometimes called attributes in LightDB contexts.) Only those attributes are shown that the current user has access to (by way of being the owner of or having some privilege on the type).

**Table 35.4. attributes Columns**

Column Type	Description
udt_catalog sql_identifier	Name of the database containing the data type (always the current database)
udt_schema sql_identifier	Name of the schema containing the data type
udt_name sql_identifier	Name of the data type
attribute_name sql_identifier	Name of the attribute
ordinal_position cardinal_number	Ordinal position of the attribute within the data type (count starts at 1)
attribute_default character_data	Default expression of the attribute
is_nullable yes_or_no	YES if the attribute is possibly nullable, NO if it is known not nullable.
data_type character_data	Data type of the attribute, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code> ), else USER-DEFINED (in that case, the type is identified in <code>attribute_udt_name</code> and associated columns).
character_maximum_length cardinal_number	If <code>data_type</code> identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length cardinal_number	If <code>data_type</code> identifies a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog sql_identifier	Applies to a feature not available in LightDB
character_set_schema sql_identifier	Applies to a feature not available in LightDB
character_set_name sql_identifier	Applies to a feature not available in LightDB

<b>Column Type</b>	<b>Description</b>
<code>collation_catalog sql_identifier</code>	Name of the database containing the collation of the attribute (always the current database), null if default or the data type of the attribute is not collatable
<code>collation_schema sql_identifier</code>	Name of the schema containing the collation of the attribute, null if default or the data type of the attribute is not collatable
<code>collation_name sql_identifier</code>	Name of the collation of the attribute, null if default or the data type of the attribute is not collatable
<code>numeric_precision cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column contains the (declared or implicit) precision of the type for this attribute. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>numeric_precision_radix cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10. For all other data types, this column is null.
<code>numeric_scale cardinal_number</code>	If <code>data_type</code> identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this attribute. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>datetime_precision cardinal_number</code>	If <code>data_type</code> identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this attribute, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
<code>interval_type character_data</code>	If <code>data_type</code> identifies an interval type, this column contains the specification which fields the intervals include for this attribute, e.g., <code>YEAR TO MONTH</code> , <code>DAY TO SECOND</code> , etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
<code>interval_precision cardinal_number</code>	Applies to a feature not available in LightDB (see <code>datetime_precision</code> for the fractional seconds precision of interval type attributes)
<code>attribute_udt_catalog sql_identifier</code>	Name of the database that the attribute data type is defined in (always the current database)
<code>attribute_udt_schema sql_identifier</code>	Name of the schema that the attribute data type is defined in
<code>attribute_udt_name sql_identifier</code>	Name of the attribute data type
<code>scope_catalog sql_identifier</code>	Applies to a feature not available in LightDB
<code>scope_schema sql_identifier</code>	Applies to a feature not available in LightDB
<code>scope_name sql_identifier</code>	



Column Type	Description
	Applies to a feature not available in LightDB
maximum_cardinality cardinal_number	Always null, because arrays always have unlimited maximum cardinality in LightDB
dtd_identifier sql_identifier	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
is_derived_reference_attribute yes_or_no	Applies to a feature not available in LightDB

See also under Section 35.17, a similarly structured view, for further information on some of the columns.

## 35.7. character\_sets

The view `character_sets` identifies the character sets available in the current database. Since LightDB does not support multiple character sets within one database, this view only shows one, which is the database encoding.

Take note of how the following terms are used in the SQL standard:

character repertoire

An abstract collection of characters, for example UNICODE, UCS, or LATIN1. Not exposed as an SQL object, but visible in this view.

character encoding form

An encoding of some character repertoire. Most older character repertoires only use one encoding form, and so there are no separate names for them (e.g., LATIN1 is an encoding form applicable to the LATIN1 repertoire). But for example Unicode has the encoding forms UTF8, UTF16, etc. (not all supported by LightDB). Encoding forms are not exposed as an SQL object, but are visible in this view.

character set

A named SQL object that identifies a character repertoire, a character encoding, and a default collation. A predefined character set would typically have the same name as an encoding form, but users could define other names. For example, the character set UTF8 would typically identify the character repertoire UCS, encoding form UTF8, and some default collation.

You can think of an “encoding” in LightDB either as a character set or a character encoding form. They will have the same name, and there can only be one in one database.

**Table 35.5. character\_sets Columns**

Column Type	Description
character_set_catalog sql_identifier	Character sets are currently not implemented as schema objects, so this column is null.
character_set_schema sql_identifier	Character sets are currently not implemented as schema objects, so this column is null.
character_set_name sql_identifier	

Column Type	Description
	Name of the character set, currently implemented as showing the name of the database encoding
character_repertoire sql_identifier	Character repertoire, showing UCS if the encoding is UTF8, else just the encoding name
form_of_use sql_identifier	Character encoding form, same as the database encoding
default_collate_catalog sql_identifier	Name of the database containing the default collation (always the current database, if any collation is identified)
default_collate_schema sql_identifier	Name of the schema containing the default collation
default_collate_name sql_identifier	Name of the default collation. The default collation is identified as the collation that matches the COLLATE and CTYPE settings of the current database. If there is no such collation, then this column and the associated schema and catalog columns are null.

## 35.8. check\_constraint\_routine\_usage

The view `check_constraint_routine_usage` identifies routines (functions and procedures) that are used by a check constraint. Only those routines are shown that are owned by a currently enabled role.

**Table 35.6. check\_constraint\_routine\_usage Columns**

Column Type	Description
constraint_catalog sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema containing the constraint
constraint_name sql_identifier	Name of the constraint
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. See Section 35.41 for more information.

## 35.9. check\_constraints

The view `check_constraints` contains all check constraints, either defined on a table or on a domain, that are owned by a currently enabled role. (The owner of the table or domain is the owner of the constraint.)

**Table 35.7. check\_constraints Columns**

Column Type	Description
constraint_catalog sql_identifier	

Column Type	Description
	Name of the database containing the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema containing the constraint
constraint_name sql_identifier	Name of the constraint
check_clause character_data	The check expression of the check constraint

## 35.10. collations

The view `collations` contains the collations available in the current database.

**Table 35.8. collations Columns**

Column Type	Description
collation_catalog sql_identifier	Name of the database containing the collation (always the current database)
collation_schema sql_identifier	Name of the schema containing the collation
collation_name sql_identifier	Name of the default collation
pad_attribute character_data	Always NO PAD (The alternative PAD SPACE is not supported by LightDB.)

## 35.11. collation\_character\_set\_\_applicability

The view `collation_character_set_applicability` identifies which character set the available collations are applicable to. In LightDB, there is only one character set per database (see explanation in Section 35.7), so this view does not provide much useful information.

**Table 35.9. collation\_character\_set\_applicability Columns**

Column Type	Description
collation_catalog sql_identifier	Name of the database containing the collation (always the current database)
collation_schema sql_identifier	Name of the schema containing the collation
collation_name sql_identifier	Name of the default collation
character_set_catalog sql_identifier	Character sets are currently not implemented as schema objects, so this column is null
character_set_schema sql_identifier	Character sets are currently not implemented as schema objects, so this column is null
character_set_name sql_identifier	Name of the character set

## 35.12. column\_column\_usage

The view `column_column_usage` identifies all generated columns that depend on another base column in the same table. Only tables owned by a currently enabled role are included.

**Table 35.10. column\_column\_usage Columns**

Column Type	Description
<code>table_catalog sql_identifier</code>	Name of the database containing the table (always the current database)
<code>table_schema sql_identifier</code>	Name of the schema containing the table
<code>table_name sql_identifier</code>	Name of the table
<code>column_name sql_identifier</code>	Name of the base column that a generated column depends on
<code>dependent_column sql_identifier</code>	Name of the generated column

## 35.13. column\_domain\_usage

The view `column_domain_usage` identifies all columns (of a table or a view) that make use of some domain defined in the current database and owned by a currently enabled role.

**Table 35.11. column\_domain\_usage Columns**

Column Type	Description
<code>domain_catalog sql_identifier</code>	Name of the database containing the domain (always the current database)
<code>domain_schema sql_identifier</code>	Name of the schema containing the domain
<code>domain_name sql_identifier</code>	Name of the domain
<code>table_catalog sql_identifier</code>	Name of the database containing the table (always the current database)
<code>table_schema sql_identifier</code>	Name of the schema containing the table
<code>table_name sql_identifier</code>	Name of the table
<code>column_name sql_identifier</code>	Name of the column

## 35.14. column\_options

The view `column_options` contains all the options defined for foreign table columns in the current database. Only those foreign table columns are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.12. column\_options Columns**

<b>Column Type</b>	<b>Description</b>
table_catalog sql_identifier	Name of the database that contains the foreign table (always the current database)
table_schema sql_identifier	Name of the schema that contains the foreign table
table_name sql_identifier	Name of the foreign table
column_name sql_identifier	Name of the column
option_name sql_identifier	Name of an option
option_value character_data	Value of the option

## 35.15. column\_privileges

The view `column_privileges` identifies all privileges granted on columns to a currently enabled role or by a currently enabled role. There is one row for each combination of column, grantor, and grantee.

If a privilege has been granted on an entire table, it will show up in this view as a grant for each column, but only for the privilege types where column granularity is possible: `SELECT`, `INSERT`, `UPDATE`, `REFERENCES`.

**Table 35.13. column\_privileges Columns**

<b>Column Type</b>	<b>Description</b>
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
table_catalog sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema sql_identifier	Name of the schema that contains the table that contains the column
table_name sql_identifier	Name of the table that contains the column
column_name sql_identifier	Name of the column
privilege_type character_data	Type of the privilege: <code>SELECT</code> , <code>INSERT</code> , <code>UPDATE</code> , or <code>REFERENCES</code>
is_grantable yes_or_no	YES if the privilege is grantable, NO if not

## 35.16. column\_udt\_usage

The view `column_udt_usage` identifies all columns that use data types owned by a currently enabled role. Note that in LightDB, built-in data types behave like user-defined types, so they are included here as well. See also Section 35.17 for details.

**Table 35.14. column\_udt\_usage Columns**

Column Type	Description
<code>udt_catalog sql_identifier</code>	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
<code>udt_schema sql_identifier</code>	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in
<code>udt_name sql_identifier</code>	Name of the column data type (the underlying type of the domain, if applicable)
<code>table_catalog sql_identifier</code>	Name of the database containing the table (always the current database)
<code>table_schema sql_identifier</code>	Name of the schema containing the table
<code>table_name sql_identifier</code>	Name of the table
<code>column_name sql_identifier</code>	Name of the column

## 35.17. columns

The view `columns` contains information about all table columns (or view columns) in the database. System columns (`ctid`, etc.) are not included. Only those columns are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.15. columns Columns**

Column Type	Description
<code>table_catalog sql_identifier</code>	Name of the database containing the table (always the current database)
<code>table_schema sql_identifier</code>	Name of the schema containing the table
<code>table_name sql_identifier</code>	Name of the table
<code>column_name sql_identifier</code>	Name of the column
<code>ordinal_position cardinal_number</code>	Ordinal position of the column within the table (count starts at 1)
<code>column_default character_data</code>	Default expression of the column
<code>is_nullable yes_or_no</code>	YES if the column is possibly nullable, NO if it is known not nullable. A not-null constraint is one way a column can be known not nullable, but there can be others.

<b>Column Type</b>	<b>Description</b>
<code>data_type</code> <code>character_data</code>	Data type of the column, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code> ), else USER-DEFINED (in that case, the type is identified in <code>udt_name</code> and associated columns). If the column is based on a domain, this column refers to the type underlying the domain (and the domain is identified in <code>domain_name</code> and associated columns).
<code>character_maximum_length</code> <code>cardinal_number</code>	If <code>data_type</code> identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
<code>character_octet_length</code> <code>cardinal_number</code>	If <code>data_type</code> identifies a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
<code>numeric_precision</code> <code>cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column contains the (declared or implicit) precision of the type for this column. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>numeric_precision_radix</code> <code>cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10. For all other data types, this column is null.
<code>numeric_scale</code> <code>cardinal_number</code>	If <code>data_type</code> identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this column. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>datetime_precision</code> <code>cardinal_number</code>	If <code>data_type</code> identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this column, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
<code>interval_type</code> <code>character_data</code>	If <code>data_type</code> identifies an interval type, this column contains the specification which fields the intervals include for this column, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
<code>interval_precision</code> <code>cardinal_number</code>	Applies to a feature not available in LightDB (see <code>datetime_precision</code> for the fractional seconds precision of interval type columns)
<code>character_set_catalog</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_schema</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_name</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>collation_catalog</code> <code>sql_identifier</code>	

<b>Column Type</b>	<b>Description</b>
	Name of the database containing the collation of the column (always the current database), null if default or the data type of the column is not collatable
collation_schema sql_identifier	Name of the schema containing the collation of the column, null if default or the data type of the column is not collatable
collation_name sql_identifier	Name of the collation of the column, null if default or the data type of the column is not collatable
domain_catalog sql_identifier	If the column has a domain type, the name of the database that the domain is defined in (always the current database), else null.
domain_schema sql_identifier	If the column has a domain type, the name of the schema that the domain is defined in, else null.
domain_name sql_identifier	If the column has a domain type, the name of the domain, else null.
udt_catalog sql_identifier	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
udt_schema sql_identifier	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in
udt_name sql_identifier	Name of the column data type (the underlying type of the domain, if applicable)
scope_catalog sql_identifier	Applies to a feature not available in LightDB
scope_schema sql_identifier	Applies to a feature not available in LightDB
scope_name sql_identifier	Applies to a feature not available in LightDB
maximum_cardinality cardinal_number	Always null, because arrays always have unlimited maximum cardinality in LightDB
dtd_identifier sql_identifier	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
is_self_referencing yes_or_no	Applies to a feature not available in LightDB
is_identity yes_or_no	If the column is an identity column, then YES, else NO.
identity_generation character_data	If the column is an identity column, then ALWAYS or BY DEFAULT, reflecting the definition of the column.
identity_start character_data	If the column is an identity column, then the start value of the internal sequence, else null.
identity_increment character_data	



<b>Column Type</b>	<b>Description</b>
	If the column is an identity column, then the increment of the internal sequence, else null.
<code>identity_maximum</code> <code>character_data</code>	If the column is an identity column, then the maximum value of the internal sequence, else null.
<code>identity_minimum</code> <code>character_data</code>	If the column is an identity column, then the minimum value of the internal sequence, else null.
<code>identity_cycle</code> <code>yes_or_no</code>	If the column is an identity column, then YES if the internal sequence cycles or NO if it does not; otherwise null.
<code>is_generated</code> <code>character_data</code>	If the column is a generated column, then ALWAYS, else NEVER.
<code>generation_expression</code> <code>character_data</code>	If the column is a generated column, then the generation expression, else null.
<code>is_updatable</code> <code>yes_or_no</code>	YES if the column is updatable, NO if not (Columns in base tables are always updatable, columns in views not necessarily)

Since data types can be defined in a variety of ways in SQL, and LightDB contains additional ways to define data types, their representation in the information schema can be somewhat difficult. The column `data_type` is supposed to identify the underlying built-in type of the column. In LightDB, this means that the type is defined in the system catalog schema `pg_catalog`. This column might be useful if the application can handle the well-known built-in types specially (for example, format the numeric types differently or use the data in the precision columns). The columns `udt_name`, `udt_schema`, and `udt_catalog` always identify the underlying data type of the column, even if the column is based on a domain. (Since LightDB treats built-in types like user-defined types, built-in types appear here as well. This is an extension of the SQL standard.) These columns should be used if an application wants to process data differently according to the type, because in that case it wouldn't matter if the column is really based on a domain. If the column is based on a domain, the identity of the domain is stored in the columns `domain_name`, `domain_schema`, and `domain_catalog`. If you want to pair up columns with their associated data types and treat domains as separate types, you could write `coalesce(domain_name, udt_name)`, etc.

## 35.18. `constraint_column_usage`

The view `constraint_column_usage` identifies all columns in the current database that are used by some constraint. Only those columns are shown that are contained in a table owned by a currently enabled role. For a check constraint, this view identifies the columns that are used in the check expression. For a foreign key constraint, this view identifies the columns that the foreign key references. For a unique or primary key constraint, this view identifies the constrained columns.

**Table 35.16. `constraint_column_usage` Columns**

<b>Column Type</b>	<b>Description</b>
<code>table_catalog</code> <code>sql_identifier</code>	Name of the database that contains the table that contains the column that is used by some constraint (always the current database)
<code>table_schema</code> <code>sql_identifier</code>	Name of the schema that contains the table that contains the column that is used by some constraint

Column Type	Description
table_name sql_identifier	Name of the table that contains the column that is used by some constraint
column_name sql_identifier	Name of the column that is used by some constraint
constraint_catalog sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema that contains the constraint
constraint_name sql_identifier	Name of the constraint

## 35.19. constraint\_table\_usage

The view `constraint_table_usage` identifies all tables in the current database that are used by some constraint and are owned by a currently enabled role. (This is different from the view `table_constraints`, which identifies all table constraints along with the table they are defined on.) For a foreign key constraint, this view identifies the table that the foreign key references. For a unique or primary key constraint, this view simply identifies the table the constraint belongs to. Check constraints and not-null constraints are not included in this view.

**Table 35.17. constraint\_table\_usage Columns**

Column Type	Description
table_catalog sql_identifier	Name of the database that contains the table that is used by some constraint (always the current database)
table_schema sql_identifier	Name of the schema that contains the table that is used by some constraint
table_name sql_identifier	Name of the table that is used by some constraint
constraint_catalog sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema that contains the constraint
constraint_name sql_identifier	Name of the constraint

## 35.20. data\_type\_privileges

The view `data_type_privileges` identifies all data type descriptors that the current user has access to, by way of being the owner of the described object or having some privilege for it. A data type descriptor is generated whenever a data type is used in the definition of a table column, a domain, or a function (as parameter or return type) and stores some information about how the data type is used in that instance (for example, the declared maximum length, if applicable). Each data type descriptor is assigned an arbitrary identifier that is unique among the data type descriptor identifiers assigned for one object (table, domain, function). This view is probably not useful for applications, but it is used to define some other views in the information schema.

**Table 35.18. data\_type\_privileges Columns**

<b>Column Type</b>	<b>Description</b>
object_catalog sql_identifier	Name of the database that contains the described object (always the current database)
object_schema sql_identifier	Name of the schema that contains the described object
object_name sql_identifier	Name of the described object
object_type character_data	The type of the described object: one of TABLE (the data type descriptor pertains to a column of that table), DOMAIN (the data type descriptors pertains to that domain), ROUTINE (the data type descriptor pertains to a parameter or the return data type of that function).
dtd_identifier sql_identifier	The identifier of the data type descriptor, which is unique among the data type descriptors for that same object.

## 35.21. domain\_constraints

The view `domain_constraints` contains all constraints belonging to domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.19. domain\_constraints Columns**

<b>Column Type</b>	<b>Description</b>
constraint_catalog sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema that contains the constraint
constraint_name sql_identifier	Name of the constraint
domain_catalog sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema sql_identifier	Name of the schema that contains the domain
domain_name sql_identifier	Name of the domain
is_deferrable yes_or_no	YES if the constraint is deferrable, NO if not
initially_deferred yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not

## 35.22. domain\_udt\_usage

The view `domain_udt_usage` identifies all domains that are based on data types owned by a currently enabled role. Note that in LightDB, built-in data types behave like user-defined types, so they are included here as well.

**Table 35.20. domain\_udt\_usage Columns**

<b>Column Type</b>	<b>Description</b>
udt_catalog sql_identifier	Name of the database that the domain data type is defined in (always the current database)
udt_schema sql_identifier	Name of the schema that the domain data type is defined in
udt_name sql_identifier	Name of the domain data type
domain_catalog sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema sql_identifier	Name of the schema that contains the domain
domain_name sql_identifier	Name of the domain

## 35.23. domains

The view `domains` contains all domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.21. domains Columns**

<b>Column Type</b>	<b>Description</b>
domain_catalog sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema sql_identifier	Name of the schema that contains the domain
domain_name sql_identifier	Name of the domain
data_type character_data	Data type of the domain, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code> ), else USER-DEFINED (in that case, the type is identified in <code>udt_name</code> and associated columns).
character_maximum_length cardinal_number	If the domain has a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length cardinal_number	If the domain has a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog sql_identifier	Applies to a feature not available in LightDB
character_set_schema sql_identifier	Applies to a feature not available in LightDB
character_set_name sql_identifier	Applies to a feature not available in LightDB
collation_catalog sql_identifier	

<b>Column Type</b>	<b>Description</b>
	Name of the database containing the collation of the domain (always the current database), null if default or the data type of the domain is not collatable
collation_schema sql_identifier	Name of the schema containing the collation of the domain, null if default or the data type of the domain is not collatable
collation_name sql_identifier	Name of the collation of the domain, null if default or the data type of the domain is not collatable
numeric_precision cardinal_number	If the domain has a numeric type, this column contains the (declared or implicit) precision of the type for this domain. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
numeric_precision_radix cardinal_number	If the domain has a numeric type, this column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale cardinal_number	If the domain has an exact numeric type, this column contains the (declared or implicit) scale of the type for this domain. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
datetime_precision cardinal_number	If data_type identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this domain, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
interval_type character_data	If data_type identifies an interval type, this column contains the specification which fields the intervals include for this domain, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
interval_precision cardinal_number	Applies to a feature not available in LightDB (see datetime_precision for the fractional seconds precision of interval type domains)
domain_default character_data	Default expression of the domain
udt_catalog sql_identifier	Name of the database that the domain data type is defined in (always the current database)
udt_schema sql_identifier	Name of the schema that the domain data type is defined in
udt_name sql_identifier	Name of the domain data type
scope_catalog sql_identifier	Applies to a feature not available in LightDB
scope_schema sql_identifier	Applies to a feature not available in LightDB

Column Type	Description
<code>scope_name sql_identifier</code>	Applies to a feature not available in LightDB
<code>maximum_cardinality cardinal_number</code>	Always null, because arrays always have unlimited maximum cardinality in LightDB
<code>dtd_identifier sql_identifier</code>	An identifier of the data type descriptor of the domain, unique among the data type descriptors pertaining to the domain (which is trivial, because a domain only contains one data type descriptor). This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)

## 35.24. `element_types`

The view `element_types` contains the data type descriptors of the elements of arrays. When a table column, composite-type attribute, domain, function parameter, or function return value is defined to be of an array type, the respective information schema view only contains `ARRAY` in the column `data_type`. To obtain information on the element type of the array, you can join the respective view with this view. For example, to show the columns of a table with data types and array element types, if applicable, you could do:

```
SELECT c.column_name, c.data_type, e.data_type AS element_type
FROM information_schema.columns c LEFT JOIN
information_schema.element_types e
ON ((c.table_catalog, c.table_schema, c.table_name, 'TABLE',
c.dtd_identifier)
= (e.object_catalog, e.object_schema, e.object_name,
e.object_type, e.collection_type_identifier))
WHERE c.table_schema = '...' AND c.table_name = '...'
ORDER BY c.ordinal_position;
```

This view only includes objects that the current user has access to, by way of being the owner or having some privilege.

**Table 35.22. `element_types` Columns**

Column Type	Description
<code>object_catalog sql_identifier</code>	Name of the database that contains the object that uses the array being described (always the current database)
<code>object_schema sql_identifier</code>	Name of the schema that contains the object that uses the array being described
<code>object_name sql_identifier</code>	Name of the object that uses the array being described
<code>object_type character_data</code>	The type of the object that uses the array being described: one of <code>TABLE</code> (the array is used by a column of that table), <code>USER-DEFINED TYPE</code> (the array is used by an attribute of that composite type), <code>DOMAIN</code> (the array is used by that domain), <code>ROUTINE</code> (the array is used by a parameter or the return data type of that function).
<code>collection_type_identifier sql_identifier</code>	The identifier of the data type descriptor of the array being described. Use this to join with the <code>dtd_identifier</code> columns of other information schema views.

<b>Column Type</b>	<b>Description</b>
<code>data_type</code> <code>character_data</code>	Data type of the array elements, if it is a built-in type, else USER-DEFINED (in that case, the type is identified in <code>udt_name</code> and associated columns).
<code>character_maximum_length</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>character_octet_length</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>character_set_catalog</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_schema</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_name</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>collation_catalog</code> <code>sql_identifier</code>	Name of the database containing the collation of the element type (always the current database), null if default or the data type of the element is not collatable
<code>collation_schema</code> <code>sql_identifier</code>	Name of the schema containing the collation of the element type, null if default or the data type of the element is not collatable
<code>collation_name</code> <code>sql_identifier</code>	Name of the collation of the element type, null if default or the data type of the element is not collatable
<code>numeric_precision</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>numeric_precision_radix</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>numeric_scale</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>datetime_precision</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>interval_type</code> <code>character_data</code>	Always null, since this information is not applied to array element data types in LightDB
<code>interval_precision</code> <code>cardinal_number</code>	Always null, since this information is not applied to array element data types in LightDB
<code>domain_default</code> <code>character_data</code>	Not yet implemented
<code>udt_catalog</code> <code>sql_identifier</code>	Name of the database that the data type of the elements is defined in (always the current database)
<code>udt_schema</code> <code>sql_identifier</code>	Name of the schema that the data type of the elements is defined in
<code>udt_name</code> <code>sql_identifier</code>	Name of the data type of the elements
<code>scope_catalog</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>scope_schema</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB

Column Type	Description
scope_name sql_identifier	Applies to a feature not available in LightDB
maximum_cardinality cardinal_number	Always null, because arrays always have unlimited maximum cardinality in LightDB
dtd_identifier sql_identifier	An identifier of the data type descriptor of the element. This is currently not useful.

## 35.25. enabled\_roles

The view `enabled_roles` identifies the currently “enabled roles”. The enabled roles are recursively defined as the current user together with all roles that have been granted to the enabled roles with automatic inheritance. In other words, these are all roles that the current user has direct or indirect, automatically inheriting membership in.

For permission checking, the set of “applicable roles” is applied, which can be broader than the set of enabled roles. So generally, it is better to use the view `applicable_roles` instead of this one; See Section 35.5 for details on `applicable_roles` view.

**Table 35.23. enabled\_roles Columns**

Column Type	Description
role_name sql_identifier	Name of a role

## 35.26. foreign\_data\_wrapper\_options

The view `foreign_data_wrapper_options` contains all the options defined for foreign-data wrappers in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.24. foreign\_data\_wrapper\_options Columns**

Column Type	Description
foreign_data_wrapper_catalog sql_identifier	Name of the database that the foreign-data wrapper is defined in (always the current database)
foreign_data_wrapper_name sql_identifier	Name of the foreign-data wrapper
option_name sql_identifier	Name of an option
option_value character_data	Value of the option

## 35.27. foreign\_data\_wrappers

The view `foreign_data_wrappers` contains all foreign-data wrappers defined in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).



**Table 35.25. foreign\_data\_wrappers Columns**

Column Type	Description
foreign_data_wrapper_catalog sql_identifier	Name of the database that contains the foreign-data wrapper (always the current database)
foreign_data_wrapper_name sql_identifier	Name of the foreign-data wrapper
authorization_identifier sql_identifier	Name of the owner of the foreign server
library_name character_data	File name of the library that implementing this foreign-data wrapper
foreign_data_wrapper_language character_data	Language used to implement this foreign-data wrapper

## 35.28. foreign\_server\_options

The view `foreign_server_options` contains all the options defined for foreign servers in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.26. foreign\_server\_options Columns**

Column Type	Description
foreign_server_catalog sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name sql_identifier	Name of the foreign server
option_name sql_identifier	Name of an option
option_value character_data	Value of the option

## 35.29. foreign\_servers

The view `foreign_servers` contains all foreign servers defined in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.27. foreign\_servers Columns**

Column Type	Description
foreign_server_catalog sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name sql_identifier	Name of the foreign server
foreign_data_wrapper_catalog sql_identifier	Name of the database that contains the foreign-data wrapper used by the foreign server (always the current database)

Column Type	Description
foreign_data_wrapper_name sql_identifier	Name of the foreign-data wrapper used by the foreign server
foreign_server_type character_data	Foreign server type information, if specified upon creation
foreign_server_version character_data	Foreign server version information, if specified upon creation
authorization_identifier sql_identifier	Name of the owner of the foreign server

## 35.30. foreign\_table\_options

The view `foreign_table_options` contains all the options defined for foreign tables in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.28. foreign\_table\_options Columns**

Column Type	Description
foreign_table_catalog sql_identifier	Name of the database that contains the foreign table (always the current database)
foreign_table_schema sql_identifier	Name of the schema that contains the foreign table
foreign_table_name sql_identifier	Name of the foreign table
option_name sql_identifier	Name of an option
option_value character_data	Value of the option

## 35.31. foreign\_tables

The view `foreign_tables` contains all foreign tables defined in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.29. foreign\_tables Columns**

Column Type	Description
foreign_table_catalog sql_identifier	Name of the database that the foreign table is defined in (always the current database)
foreign_table_schema sql_identifier	Name of the schema that contains the foreign table
foreign_table_name sql_identifier	Name of the foreign table
foreign_server_catalog sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name sql_identifier	Name of the foreign server

## 35.32. key\_column\_usage

The view `key_column_usage` identifies all columns in the current database that are restricted by some unique, primary key, or foreign key constraint. Check constraints are not included in this view. Only those columns are shown that the current user has access to, by way of being the owner or having some privilege.

**Table 35.30. key\_column\_usage Columns**

Column Type	Description
<code>constraint_catalog sql_identifier</code>	Name of the database that contains the constraint (always the current database)
<code>constraint_schema sql_identifier</code>	Name of the schema that contains the constraint
<code>constraint_name sql_identifier</code>	Name of the constraint
<code>table_catalog sql_identifier</code>	Name of the database that contains the table that contains the column that is restricted by this constraint (always the current database)
<code>table_schema sql_identifier</code>	Name of the schema that contains the table that contains the column that is restricted by this constraint
<code>table_name sql_identifier</code>	Name of the table that contains the column that is restricted by this constraint
<code>column_name sql_identifier</code>	Name of the column that is restricted by this constraint
<code>ordinal_position cardinal_number</code>	Ordinal position of the column within the constraint key (count starts at 1)
<code>position_in_unique_constraint cardinal_number</code>	For a foreign-key constraint, ordinal position of the referenced column within its unique constraint (count starts at 1); otherwise null

## 35.33. parameters

The view `parameters` contains information about the parameters (arguments) of all functions in the current database. Only those functions are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.31. parameters Columns**

Column Type	Description
<code>specific_catalog sql_identifier</code>	Name of the database containing the function (always the current database)
<code>specific_schema sql_identifier</code>	Name of the schema containing the function
<code>specific_name sql_identifier</code>	The “specific name” of the function. See Section 35.41 for more information.
<code>ordinal_position cardinal_number</code>	Ordinal position of the parameter in the argument list of the function (count starts at 1)
<code>parameter_mode character_data</code>	

<b>Column Type</b>	<b>Description</b>
	IN for input parameter, OUT for output parameter, and INOUT for input/output parameter.
is_result yes_or_no	Applies to a feature not available in LightDB
as_locator yes_or_no	Applies to a feature not available in LightDB
parameter_name sql_identifier	Name of the parameter, or null if the parameter has no name
data_type character_data	Data type of the parameter, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in udt_name and associated columns).
character_maximum_length cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
character_octet_length cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
character_set_catalog sql_identifier	Applies to a feature not available in LightDB
character_set_schema sql_identifier	Applies to a feature not available in LightDB
character_set_name sql_identifier	Applies to a feature not available in LightDB
collation_catalog sql_identifier	Always null, since this information is not applied to parameter data types in LightDB
collation_schema sql_identifier	Always null, since this information is not applied to parameter data types in LightDB
collation_name sql_identifier	Always null, since this information is not applied to parameter data types in LightDB
numeric_precision cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
numeric_precision_radix cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
numeric_scale cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
datetime_precision cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
interval_type character_data	Always null, since this information is not applied to parameter data types in LightDB
interval_precision cardinal_number	Always null, since this information is not applied to parameter data types in LightDB
udt_catalog sql_identifier	Name of the database that the data type of the parameter is defined in (always the current database)
udt_schema sql_identifier	Name of the schema that the data type of the parameter is defined in
udt_name sql_identifier	Name of the data type of the parameter

<b>Column Type</b>	<b>Description</b>
scope_catalog sql_identifier	Applies to a feature not available in LightDB
scope_schema sql_identifier	Applies to a feature not available in LightDB
scope_name sql_identifier	Applies to a feature not available in LightDB
maximum_cardinality cardinal_number	Always null, because arrays always have unlimited maximum cardinality in LightDB
dtd_identifier sql_identifier	An identifier of the data type descriptor of the parameter, unique among the data type descriptors pertaining to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
parameter_default character_data	The default expression of the parameter, or null if none or if the function is not owned by a currently enabled role.

## 35.34. referential\_constraints

The view `referential_constraints` contains all referential (foreign key) constraints in the current database. Only those constraints are shown for which the current user has write access to the referencing table (by way of being the owner or having some privilege other than `SELECT`).

**Table 35.32. referential\_constraints Columns**

<b>Column Type</b>	<b>Description</b>
constraint_catalog sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema sql_identifier	Name of the schema containing the constraint
constraint_name sql_identifier	Name of the constraint
unique_constraint_catalog sql_identifier	Name of the database that contains the unique or primary key constraint that the foreign key constraint references (always the current database)
unique_constraint_schema sql_identifier	Name of the schema that contains the unique or primary key constraint that the foreign key constraint references
unique_constraint_name sql_identifier	Name of the unique or primary key constraint that the foreign key constraint references
match_option character_data	Match option of the foreign key constraint: <code>FULL</code> , <code>PARTIAL</code> , or <code>NONE</code> .
update_rule character_data	Update rule of the foreign key constraint: <code>CASCADE</code> , <code>SET NULL</code> , <code>SET DEFAULT</code> , <code>RESTRICT</code> , or <code>NO ACTION</code> .
delete_rule character_data	Delete rule of the foreign key constraint: <code>CASCADE</code> , <code>SET NULL</code> , <code>SET DEFAULT</code> , <code>RESTRICT</code> , or <code>NO ACTION</code> .

## 35.35. role\_column\_grants

The view `role_column_grants` identifies all privileges granted on columns where the grantor or grantee is a currently enabled role. Further information can be found under `column_privileges`. The only effective difference between this view and `column_privileges` is that this view omits columns that have been made accessible to the current user by way of a grant to PUBLIC.

**Table 35.33. role\_column\_grants Columns**

Column Type	Description
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
table_catalog sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema sql_identifier	Name of the schema that contains the table that contains the column
table_name sql_identifier	Name of the table that contains the column
column_name sql_identifier	Name of the column
privilege_type character_data	Type of the privilege: SELECT, INSERT, UPDATE, or REFERENCES
is_grantable yes_or_no	YES if the privilege is grantable, NO if not

## 35.36. role\_routine\_grants

The view `role_routine_grants` identifies all privileges granted on functions where the grantor or grantee is a currently enabled role. Further information can be found under `routine_privileges`. The only effective difference between this view and `routine_privileges` is that this view omits functions that have been made accessible to the current user by way of a grant to PUBLIC.

**Table 35.34. role\_routine\_grants Columns**

Column Type	Description
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. See Section 35.41 for more information.

Column Type	Description
<code>routine_catalog</code> <code>sql_identifier</code>	Name of the database containing the function (always the current database)
<code>routine_schema</code> <code>sql_identifier</code>	Name of the schema containing the function
<code>routine_name</code> <code>sql_identifier</code>	Name of the function (might be duplicated in case of overloading)
<code>privilege_type</code> <code>character_data</code>	Always EXECUTE (the only privilege type for functions)
<code>is_grantable</code> <code>yes_or_no</code>	YES if the privilege is grantable, NO if not

## 35.37. `role_table_grants`

The view `role_table_grants` identifies all privileges granted on tables or views where the grantor or grantee is a currently enabled role. Further information can be found under `table_privileges`. The only effective difference between this view and `table_privileges` is that this view omits tables that have been made accessible to the current user by way of a grant to PUBLIC.

**Table 35.35. `role_table_grants` Columns**

Column Type	Description
<code>grantor</code> <code>sql_identifier</code>	Name of the role that granted the privilege
<code>grantee</code> <code>sql_identifier</code>	Name of the role that the privilege was granted to
<code>table_catalog</code> <code>sql_identifier</code>	Name of the database that contains the table (always the current database)
<code>table_schema</code> <code>sql_identifier</code>	Name of the schema that contains the table
<code>table_name</code> <code>sql_identifier</code>	Name of the table
<code>privilege_type</code> <code>character_data</code>	Type of the privilege: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER
<code>is_grantable</code> <code>yes_or_no</code>	YES if the privilege is grantable, NO if not
<code>with_hierarchy</code> <code>yes_or_no</code>	In the SQL standard, WITH HIERARCHY OPTION is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In LightDB, this is included in the SELECT privilege, so this column shows YES if the privilege is SELECT, else NO.

## 35.38. `role_udt_grants`

The view `role_udt_grants` is intended to identify USAGE privileges granted on user-defined types where the grantor or grantee is a currently enabled role. Further information can be found under `udt_privileges`. The only effective difference between this view and `udt_privileges` is that this view omits objects that have been made accessible to the current user by way of a grant

to PUBLIC. Since data types do not have real privileges in LightDB, but only an implicit grant to PUBLIC, this view is empty.

**Table 35.36. role\_udt\_grants Columns**

<b>Column Type</b>	<b>Description</b>
grantor sql_identifier	The name of the role that granted the privilege
grantee sql_identifier	The name of the role that the privilege was granted to
udt_catalog sql_identifier	Name of the database containing the type (always the current database)
udt_schema sql_identifier	Name of the schema containing the type
udt_name sql_identifier	Name of the type
privilege_type character_data	Always TYPE USAGE
is_grantable yes_or_no	YES if the privilege is grantable, NO if not

## 35.39. role\_usage\_grants

The view `role_usage_grants` identifies USAGE privileges granted on various kinds of objects where the grantor or grantee is a currently enabled role. Further information can be found under `usage_privileges`. The only effective difference between this view and `usage_privileges` is that this view omits objects that have been made accessible to the current user by way of a grant to PUBLIC.

**Table 35.37. role\_usage\_grants Columns**

<b>Column Type</b>	<b>Description</b>
grantor sql_identifier	The name of the role that granted the privilege
grantee sql_identifier	The name of the role that the privilege was granted to
object_catalog sql_identifier	Name of the database containing the object (always the current database)
object_schema sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name sql_identifier	Name of the object
object_type character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type character_data	Always USAGE
is_grantable yes_or_no	YES if the privilege is grantable, NO if not



## 35.40. routine\_privileges

The view `routine_privileges` identifies all privileges granted on functions to a currently enabled role or by a currently enabled role. There is one row for each combination of function, grantor, and grantee.

**Table 35.38. routine\_privileges Columns**

Column Type	Description
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. See Section 35.41 for more information.
routine_catalog sql_identifier	Name of the database containing the function (always the current database)
routine_schema sql_identifier	Name of the schema containing the function
routine_name sql_identifier	Name of the function (might be duplicated in case of overloading)
privilege_type character_data	Always EXECUTE (the only privilege type for functions)
is_grantable yes_or_no	YES if the privilege is grantable, NO if not

## 35.41. routines

The view `routines` contains all functions and procedures in the current database. Only those functions and procedures are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.39. routines Columns**

Column Type	Description
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. This is a name that uniquely identifies the function in the schema, even if the real name of the function is overloaded. The format of the specific name is not defined, it should only be used to compare it to other instances of specific routine names.
routine_catalog sql_identifier	Name of the database containing the function (always the current database)

<b>Column Type</b>	<b>Description</b>
<code>routine_schema sql_identifier</code>	Name of the schema containing the function
<code>routine_name sql_identifier</code>	Name of the function (might be duplicated in case of overloading)
<code>routine_type character_data</code>	FUNCTION for a function, PROCEDURE for a procedure
<code>module_catalog sql_identifier</code>	Applies to a feature not available in LightDB
<code>module_schema sql_identifier</code>	Applies to a feature not available in LightDB
<code>module_name sql_identifier</code>	Applies to a feature not available in LightDB
<code>udt_catalog sql_identifier</code>	Applies to a feature not available in LightDB
<code>udt_schema sql_identifier</code>	Applies to a feature not available in LightDB
<code>udt_name sql_identifier</code>	Applies to a feature not available in LightDB
<code>data_type character_data</code>	Return data type of the function, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code> ), else USER-DEFINED (in that case, the type is identified in <code>type_udt_name</code> and associated columns). Null for a procedure.
<code>character_maximum_length cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>character_octet_length cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>character_set_catalog sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_schema sql_identifier</code>	Applies to a feature not available in LightDB
<code>character_set_name sql_identifier</code>	Applies to a feature not available in LightDB
<code>collation_catalog sql_identifier</code>	Always null, since this information is not applied to return data types in LightDB
<code>collation_schema sql_identifier</code>	Always null, since this information is not applied to return data types in LightDB
<code>collation_name sql_identifier</code>	Always null, since this information is not applied to return data types in LightDB
<code>numeric_precision cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>numeric_precision_radix cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>numeric_scale cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>datetime_precision cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>interval_type character_data</code>	

<b>Column Type</b>	<b>Description</b>
	Always null, since this information is not applied to return data types in LightDB
<code>interval_precision</code> <code>cardinal_number</code>	Always null, since this information is not applied to return data types in LightDB
<code>type_udt_catalog</code> <code>sql_identifier</code>	Name of the database that the return data type of the function is defined in (always the current database). Null for a procedure.
<code>type_udt_schema</code> <code>sql_identifier</code>	Name of the schema that the return data type of the function is defined in. Null for a procedure.
<code>type_udt_name</code> <code>sql_identifier</code>	Name of the return data type of the function. Null for a procedure.
<code>scope_catalog</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>scope_schema</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>scope_name</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>maximum_cardinality</code> <code>cardinal_number</code>	Always null, because arrays always have unlimited maximum cardinality in LightDB
<code>dtd_identifier</code> <code>sql_identifier</code>	An identifier of the data type descriptor of the return data type of this function, unique among the data type descriptors pertaining to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
<code>routine_body</code> <code>character_data</code>	If the function is an SQL function, then SQL, else EXTERNAL.
<code>routine_definition</code> <code>character_data</code>	The source text of the function (null if the function is not owned by a currently enabled role). (According to the SQL standard, this column is only applicable if <code>routine_body</code> is SQL, but in LightDB it will contain whatever source text was specified when the function was created.)
<code>external_name</code> <code>character_data</code>	If this function is a C function, then the external name (link symbol) of the function; else null. (This works out to be the same value that is shown in <code>routine_definition</code> .)
<code>external_language</code> <code>character_data</code>	The language the function is written in
<code>parameter_style</code> <code>character_data</code>	Always GENERAL (The SQL standard defines other parameter styles, which are not available in LightDB.)
<code>is_deterministic</code> <code>yes_or_no</code>	If the function is declared immutable (called deterministic in the SQL standard), then YES, else NO. (You cannot query the other volatility levels available in LightDB through the information schema.)
<code>sql_data_access</code> <code>character_data</code>	Always MODIFIES, meaning that the function possibly modifies SQL data. This information is not useful for LightDB.
<code>is_null_call</code> <code>yes_or_no</code>	If the function automatically returns null if any of its arguments are null, then YES, else NO. Null for a procedure.

<b>Column Type</b>	<b>Description</b>
sql_path character_data	Applies to a feature not available in LightDB
schema_level_routine yes_or_no	Always YES (The opposite would be a method of a user-defined type, which is a feature not available in LightDB.)
max_dynamic_result_sets cardinal_number	Applies to a feature not available in LightDB
is_user_defined_cast yes_or_no	Applies to a feature not available in LightDB
is_implicitly_invocable yes_or_no	Applies to a feature not available in LightDB
security_type character_data	If the function runs with the privileges of the current user, then INVOKER, if the function runs with the privileges of the user who defined it, then DEFINER.
to_sql_specific_catalog sql_identifier	Applies to a feature not available in LightDB
to_sql_specific_schema sql_identifier	Applies to a feature not available in LightDB
to_sql_specific_name sql_identifier	Applies to a feature not available in LightDB
as_locator yes_or_no	Applies to a feature not available in LightDB
created time_stamp	Applies to a feature not available in LightDB
last_altered time_stamp	Applies to a feature not available in LightDB
new_savepoint_level yes_or_no	Applies to a feature not available in LightDB
is_udt_dependent yes_or_no	Currently always NO. The alternative YES applies to a feature not available in LightDB.
result_cast_from_data_type character_data	Applies to a feature not available in LightDB
result_cast_as_locator yes_or_no	Applies to a feature not available in LightDB
result_cast_char_max_length cardinal_number	Applies to a feature not available in LightDB
result_cast_char_octet_length cardinal_number	Applies to a feature not available in LightDB
result_cast_char_set_catalog sql_identifier	Applies to a feature not available in LightDB
result_cast_char_set_schema sql_identifier	Applies to a feature not available in LightDB
result_cast_char_set_name sql_identifier	Applies to a feature not available in LightDB
result_cast_collation_catalog sql_identifier	Applies to a feature not available in LightDB
result_cast_collation_schema sql_identifier	

<b>Column Type</b>	<b>Description</b>
	Applies to a feature not available in LightDB
result_cast_collation_name sql_identifier	Applies to a feature not available in LightDB
result_cast_numeric_precision cardinal_number	Applies to a feature not available in LightDB
result_cast_numeric_precision_radix cardinal_number	Applies to a feature not available in LightDB
result_cast_numeric_scale cardinal_number	Applies to a feature not available in LightDB
result_cast_datetime_precision cardinal_number	Applies to a feature not available in LightDB
result_cast_interval_type character_data	Applies to a feature not available in LightDB
result_cast_interval_precision cardinal_number	Applies to a feature not available in LightDB
result_cast_type_udt_catalog sql_identifier	Applies to a feature not available in LightDB
result_cast_type_udt_schema sql_identifier	Applies to a feature not available in LightDB
result_cast_type_udt_name sql_identifier	Applies to a feature not available in LightDB
result_cast_scope_catalog sql_identifier	Applies to a feature not available in LightDB
result_cast_scope_schema sql_identifier	Applies to a feature not available in LightDB
result_cast_scope_name sql_identifier	Applies to a feature not available in LightDB
result_cast_maximum_cardinality cardinal_number	Applies to a feature not available in LightDB
result_cast_dtd_identifier sql_identifier	Applies to a feature not available in LightDB

## 35.42. schemata

The view `schemata` contains all schemas in the current database that the current user has access to (by way of being the owner or having some privilege).

**Table 35.40. schemata Columns**

<b>Column Type</b>	<b>Description</b>
catalog_name sql_identifier	Name of the database that the schema is contained in (always the current database)
schema_name sql_identifier	Name of the schema
schema_owner sql_identifier	Name of the owner of the schema
default_character_set_catalog sql_identifier	

<b>Column Type</b>	<b>Description</b>
	Applies to a feature not available in LightDB
default_character_set_schema sql_identifier	Applies to a feature not available in LightDB
default_character_set_name sql_identifier	Applies to a feature not available in LightDB
sql_path character_data	Applies to a feature not available in LightDB

## 35.43. sequences

The view `sequences` contains all sequences defined in the current database. Only those sequences are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.41. sequences Columns**

<b>Column Type</b>	<b>Description</b>
sequence_catalog sql_identifier	Name of the database that contains the sequence (always the current database)
sequence_schema sql_identifier	Name of the schema that contains the sequence
sequence_name sql_identifier	Name of the sequence
data_type character_data	The data type of the sequence.
numeric_precision cardinal_number	This column contains the (declared or implicit) precision of the sequence data type (see above). The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> .
numeric_precision_radix cardinal_number	This column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10.
numeric_scale cardinal_number	This column contains the (declared or implicit) scale of the sequence data type (see above). The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> .
start_value character_data	The start value of the sequence
minimum_value character_data	The minimum value of the sequence
maximum_value character_data	The maximum value of the sequence
increment character_data	The increment of the sequence
cycle_option yes_or_no	YES if the sequence cycles, else NO

Note that in accordance with the SQL standard, the start, minimum, maximum, and increment values are returned as character strings.

## 35.44. sql\_features

The table `sql_features` contains information about which formal features defined in the SQL standard are supported by LightDB. This is the same information that is presented in Appendix D. There you can also find some additional background information.

**Table 35.42. sql\_features Columns**

Column Type	Description
<code>feature_id</code> <code>character_data</code>	Identifier string of the feature
<code>feature_name</code> <code>character_data</code>	Descriptive name of the feature
<code>sub_feature_id</code> <code>character_data</code>	Identifier string of the subfeature, or a zero-length string if not a subfeature
<code>sub_feature_name</code> <code>character_data</code>	Descriptive name of the subfeature, or a zero-length string if not a subfeature
<code>is_supported</code> <code>yes_or_no</code>	YES if the feature is fully supported by the current version of LightDB, NO if not
<code>is_verified_by</code> <code>character_data</code>	Always null, since the LightDB development group does not perform formal testing of feature conformance
<code>comments</code> <code>character_data</code>	Possibly a comment about the supported status of the feature

## 35.45. sql\_implementation\_info

The table `sql_implementation_info` contains information about various aspects that are left implementation-defined by the SQL standard. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual implementation information items are not described here; you will find them in the description of the ODBC interface.

**Table 35.43. sql\_implementation\_info Columns**

Column Type	Description
<code>implementation_info_id</code> <code>character_data</code>	Identifier string of the implementation information item
<code>implementation_info_name</code> <code>character_data</code>	Descriptive name of the implementation information item
<code>integer_value</code> <code>cardinal_number</code>	Value of the implementation information item, or null if the value is contained in the column <code>character_value</code>
<code>character_value</code> <code>character_data</code>	Value of the implementation information item, or null if the value is contained in the column <code>integer_value</code>
<code>comments</code> <code>character_data</code>	Possibly a comment pertaining to the implementation information item

## 35.46. sql\_parts

The table `sql_parts` contains information about which of the several parts of the SQL standard are supported by LightDB.

**Table 35.44. sql\_parts Columns**

Column Type	Description
feature_id character_data	An identifier string containing the number of the part
feature_name character_data	Descriptive name of the part
is_supported yes_or_no	YES if the part is fully supported by the current version of LightDB, NO if not
is_verified_by character_data	Always null, since the LightDB development group does not perform formal testing of feature conformance
comments character_data	Possibly a comment about the supported status of the part

## 35.47. sql\_sizing

The table `sql_sizing` contains information about various size limits and maximum values in LightDB. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual sizing items are not described here; you will find them in the description of the ODBC interface.

**Table 35.45. sql\_sizing Columns**

Column Type	Description
sizing_id cardinal_number	Identifier of the sizing item
sizing_name character_data	Descriptive name of the sizing item
supported_value cardinal_number	Value of the sizing item, or 0 if the size is unlimited or cannot be determined, or null if the features for which the sizing item is applicable are not supported
comments character_data	Possibly a comment pertaining to the sizing item

## 35.48. table\_constraints

The view `table_constraints` contains all constraints belonging to tables that the current user owns or has some privilege other than `SELECT` on.

**Table 35.46. table\_constraints Columns**

Column Type	Description
constraint_catalog sql_identifier	Name of the database that contains the constraint (always the current database)



<b>Column Type</b>	<b>Description</b>
constraint_schema sql_identifier	Name of the schema that contains the constraint
constraint_name sql_identifier	Name of the constraint
table_catalog sql_identifier	Name of the database that contains the table (always the current database)
table_schema sql_identifier	Name of the schema that contains the table
table_name sql_identifier	Name of the table
constraint_type character_data	Type of the constraint: CHECK, FOREIGN KEY, PRIMARY KEY, or UNIQUE
is_deferrable yes_or_no	YES if the constraint is deferrable, NO if not
initially_deferred yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not
enforced yes_or_no	Applies to a feature not available in LightDB (currently always YES)

## 35.49. table\_privileges

The view `table_privileges` identifies all privileges granted on tables or views to a currently enabled role or by a currently enabled role. There is one row for each combination of table, grantor, and grantee.

**Table 35.47. table\_privileges Columns**

<b>Column Type</b>	<b>Description</b>
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
table_catalog sql_identifier	Name of the database that contains the table (always the current database)
table_schema sql_identifier	Name of the schema that contains the table
table_name sql_identifier	Name of the table
privilege_type character_data	Type of the privilege: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER
is_grantable yes_or_no	YES if the privilege is grantable, NO if not
with_hierarchy yes_or_no	In the SQL standard, WITH HIERARCHY OPTION is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In LightDB, this is included in the SELECT privilege, so this column shows YES if the privilege is SELECT, else NO.

## 35.50. tables

The view `tables` contains all tables and views defined in the current database. Only those tables and views are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.48. tables Columns**

Column Type	Description
<code>table_catalog</code> <code>sql_identifier</code>	Name of the database that contains the table (always the current database)
<code>table_schema</code> <code>sql_identifier</code>	Name of the schema that contains the table
<code>table_name</code> <code>sql_identifier</code>	Name of the table
<code>table_type</code> <code>character_data</code>	Type of the table: <code>BASE TABLE</code> for a persistent base table (the normal table type), <code>VIEW</code> for a view, <code>FOREIGN</code> for a foreign table, or <code>LOCAL TEMPORARY</code> for a temporary table
<code>self_referencing_column_name</code> <code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>reference_generation</code> <code>character_data</code>	Applies to a feature not available in LightDB
<code>user_defined_type_catalog</code> <code>sql_identifier</code>	If the table is a typed table, the name of the database that contains the underlying data type (always the current database), else null.
<code>user_defined_type_schema</code> <code>sql_identifier</code>	If the table is a typed table, the name of the schema that contains the underlying data type, else null.
<code>user_defined_type_name</code> <code>sql_identifier</code>	If the table is a typed table, the name of the underlying data type, else null.
<code>is_insertable_into</code> <code>yes_or_no</code>	<code>YES</code> if the table is insertable into, <code>NO</code> if not (Base tables are always insertable into, views not necessarily.)
<code>is_typed</code> <code>yes_or_no</code>	<code>YES</code> if the table is a typed table, <code>NO</code> if not
<code>commit_action</code> <code>character_data</code>	Not yet implemented

## 35.51. transforms

The view `transforms` contains information about the transforms defined in the current database. More precisely, it contains a row for each function contained in a transform (the “from SQL” or “to SQL” function).

**Table 35.49. transforms Columns**

Column Type	Description
<code>udt_catalog</code> <code>sql_identifier</code>	

<b>Column Type</b>	<b>Description</b>
	Name of the database that contains the type the transform is for (always the current database)
udt_schema sql_identifier	Name of the schema that contains the type the transform is for
udt_name sql_identifier	Name of the type the transform is for
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. See Section 35.41 for more information.
group_name sql_identifier	The SQL standard allows defining transforms in “groups”, and selecting a group at run time. LightDB does not support this. Instead, transforms are specific to a language. As a compromise, this field contains the language the transform is for.
transform_type character_data	FROM SQL or TO SQL

## 35.52. triggered\_update\_columns

For triggers in the current database that specify a column list (like UPDATE OF column1, column2), the view `triggered_update_columns` identifies these columns. Triggers that do not specify a column list are not included in this view. Only those columns are shown that the current user owns or has some privilege other than `SELECT` on.

**Table 35.50. triggered\_update\_columns Columns**

<b>Column Type</b>	<b>Description</b>
trigger_catalog sql_identifier	Name of the database that contains the trigger (always the current database)
trigger_schema sql_identifier	Name of the schema that contains the trigger
trigger_name sql_identifier	Name of the trigger
event_object_catalog sql_identifier	Name of the database that contains the table that the trigger is defined on (always the current database)
event_object_schema sql_identifier	Name of the schema that contains the table that the trigger is defined on
event_object_table sql_identifier	Name of the table that the trigger is defined on
event_object_column sql_identifier	Name of the column that the trigger is defined on

## 35.53. triggers

The view `triggers` contains all triggers defined in the current database on tables and views that the current user owns or has some privilege other than `SELECT` on.

**Table 35.51. triggers Columns**

Column	Type	Description
<code>trigger_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the trigger (always the current database)
<code>trigger_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the trigger
<code>trigger_name</code>	<code>sql_identifier</code>	Name of the trigger
<code>event_manipulation</code>	<code>character_data</code>	Event that fires the trigger ( <code>INSERT</code> , <code>UPDATE</code> , or <code>DELETE</code> )
<code>event_object_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the table that the trigger is defined on (always the current database)
<code>event_object_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the table that the trigger is defined on
<code>event_object_table</code>	<code>sql_identifier</code>	Name of the table that the trigger is defined on
<code>action_order</code>	<code>cardinal_number</code>	Firing order among triggers on the same table having the same <code>event_manipulation</code> , <code>action_timing</code> , and <code>action_orientation</code> . In LightDB, triggers are fired in name order, so this column reflects that.
<code>action_condition</code>	<code>character_data</code>	<code>WHEN</code> condition of the trigger, null if none (also null if the table is not owned by a currently enabled role)
<code>action_statement</code>	<code>character_data</code>	Statement that is executed by the trigger (currently always <code>EXECUTE FUNCTION function(...)</code> )
<code>action_orientation</code>	<code>character_data</code>	Identifies whether the trigger fires once for each processed row or once for each statement ( <code>ROW</code> or <code>STATEMENT</code> )
<code>action_timing</code>	<code>character_data</code>	Time at which the trigger fires ( <code>BEFORE</code> , <code>AFTER</code> , or <code>INSTEAD OF</code> )
<code>action_reference_old_table</code>	<code>sql_identifier</code>	Name of the "old" transition table, or null if none
<code>action_reference_new_table</code>	<code>sql_identifier</code>	Name of the "new" transition table, or null if none
<code>action_reference_old_row</code>	<code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>action_reference_new_row</code>	<code>sql_identifier</code>	Applies to a feature not available in LightDB
<code>created</code>	<code>time_stamp</code>	Applies to a feature not available in LightDB

Triggers in LightDB have two incompatibilities with the SQL standard that affect the representation in the information schema. First, trigger names are local to each table in LightDB, rather than being independent schema objects. Therefore there can be duplicate trigger names defined in one schema, so long as they belong to different tables. (`trigger_catalog` and `trigger_schema` are really the values pertaining to the table that the trigger is defined on.) Second, triggers can be defined to fire on multiple events in LightDB (e.g., `ON INSERT OR UPDATE`), whereas the SQL standard only allows one. If a trigger is defined to fire on multiple events, it is represented as multiple rows in the information schema, one for each type of event. As a consequence of these two issues, the primary key of the view `triggers` is really (`trigger_catalog`, `trigger_schema`, `event_object_table`, `trigger_name`, `event_manipulation`) instead of (`trigger_catalog`, `trigger_schema`, `trigger_name`), which is what the SQL standard specifies. Nonetheless, if you define your triggers in a manner that conforms with the SQL standard (trigger names unique in the schema and only one event type per trigger), this will not affect you.

**Note**

Prior to LightDB 9.1, this view's columns `action_timing`, `action_reference_old_table`, `action_reference_new_table`, `action_reference_old_row`, and `action_reference_new_row` were named `condition_timing`, `condition_reference_old_table`, `condition_reference_new_table`, `condition_reference_old_row`, and `condition_reference_new_row` respectively. That was how they were named in the SQL:1999 standard. The new naming conforms to SQL:2003 and later.

## 35.54. `udt_privileges`

The view `udt_privileges` identifies `USAGE` privileges granted on user-defined types to a currently enabled role or by a currently enabled role. There is one row for each combination of type, grantor, and grantee. This view shows only composite types (see under Section 35.56 for why); see Section 35.55 for domain privileges.

**Table 35.52. `udt_privileges` Columns**

Column	Type	Description
<code>grantor</code>	<code>sql_identifier</code>	Name of the role that granted the privilege
<code>grantee</code>	<code>sql_identifier</code>	Name of the role that the privilege was granted to
<code>udt_catalog</code>	<code>sql_identifier</code>	Name of the database containing the type (always the current database)
<code>udt_schema</code>	<code>sql_identifier</code>	Name of the schema containing the type
<code>udt_name</code>	<code>sql_identifier</code>	Name of the type
<code>privilege_type</code>	<code>character_data</code>	Always <code>TYPE USAGE</code>
<code>is_grantable</code>	<code>yes_or_no</code>	<code>YES</code> if the privilege is grantable, <code>NO</code> if not

## 35.55. usage\_privileges

The view `usage_privileges` identifies `USAGE` privileges granted on various kinds of objects to a currently enabled role or by a currently enabled role. In LightDB, this currently applies to collations, domains, foreign-data wrappers, foreign servers, and sequences. There is one row for each combination of object, grantor, and grantee.

Since collations do not have real privileges in LightDB, this view shows implicit non-grantable `USAGE` privileges granted by the owner to `PUBLIC` for all collations. The other object types, however, show real privileges.

In LightDB, sequences also support `SELECT` and `UPDATE` privileges in addition to the `USAGE` privilege. These are nonstandard and therefore not visible in the information schema.

**Table 35.53. usage\_privileges Columns**

Column Type	Description
grantor sql_identifier	Name of the role that granted the privilege
grantee sql_identifier	Name of the role that the privilege was granted to
object_catalog sql_identifier	Name of the database containing the object (always the current database)
object_schema sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name sql_identifier	Name of the object
object_type character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type character_data	Always <code>USAGE</code>
is_grantable yes_or_no	YES if the privilege is grantable, NO if not

## 35.56. user\_defined\_types

The view `user_defined_types` currently contains all composite types defined in the current database. Only those types are shown that the current user has access to (by way of being the owner or having some privilege).

SQL knows about two kinds of user-defined types: structured types (also known as composite types in LightDB) and distinct types (not implemented in LightDB). To be future-proof, use the column `user_defined_type_category` to differentiate between these. Other user-defined types such as base types and enums, which are LightDB extensions, are not shown here. For domains, see Section 35.23 instead.

**Table 35.54. user\_defined\_types Columns**

Column Type	Description
user_defined_type_catalog sql_identifier	Name of the database that contains the type (always the current database)

<b>Column Type</b>	<b>Description</b>
user_defined_type_schema sql_identifier	Name of the schema that contains the type
user_defined_type_name sql_identifier	Name of the type
user_defined_type_category character_data	Currently always STRUCTURED
is_instantiable yes_or_no	Applies to a feature not available in LightDB
is_final yes_or_no	Applies to a feature not available in LightDB
ordering_form character_data	Applies to a feature not available in LightDB
ordering_category character_data	Applies to a feature not available in LightDB
ordering_routine_catalog sql_identifier	Applies to a feature not available in LightDB
ordering_routine_schema sql_identifier	Applies to a feature not available in LightDB
ordering_routine_name sql_identifier	Applies to a feature not available in LightDB
reference_type character_data	Applies to a feature not available in LightDB
data_type character_data	Applies to a feature not available in LightDB
character_maximum_length cardinal_number	Applies to a feature not available in LightDB
character_octet_length cardinal_number	Applies to a feature not available in LightDB
character_set_catalog sql_identifier	Applies to a feature not available in LightDB
character_set_schema sql_identifier	Applies to a feature not available in LightDB
character_set_name sql_identifier	Applies to a feature not available in LightDB
collation_catalog sql_identifier	Applies to a feature not available in LightDB
collation_schema sql_identifier	Applies to a feature not available in LightDB
collation_name sql_identifier	Applies to a feature not available in LightDB
numeric_precision cardinal_number	Applies to a feature not available in LightDB
numeric_precision_radix cardinal_number	Applies to a feature not available in LightDB
numeric_scale cardinal_number	Applies to a feature not available in LightDB

Column Type	Description
datetime_precision cardinal_number	Applies to a feature not available in LightDB
interval_type character_data	Applies to a feature not available in LightDB
interval_precision cardinal_number	Applies to a feature not available in LightDB
source_dtd_identifier sql_identifier	Applies to a feature not available in LightDB
ref_dtd_identifier sql_identifier	Applies to a feature not available in LightDB

## 35.57. user\_mapping\_options

The view `user_mapping_options` contains all the options defined for user mappings in the current database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

**Table 35.55. user\_mapping\_options Columns**

Column Type	Description
authorization_identifier sql_identifier	Name of the user being mapped, or PUBLIC if the mapping is public
foreign_server_catalog sql_identifier	Name of the database that the foreign server used by this mapping is defined in (always the current database)
foreign_server_name sql_identifier	Name of the foreign server used by this mapping
option_name sql_identifier	Name of an option
option_value character_data	Value of the option. This column will show as null unless the current user is the user being mapped, or the mapping is for PUBLIC and the current user is the server owner, or the current user is a superuser. The intent is to protect password information stored as user mapping option.

## 35.58. user\_mappings

The view `user_mappings` contains all user mappings defined in the current database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

**Table 35.56. user\_mappings Columns**

Column Type	Description
authorization_identifier sql_identifier	Name of the user being mapped, or PUBLIC if the mapping is public
foreign_server_catalog sql_identifier	



Column Type	Description
	Name of the database that the foreign server used by this mapping is defined in (always the current database)
foreign_server_name sql_identifier	Name of the foreign server used by this mapping

## 35.59. view\_column\_usage

The view `view_column_usage` identifies all columns that are used in the query expression of a view (the `SELECT` statement that defines the view). A column is only included if the table that contains the column is owned by a currently enabled role.

### Note

Columns of system tables are not included. This should be fixed sometime.

**Table 35.57. view\_column\_usage Columns**

Column Type	Description
view_catalog sql_identifier	Name of the database that contains the view (always the current database)
view_schema sql_identifier	Name of the schema that contains the view
view_name sql_identifier	Name of the view
table_catalog sql_identifier	Name of the database that contains the table that contains the column that is used by the view (always the current database)
table_schema sql_identifier	Name of the schema that contains the table that contains the column that is used by the view
table_name sql_identifier	Name of the table that contains the column that is used by the view
column_name sql_identifier	Name of the column that is used by the view

## 35.60. view\_routine\_usage

The view `view_routine_usage` identifies all routines (functions and procedures) that are used in the query expression of a view (the `SELECT` statement that defines the view). A routine is only included if that routine is owned by a currently enabled role.

**Table 35.58. view\_routine\_usage Columns**

Column Type	Description
table_catalog sql_identifier	Name of the database containing the view (always the current database)
table_schema sql_identifier	

Column Type	Description
	Name of the schema containing the view
table_name sql_identifier	Name of the view
specific_catalog sql_identifier	Name of the database containing the function (always the current database)
specific_schema sql_identifier	Name of the schema containing the function
specific_name sql_identifier	The “specific name” of the function. See Section 35.41 for more information.

## 35.61. view\_table\_usage

The view `view_table_usage` identifies all tables that are used in the query expression of a view (the `SELECT` statement that defines the view). A table is only included if that table is owned by a currently enabled role.

### Note

System tables are not included. This should be fixed sometime.

**Table 35.59. view\_table\_usage Columns**

Column Type	Description
view_catalog sql_identifier	Name of the database that contains the view (always the current database)
view_schema sql_identifier	Name of the schema that contains the view
view_name sql_identifier	Name of the view
table_catalog sql_identifier	Name of the database that contains the table that is used by the view (always the current database)
table_schema sql_identifier	Name of the schema that contains the table that is used by the view
table_name sql_identifier	Name of the table that is used by the view

## 35.62. views

The view `views` contains all views defined in the current database. Only those views are shown that the current user has access to (by way of being the owner or having some privilege).

**Table 35.60. views Columns**

Column Type	Description
table_catalog sql_identifier	

<b>Column Type</b>	<b>Description</b>
	Name of the database that contains the view (always the current database)
table_schema sql_identifier	Name of the schema that contains the view
table_name sql_identifier	Name of the view
view_definition character_data	Query expression defining the view (null if the view is not owned by a currently enabled role)
check_option character_data	CASCADED or LOCAL if the view has a CHECK OPTION defined on it, NONE if not
is_updatable yes_or_no	YES if the view is updatable (allows UPDATE and DELETE), NO if not
is_insertable_into yes_or_no	YES if the view is insertable into (allows INSERT), NO if not
is_trigger_updatable yes_or_no	YES if the view has an INSTEAD OF UPDATE trigger defined on it, NO if not
is_trigger_deletable yes_or_no	YES if the view has an INSTEAD OF DELETE trigger defined on it, NO if not
is_trigger_insertable_into yes_or_no	YES if the view has an INSTEAD OF INSERT trigger defined on it, NO if not

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# Part V. Server Programming

This part is about extending the server functionality with user-defined functions, data types, triggers, etc. These are advanced topics which should probably be approached only after all the other user documentation about LightDB has been understood. Later chapters in this part describe the server-side programming languages available in the LightDB distribution as well as general issues concerning server-side programming languages. It is essential to read at least the earlier sections of Chapter 36 (covering functions) before diving into the material about server-side programming languages.

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# Chapter 36. Extending SQL

In the sections that follow, we will discuss how you can extend the LightDB SQL query language by adding:

- functions (starting in Section 36.3)
- aggregates (starting in Section 36.12)
- data types (starting in Section 36.13)
- operators (starting in Section 36.14)
- operator classes for indexes (starting in Section 36.16)
- packages of related objects (starting in Section 36.17)

## 36.1. How Extensibility Works

LightDB is extensible because its operation is catalog-driven. If you are familiar with standard relational database systems, you know that they store information about databases, tables, columns, etc., in what are commonly known as system catalogs. (Some systems call this the data dictionary.) The catalogs appear to the user as tables like any other, but the DBMS stores its internal bookkeeping in them. One key difference between LightDB and standard relational database systems is that LightDB stores much more information in its catalogs: not only information about tables and columns, but also information about data types, functions, access methods, and so on. These tables can be modified by the user, and since LightDB bases its operation on these tables, this means that LightDB can be extended by users. By comparison, conventional database systems can only be extended by changing hardcoded procedures in the source code or by loading modules specially written by the DBMS vendor.

The LightDB server can moreover incorporate user-written code into itself through dynamic loading. That is, the user can specify an object code file (e.g., a shared library) that implements a new type or function, and LightDB will load it as required. Code written in SQL is even more trivial to add to the server. This ability to modify its operation “on the fly” makes LightDB uniquely suited for rapid prototyping of new applications and storage structures.

## 36.2. The LightDB Type System

LightDB data types can be divided into base types, container types, domains, and pseudo-types.

### 36.2.1. Base Types

Base types are those, like `integer`, that are implemented below the level of the SQL language (typically in a low-level language such as C). They generally correspond to what are often known as abstract data types. LightDB can only operate on such types through functions provided by the user and only understands the behavior of such types to the extent that the user describes them. The built-in base types are described in Chapter 8.

Enumerated (enum) types can be considered as a subcategory of base types. The main difference is that they can be created using just SQL commands, without any low-level programming. Refer to Section 8.7 for more information.

### 36.2.2. Container Types

LightDB has three kinds of “container” types, which are types that contain multiple values of other types. These are arrays, composites, and ranges.

Arrays can hold multiple values that are all of the same type. An array type is automatically created for each base type, composite type, range type, and domain type. But there are no arrays of arrays. So

far as the type system is concerned, multi-dimensional arrays are the same as one-dimensional arrays. Refer to Section 8.15 for more information.

Composite types, or row types, are created whenever the user creates a table. It is also possible to use `CREATE TYPE` to define a “stand-alone” composite type with no associated table. A composite type is simply a list of types with associated field names. A value of a composite type is a row or record of field values. Refer to Section 8.16 for more information.

A range type can hold two values of the same type, which are the lower and upper bounds of the range. Range types are user-created, although a few built-in ones exist. Refer to Section 8.17 for more information.

### 36.2.3. Domains

A domain is based on a particular underlying type and for many purposes is interchangeable with its underlying type. However, a domain can have constraints that restrict its valid values to a subset of what the underlying type would allow. Domains are created using the SQL command `CREATE DOMAIN`. Refer to Section 8.18 for more information.

### 36.2.4. Pseudo-Types

There are a few “pseudo-types” for special purposes. Pseudo-types cannot appear as columns of tables or components of container types, but they can be used to declare the argument and result types of functions. This provides a mechanism within the type system to identify special classes of functions. Table 8.27 lists the existing pseudo-types.

### 36.2.5. Polymorphic Types

Some pseudo-types of special interest are the *polymorphic types*, which are used to declare *polymorphic functions*. This powerful feature allows a single function definition to operate on many different data types, with the specific data type(s) being determined by the data types actually passed to it in a particular call. The polymorphic types are shown in Table 36.1. Some examples of their use appear in Section 36.5.10.

**Table 36.1. Polymorphic Types**

Name	Family	Description
<code>anyelement</code>	Simple	Indicates that a function accepts any data type
<code>anyarray</code>	Simple	Indicates that a function accepts any array data type
<code>anynonarray</code>	Simple	Indicates that a function accepts any non-array data type
<code>anyenum</code>	Simple	Indicates that a function accepts any enum data type (see Section 8.7)
<code>anyrange</code>	Simple	Indicates that a function accepts any range data type (see Section 8.17)
<code>anycompatible</code>	Common	Indicates that a function accepts any data type, with automatic promotion of multiple arguments to a common data type
<code>anycompatiblearray</code>	Common	Indicates that a function accepts any array data type, with automatic promotion of multiple arguments to a common data type

Name	Family	Description
<code>anycompatiblenonarray</code>	Common	Indicates that a function accepts any non-array data type, with automatic promotion of multiple arguments to a common data type
<code>anycompatiblerange</code>	Common	Indicates that a function accepts any range data type, with automatic promotion of multiple arguments to a common data type

Polymorphic arguments and results are tied to each other and are resolved to specific data types when a query calling a polymorphic function is parsed. When there is more than one polymorphic argument, the actual data types of the input values must match up as described below. If the function's result type is polymorphic, or it has output parameters of polymorphic types, the types of those results are deduced from the actual types of the polymorphic inputs as described below.

For the “simple” family of polymorphic types, the matching and deduction rules work like this:

Each position (either argument or return value) declared as `anyelement` is allowed to have any specific actual data type, but in any given call they must all be the *same* actual type. Each position declared as `anyarray` can have any array data type, but similarly they must all be the same type. And similarly, positions declared as `anyrange` must all be the same range type. Furthermore, if there are positions declared `anyarray` and others declared `anyelement`, the actual array type in the `anyarray` positions must be an array whose elements are the same type appearing in the `anyelement` positions. Similarly, if there are positions declared `anyrange` and others declared `anyelement` or `anyarray`, the actual range type in the `anyrange` positions must be a range whose subtype is the same type appearing in the `anyelement` positions and the same as the element type of the `anyarray` positions. `anynonarray` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must not be an array type. `anyenum` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must be an enum type.

Thus, when more than one argument position is declared with a polymorphic type, the net effect is that only certain combinations of actual argument types are allowed. For example, a function declared as `equal(anyelement, anyelement)` will take any two input values, so long as they are of the same data type.

When the return value of a function is declared as a polymorphic type, there must be at least one argument position that is also polymorphic, and the actual data type(s) supplied for the polymorphic arguments determine the actual result type for that call. For example, if there were not already an array subscripting mechanism, one could define a function that implements subscripting as `subscript(anyarray, integer) returns anyelement`. This declaration constrains the actual first argument to be an array type, and allows the parser to infer the correct result type from the actual first argument's type. Another example is that a function declared as `f(anyarray) returns anyenum` will only accept arrays of enum types.

In most cases, the parser can infer the actual data type for a polymorphic result type from arguments that are of a different polymorphic type in the same family; for example `anyarray` can be deduced from `anyelement` or vice versa. An exception is that a polymorphic result of type `anyrange` requires an argument of type `anyrange`; it cannot be deduced from `anyarray` or `anyelement` arguments. This is because there could be multiple range types with the same subtype.

Note that `anynonarray` and `anyenum` do not represent separate type variables; they are the same type as `anyelement`, just with an additional constraint. For example, declaring a function as `f(anyelement, anyenum)` is equivalent to declaring it as `f(anyenum, anyenum)`: both actual arguments have to be the same enum type.

For the “common” family of polymorphic types, the matching and deduction rules work approximately the same as for the “simple” family, with one major difference: the actual types of the arguments need

not be identical, so long as they can be implicitly cast to a single common type. The common type is selected following the same rules as for UNION and related constructs (see Section 10.5). Selection of the common type considers the actual types of `anycompatible` and `anycompatiblearray` inputs, the array element types of `anycompatiblearray` inputs, and the range subtypes of `anycompatiblearray` inputs. If `anycompatiblearray` is present then the common type is required to be a non-array type. Once a common type is identified, arguments in `anycompatible` and `anycompatiblearray` positions are automatically cast to that type, and arguments in `anycompatiblearray` positions are automatically cast to the array type for that type.

Since there is no way to select a range type knowing only its subtype, use of `anycompatiblearray` requires that all arguments declared with that type have the same actual range type, and that that type's subtype agree with the selected common type, so that no casting of the range values is required. As with `anyrange`, use of `anycompatiblearray` as a function result type requires that there be an `anycompatiblearray` argument.

Notice that there is no `anycompatibleenum` type. Such a type would not be very useful, since there normally are not any implicit casts to enum types, meaning that there would be no way to resolve a common type for dissimilar enum inputs.

The “simple” and “common” polymorphic families represent two independent sets of type variables. Consider for example

```
CREATE FUNCTION myfunc(a anyelement, b anyelement,
                      c anycompatible, d anycompatible)
RETURNS anycompatible AS ...
```

In an actual call of this function, the first two inputs must have exactly the same type. The last two inputs must be promotable to a common type, but this type need not have anything to do with the type of the first two inputs. The result will have the common type of the last two inputs.

A variadic function (one taking a variable number of arguments, as in Section 36.5.5) can be polymorphic: this is accomplished by declaring its last parameter as `VARIADIC anyarray` or `VARIADIC anycompatiblearray`. For purposes of argument matching and determining the actual result type, such a function behaves the same as if you had written the appropriate number of `anynonarray` or `anycompatiblearray` parameters.

## 36.3. User-Defined Functions

LightDB provides four kinds of functions:

- query language functions (functions written in SQL) (Section 36.5)
- procedural language functions (functions written in, for example, PL/pgSQL or PL/Tcl) (Section 36.8)
- internal functions (Section 36.9)
- C-language functions (Section 36.10)

Every kind of function can take base types, composite types, or combinations of these as arguments (parameters). In addition, every kind of function can return a base type or a composite type. Functions can also be defined to return sets of base or composite values.

Many kinds of functions can take or return certain pseudo-types (such as polymorphic types), but the available facilities vary. Consult the description of each kind of function for more details.

It's easiest to define SQL functions, so we'll start by discussing those. Most of the concepts presented for SQL functions will carry over to the other types of functions.

Throughout this chapter, it can be useful to look at the reference page of the `CREATE FUNCTION` command to understand the examples better. Some examples from this chapter can be found in `funcs.sql` and `funcs.c` in the `src/tutorial` directory in the LightDB source distribution.

## 36.4. User-Defined Procedures

A procedure is a database object similar to a function. The key differences are:

- Procedures are defined with the `CREATE PROCEDURE` command, not `CREATE FUNCTION`.
- Procedures do not return a function value; hence `CREATE PROCEDURE` lacks a `RETURNS` clause. However, procedures can instead return data to their callers via output parameters.
- While a function is called as part of a query or DML command, a procedure is called in isolation using the `CALL` command.
- A procedure can commit or roll back transactions during its execution (then automatically beginning a new transaction), so long as the invoking `CALL` command is not part of an explicit transaction block. A function cannot do that.
- Certain function attributes, such as strictness, don't apply to procedures. Those attributes control how the function is used in a query, which isn't relevant to procedures.

The explanations in the following sections about how to define user-defined functions apply to procedures as well, except for the points made above.

Collectively, functions and procedures are also known as *routines*. There are commands such as `ALTER ROUTINE` and `DROP ROUTINE` that can operate on functions and procedures without having to know which kind it is. Note, however, that there is no `CREATE ROUTINE` command.

## 36.5. Query Language (SQL) Functions

SQL functions execute an arbitrary list of SQL statements, returning the result of the last query in the list. In the simple (non-set) case, the first row of the last query's result will be returned. (Bear in mind that “the first row” of a multirow result is not well-defined unless you use `ORDER BY`.) If the last query happens to return no rows at all, the null value will be returned.

Alternatively, an SQL function can be declared to return a set (that is, multiple rows) by specifying the function's return type as `SETOF some_type`, or equivalently by declaring it as `RETURNS TABLE(columns)`. In this case all rows of the last query's result are returned. Further details appear below.

The body of an SQL function must be a list of SQL statements separated by semicolons. A semicolon after the last statement is optional. Unless the function is declared to return `void`, the last statement must be a `SELECT`, or an `INSERT`, `UPDATE`, or `DELETE` that has a `RETURNING` clause.

Any collection of commands in the SQL language can be packaged together and defined as a function. Besides `SELECT` queries, the commands can include data modification queries (`INSERT`, `UPDATE`, and `DELETE`), as well as other SQL commands. (You cannot use transaction control commands, e.g., `COMMIT`, `SAVEPOINT`, and some utility commands, e.g., `VACUUM`, in SQL functions.) However, the final command must be a `SELECT` or have a `RETURNING` clause that returns whatever is specified as the function's return type. Alternatively, if you want to define a SQL function that performs actions but has no useful value to return, you can define it as returning `void`. For example, this function removes rows with negative salaries from the `emp` table:

```
CREATE FUNCTION clean_emp() RETURNS void AS '
```

```

DELETE FROM emp
    WHERE salary < 0;
' LANGUAGE SQL;

SELECT clean_emp();

clean_emp
-----

(1 row)

```

**Note**

The entire body of a SQL function is parsed before any of it is executed. While a SQL function can contain commands that alter the system catalogs (e.g., CREATE TABLE), the effects of such commands will not be visible during parse analysis of later commands in the function. Thus, for example, CREATE TABLE foo (...); INSERT INTO foo VALUES (...); will not work as desired if packaged up into a single SQL function, since foo won't exist yet when the INSERT command is parsed. It's recommended to use PL/pgSQL instead of a SQL function in this type of situation.

The syntax of the CREATE FUNCTION command requires the function body to be written as a string constant. It is usually most convenient to use dollar quoting (see Section 4.1.2.4) for the string constant. If you choose to use regular single-quoted string constant syntax, you must double single quote marks (') and backslashes (\) (assuming escape string syntax) in the body of the function (see Section 4.1.2.1).

### 36.5.1. Arguments for SQL Functions

Arguments of a SQL function can be referenced in the function body using either names or numbers. Examples of both methods appear below.

To use a name, declare the function argument as having a name, and then just write that name in the function body. If the argument name is the same as any column name in the current SQL command within the function, the column name will take precedence. To override this, qualify the argument name with the name of the function itself, that is *function\_name.argument\_name*. (If this would conflict with a qualified column name, again the column name wins. You can avoid the ambiguity by choosing a different alias for the table within the SQL command.)

In the older numeric approach, arguments are referenced using the syntax *\$n*: \$1 refers to the first input argument, \$2 to the second, and so on. This will work whether or not the particular argument was declared with a name.

If an argument is of a composite type, then the dot notation, e.g., *argname.fieldname* or *\$1.fieldname*, can be used to access attributes of the argument. Again, you might need to qualify the argument's name with the function name to make the form with an argument name unambiguous.

SQL function arguments can only be used as data values, not as identifiers. Thus for example this is reasonable:

```
INSERT INTO mytable VALUES ($1);
```

but this will not work:

```
INSERT INTO $1 VALUES (42);
```

**Note**

The ability to use names to reference SQL function arguments was added in LightDB 9.2. Functions to be used in older servers must use the  $\$n$  notation.

## 36.5.2. SQL Functions on Base Types

The simplest possible SQL function has no arguments and simply returns a base type, such as integer:

```
CREATE FUNCTION one() RETURNS integer AS $$
    SELECT 1 AS result;
$$ LANGUAGE SQL;
```

```
-- Alternative syntax for string literal:
CREATE FUNCTION one() RETURNS integer AS '
    SELECT 1 AS result;
' LANGUAGE SQL;
```

```
SELECT one();
```

```
one
-----
1
```

Notice that we defined a column alias within the function body for the result of the function (with the name `result`), but this column alias is not visible outside the function. Hence, the result is labeled `one` instead of `result`.

It is almost as easy to define SQL functions that take base types as arguments:

```
CREATE FUNCTION add_em(x integer, y integer) RETURNS integer AS $$
    SELECT x + y;
$$ LANGUAGE SQL;
```

```
SELECT add_em(1, 2) AS answer;
```

```
answer
-----
3
```

Alternatively, we could dispense with names for the arguments and use numbers:

```
CREATE FUNCTION add_em(integer, integer) RETURNS integer AS $$
    SELECT $1 + $2;
$$ LANGUAGE SQL;
```

```
SELECT add_em(1, 2) AS answer;
```

```
answer
-----
```



Here is a more useful function, which might be used to debit a bank account:

```
CREATE FUNCTION tfl (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tfl.accountno;
    SELECT 1;
$$ LANGUAGE SQL;
```

A user could execute this function to debit account 17 by \$100.00 as follows:

```
SELECT tfl(17, 100.0);
```

In this example, we chose the name `accountno` for the first argument, but this is the same as the name of a column in the `bank` table. Within the `UPDATE` command, `accountno` refers to the column `bank.accountno`, so `tfl.accountno` must be used to refer to the argument. We could of course avoid this by using a different name for the argument.

In practice one would probably like a more useful result from the function than a constant 1, so a more likely definition is:

```
CREATE FUNCTION tfl (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tfl.accountno;
    SELECT balance FROM bank WHERE accountno = tfl.accountno;
$$ LANGUAGE SQL;
```

which adjusts the balance and returns the new balance. The same thing could be done in one command using `RETURNING`:

```
CREATE FUNCTION tfl (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tfl.accountno
    RETURNING balance;
$$ LANGUAGE SQL;
```

If the final `SELECT` or `RETURNING` clause in a SQL function does not return exactly the function's declared result type, `LightDB` will automatically cast the value to the required type, if that is possible with an implicit or assignment cast. Otherwise, you must write an explicit cast. For example, suppose we wanted the previous `add_em` function to return type `float8` instead. It's sufficient to write

```
CREATE FUNCTION add_em(integer, integer) RETURNS float8 AS $$
    SELECT $1 + $2;
$$ LANGUAGE SQL;
```

since the `integer` sum can be implicitly cast to `float8`. (See Chapter 10 or `CREATE CAST` for more about casts.)

### 36.5.3. SQL Functions on Composite Types

When writing functions with arguments of composite types, we must not only specify which argument we want but also the desired attribute (field) of that argument. For example, suppose that `emp` is a table containing employee data, and therefore also the name of the composite type of each row of the table. Here is a function `double_salary` that computes what someone's salary would be if it were doubled:

```
CREATE TABLE emp (
    name      text,
    salary    numeric,
    age       integer,
    cubicle   point
);

INSERT INTO emp VALUES ('Bill', 4200, 45, '(2,1)');

CREATE FUNCTION double_salary(emp) RETURNS numeric AS $$
    SELECT $1.salary * 2 AS salary;
$$ LANGUAGE SQL;

SELECT name, double_salary(emp.*) AS dream
FROM emp
WHERE emp.cubicle ~= point '(2,1)';
```

```
name | dream
-----+-----
Bill | 8400
```

Notice the use of the syntax `$1.salary` to select one field of the argument row value. Also notice how the calling `SELECT` command uses `table_name.*` to select the entire current row of a table as a composite value. The table row can alternatively be referenced using just the table name, like this:

```
SELECT name, double_salary(emp) AS dream
FROM emp
WHERE emp.cubicle ~= point '(2,1)';
```

but this usage is deprecated since it's easy to get confused. (See Section 8.16.5 for details about these two notations for the composite value of a table row.)

Sometimes it is handy to construct a composite argument value on-the-fly. This can be done with the `ROW` construct. For example, we could adjust the data being passed to the function:

```
SELECT name, double_salary(ROW(name, salary*1.1, age, cubicle)) AS
dream
FROM emp;
```

It is also possible to build a function that returns a composite type. This is an example of a function that returns a single `emp` row:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
    SELECT text 'None' AS name,
           1000.0 AS salary,
           25 AS age,
           point '(2,2)' AS cubicle;
```

```
$$ LANGUAGE SQL;
```

In this example we have specified each of the attributes with a constant value, but any computation could have been substituted for these constants.

Note two important things about defining the function:

- The select list order in the query must be exactly the same as that in which the columns appear in the composite type. (Naming the columns, as we did above, is irrelevant to the system.)
- We must ensure each expression's type can be cast to that of the corresponding column of the composite type. Otherwise we'll get errors like this:

```
ERROR: return type mismatch in function declared to return emp
DETAIL: Final statement returns text instead of point at column
4.
```

As with the base-type case, the system will not insert explicit casts automatically, only implicit or assignment casts.

A different way to define the same function is:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
    SELECT ROW('None', 1000.0, 25, '(2,2)')::emp;
$$ LANGUAGE SQL;
```

Here we wrote a `SELECT` that returns just a single column of the correct composite type. This isn't really better in this situation, but it is a handy alternative in some cases — for example, if we need to compute the result by calling another function that returns the desired composite value. Another example is that if we are trying to write a function that returns a domain over composite, rather than a plain composite type, it is always necessary to write it as returning a single column, since there is no way to cause a coercion of the whole row result.

We could call this function directly either by using it in a value expression:

```
SELECT new_emp();

           new_emp
-----
(None,1000.0,25,"(2,2)")
```

or by calling it as a table function:

```
SELECT * FROM new_emp();

 name | salary | age | cubicle
-----+-----+-----+-----
None | 1000.0 | 25  | (2,2)
```

The second way is described more fully in Section 36.5.7.

When you use a function that returns a composite type, you might want only one field (attribute) from its result. You can do that with syntax like this:

```
SELECT (new_emp()).name;

 name
-----
None
```

The extra parentheses are needed to keep the parser from getting confused. If you try to do it without them, you get something like this:

```
SELECT new_emp().name;
ERROR:  syntax error at or near "."
LINE 1: SELECT new_emp().name;
                ^
```

Another option is to use functional notation for extracting an attribute:

```
SELECT name(new_emp());

 name
-----
None
```

As explained in Section 8.16.5, the field notation and functional notation are equivalent.

Another way to use a function returning a composite type is to pass the result to another function that accepts the correct row type as input:

```
CREATE FUNCTION getname(emp) RETURNS text AS $$
    SELECT $1.name;
$$ LANGUAGE SQL;

SELECT getname(new_emp());
 getname
-----
None
(1 row)
```

### 36.5.4. SQL Functions with Output Parameters

An alternative way of describing a function's results is to define it with *output parameters*, as in this example:

```
CREATE FUNCTION add_em (IN x int, IN y int, OUT sum int)
AS 'SELECT x + y'
LANGUAGE SQL;

SELECT add_em(3,7);
 add_em
-----
     10
(1 row)
```

This is not essentially different from the version of `add_em` shown in Section 36.5.2. The real value of output parameters is that they provide a convenient way of defining functions that return several columns. For example,

```
CREATE FUNCTION sum_n_product (x int, y int, OUT sum int, OUT
product int)
AS 'SELECT x + y, x * y'
LANGUAGE SQL;
```

```
SELECT * FROM sum_n_product(11,42);
sum | product
-----+-----
  53 |      462
(1 row)
```

What has essentially happened here is that we have created an anonymous composite type for the result of the function. The above example has the same end result as

```
CREATE TYPE sum_prod AS (sum int, product int);

CREATE FUNCTION sum_n_product (int, int) RETURNS sum_prod
AS 'SELECT $1 + $2, $1 * $2'
LANGUAGE SQL;
```

but not having to bother with the separate composite type definition is often handy. Notice that the names attached to the output parameters are not just decoration, but determine the column names of the anonymous composite type. (If you omit a name for an output parameter, the system will choose a name on its own.)

Notice that output parameters are not included in the calling argument list when invoking such a function from SQL. This is because LightDB considers only the input parameters to define the function's calling signature. That means also that only the input parameters matter when referencing the function for purposes such as dropping it. We could drop the above function with either of

```
DROP FUNCTION sum_n_product (x int, y int, OUT sum int, OUT product
int);
DROP FUNCTION sum_n_product (int, int);
```

Parameters can be marked as IN (the default), OUT, INOUT, or VARIADIC. An INOUT parameter serves as both an input parameter (part of the calling argument list) and an output parameter (part of the result record type). VARIADIC parameters are input parameters, but are treated specially as described next.

## 36.5.5. SQL Functions with Variable Numbers of Arguments

SQL functions can be declared to accept variable numbers of arguments, so long as all the “optional” arguments are of the same data type. The optional arguments will be passed to the function as an array. The function is declared by marking the last parameter as VARIADIC; this parameter must be declared as being of an array type. For example:

```
CREATE FUNCTION mleast(VARIADIC arr numeric[]) RETURNS numeric AS $
$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;

SELECT mleast(10, -1, 5, 4.4);
mleast
```

```
-----
      -1
(1 row)
```

Effectively, all the actual arguments at or beyond the `VARIADIC` position are gathered up into a one-dimensional array, as if you had written

```
SELECT mleast(ARRAY[10, -1, 5, 4.4]);    -- doesn't work
```

You can't actually write that, though — or at least, it will not match this function definition. A parameter marked `VARIADIC` matches one or more occurrences of its element type, not of its own type.

Sometimes it is useful to be able to pass an already-constructed array to a variadic function; this is particularly handy when one variadic function wants to pass on its array parameter to another one. Also, this is the only secure way to call a variadic function found in a schema that permits untrusted users to create objects; see Section 10.3. You can do this by specifying `VARIADIC` in the call:

```
SELECT mleast(VARIADIC ARRAY[10, -1, 5, 4.4]);
```

This prevents expansion of the function's variadic parameter into its element type, thereby allowing the array argument value to match normally. `VARIADIC` can only be attached to the last actual argument of a function call.

Specifying `VARIADIC` in the call is also the only way to pass an empty array to a variadic function, for example:

```
SELECT mleast(VARIADIC ARRAY[]::numeric[]);
```

Simply writing `SELECT mleast()` does not work because a variadic parameter must match at least one actual argument. (You could define a second function also named `mleast`, with no parameters, if you wanted to allow such calls.)

The array element parameters generated from a variadic parameter are treated as not having any names of their own. This means it is not possible to call a variadic function using named arguments (Section 4.3), except when you specify `VARIADIC`. For example, this will work:

```
SELECT mleast(VARIADIC arr => ARRAY[10, -1, 5, 4.4]);
```

but not these:

```
SELECT mleast(arr => 10);
SELECT mleast(arr => ARRAY[10, -1, 5, 4.4]);
```

## 36.5.6. SQL Functions with Default Values for Arguments

Functions can be declared with default values for some or all input arguments. The default values are inserted whenever the function is called with insufficiently many actual arguments. Since arguments can only be omitted from the end of the actual argument list, all parameters after a parameter with a default value have to have default values as well. (Although the use of named argument notation could allow this restriction to be relaxed, it's still enforced so that positional argument notation works sensibly.) Whether or not you use it, this capability creates a need for precautions when calling functions in databases where some users mistrust other users; see Section 10.3.

For example:

```
CREATE FUNCTION foo(a int, b int DEFAULT 2, c int DEFAULT 3)
RETURNS int
LANGUAGE SQL
AS $$
    SELECT $1 + $2 + $3;
$$;
```

```
SELECT foo(10, 20, 30);
foo
-----
   60
(1 row)
```

```
SELECT foo(10, 20);
foo
-----
   33
(1 row)
```

```
SELECT foo(10);
foo
-----
   15
(1 row)
```

```
SELECT foo(); -- fails since there is no default for the first
argument
ERROR: function foo() does not exist
```

The = sign can also be used in place of the key word DEFAULT.

## 36.5.7. SQL Functions as Table Sources

All SQL functions can be used in the FROM clause of a query, but it is particularly useful for functions returning composite types. If the function is defined to return a base type, the table function produces a one-column table. If the function is defined to return a composite type, the table function produces a column for each attribute of the composite type.

Here is an example:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);
INSERT INTO foo VALUES (1, 1, 'Joe');
INSERT INTO foo VALUES (1, 2, 'Ed');
INSERT INTO foo VALUES (2, 1, 'Mary');
```

```
CREATE FUNCTION getfoo(int) RETURNS foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;
```

```
SELECT *, upper(fooname) FROM getfoo(1) AS t1;
```

```
fooid | foosubid | fooname | upper
-----+-----+-----+-----
   1  |         1 | Joe     | JOE
(1 row)
```

As the example shows, we can work with the columns of the function's result just the same as if they were columns of a regular table.

Note that we only got one row out of the function. This is because we did not use `SETOF`. That is described in the next section.

## 36.5.8. SQL Functions Returning Sets

When an SQL function is declared as returning `SETOF sometype`, the function's final query is executed to completion, and each row it outputs is returned as an element of the result set.

This feature is normally used when calling the function in the `FROM` clause. In this case each row returned by the function becomes a row of the table seen by the query. For example, assume that table `foo` has the same contents as above, and we say:

```
CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;

SELECT * FROM getfoo(1) AS t1;
```

Then we would get:

```
fooid | foosubid | fooname
-----+-----+-----
      1 |         1 | Joe
      1 |         2 | Ed
(2 rows)
```

It is also possible to return multiple rows with the columns defined by output parameters, like this:

```
CREATE TABLE tab (y int, z int);
INSERT INTO tab VALUES (1, 2), (3, 4), (5, 6), (7, 8);

CREATE FUNCTION sum_n_product_with_tab (x int, OUT sum int, OUT
    product int)
RETURNS SETOF record
AS $$
    SELECT $1 + tab.y, $1 * tab.y FROM tab;
$$ LANGUAGE SQL;

SELECT * FROM sum_n_product_with_tab(10);
 sum | product
-----+-----
    11 |      10
    13 |      30
    15 |      50
    17 |      70
(4 rows)
```

The key point here is that you must write `RETURNS SETOF record` to indicate that the function returns multiple rows instead of just one. If there is only one output parameter, write that parameter's type instead of `record`.

It is frequently useful to construct a query's result by invoking a set-returning function multiple times, with the parameters for each invocation coming from successive rows of a table or subquery. The



preferred way to do this is to use the LATERAL key word, which is described in Section 7.2.1.5. Here is an example using a set-returning function to enumerate elements of a tree structure:

```
SELECT * FROM nodes;
  name | parent
-----+-----
  Top  |
  Child1 | Top
  Child2 | Top
  Child3 | Top
  SubChild1 | Child1
  SubChild2 | Child1
(6 rows)
```

```
CREATE FUNCTION listchildren(text) RETURNS SETOF text AS $$
  SELECT name FROM nodes WHERE parent = $1
$$ LANGUAGE SQL STABLE;
```

```
SELECT * FROM listchildren('Top');
 listchildren
-----
  Child1
  Child2
  Child3
(3 rows)
```

```
SELECT name, child FROM nodes, LATERAL listchildren(name) AS child;
  name | child
-----+-----
  Top  | Child1
  Top  | Child2
  Top  | Child3
  Child1 | SubChild1
  Child1 | SubChild2
(5 rows)
```

This example does not do anything that we couldn't have done with a simple join, but in more complex calculations the option to put some of the work into a function can be quite convenient.

Functions returning sets can also be called in the select list of a query. For each row that the query generates by itself, the set-returning function is invoked, and an output row is generated for each element of the function's result set. The previous example could also be done with queries like these:

```
SELECT listchildren('Top');
 listchildren
-----
  Child1
  Child2
  Child3
(3 rows)
```

```
SELECT name, listchildren(name) FROM nodes;
  name | listchildren
-----+-----
  Top  | Child1
  Top  | Child2
  Top  | Child3
```

```
Child1 | SubChild1
Child1 | SubChild2
(5 rows)
```

In the last `SELECT`, notice that no output row appears for `Child2`, `Child3`, etc. This happens because `listchildren` returns an empty set for those arguments, so no result rows are generated. This is the same behavior as we got from an inner join to the function result when using the `LATERAL` syntax.

LightDB's behavior for a set-returning function in a query's select list is almost exactly the same as if the set-returning function had been written in a `LATERAL FROM`-clause item instead. For example,

```
SELECT x, generate_series(1,5) AS g FROM tab;
```

is almost equivalent to

```
SELECT x, g FROM tab, LATERAL generate_series(1,5) AS g;
```

It would be exactly the same, except that in this specific example, the planner could choose to put `g` on the outside of the nested-loop join, since `g` has no actual lateral dependency on `tab`. That would result in a different output row order. Set-returning functions in the select list are always evaluated as though they are on the inside of a nested-loop join with the rest of the `FROM` clause, so that the function(s) are run to completion before the next row from the `FROM` clause is considered.

If there is more than one set-returning function in the query's select list, the behavior is similar to what you get from putting the functions into a single `LATERAL ROWS FROM( . . . ) FROM`-clause item. For each row from the underlying query, there is an output row using the first result from each function, then an output row using the second result, and so on. If some of the set-returning functions produce fewer outputs than others, null values are substituted for the missing data, so that the total number of rows emitted for one underlying row is the same as for the set-returning function that produced the most outputs. Thus the set-returning functions run “in lockstep” until they are all exhausted, and then execution continues with the next underlying row.

Set-returning functions can be nested in a select list, although that is not allowed in `FROM`-clause items. In such cases, each level of nesting is treated separately, as though it were a separate `LATERAL ROWS FROM( . . . )` item. For example, in

```
SELECT srf1(srf2(x), srf3(y)), srf4(srf5(z)) FROM tab;
```

the set-returning functions `srf2`, `srf3`, and `srf5` would be run in lockstep for each row of `tab`, and then `srf1` and `srf4` would be applied in lockstep to each row produced by the lower functions.

Set-returning functions cannot be used within conditional-evaluation constructs, such as `CASE` or `COALESCE`. For example, consider

```
SELECT x, CASE WHEN x > 0 THEN generate_series(1, 5) ELSE 0 END
FROM tab;
```

It might seem that this should produce five repetitions of input rows that have `x > 0`, and a single repetition of those that do not; but actually, because `generate_series(1, 5)` would be run in an implicit `LATERAL FROM` item before the `CASE` expression is ever evaluated, it would produce five repetitions of every input row. To reduce confusion, such cases produce a parse-time error instead.

### Note

If a function's last command is `INSERT`, `UPDATE`, or `DELETE` with `RETURNING`, that command will always be executed to completion, even if the function is not declared

with SETOF or the calling query does not fetch all the result rows. Any extra rows produced by the RETURNING clause are silently dropped, but the commanded table modifications still happen (and are all completed before returning from the function).

### Note

Before LightDB 10, putting more than one set-returning function in the same select list did not behave very sensibly unless they always produced equal numbers of rows. Otherwise, what you got was a number of output rows equal to the least common multiple of the numbers of rows produced by the set-returning functions. Also, nested set-returning functions did not work as described above; instead, a set-returning function could have at most one set-returning argument, and each nest of set-returning functions was run independently. Also, conditional execution (set-returning functions inside CASE etc) was previously allowed, complicating things even more. Use of the LATERAL syntax is recommended when writing queries that need to work in older LightDB versions, because that will give consistent results across different versions. If you have a query that is relying on conditional execution of a set-returning function, you may be able to fix it by moving the conditional test into a custom set-returning function. For example,

```
SELECT x, CASE WHEN y > 0 THEN generate_series(1, z)
        ELSE 5 END FROM tab;
```

could become

```
CREATE FUNCTION case_generate_series(cond bool, start
int, fin int, els int)
  RETURNS SETOF int AS $$
BEGIN
  IF cond THEN
    RETURN QUERY SELECT generate_series(start, fin);
  ELSE
    RETURN QUERY SELECT els;
  END IF;
END$$ LANGUAGE plpgsql;

SELECT x, case_generate_series(y > 0, 1, z, 5) FROM tab;
```

This formulation will work the same in all versions of LightDB.

## 36.5.9. SQL Functions Returning TABLE

There is another way to declare a function as returning a set, which is to use the syntax RETURNS TABLE(*columns*). This is equivalent to using one or more OUT parameters plus marking the function as returning SETOF *record* (or SETOF a single output parameter's type, as appropriate). This notation is specified in recent versions of the SQL standard, and thus may be more portable than using SETOF.

For example, the preceding sum-and-product example could also be done this way:

```
CREATE FUNCTION sum_n_product_with_tab (x int)
  RETURNS TABLE(sum int, product int) AS $$
  SELECT $1 + tab.y, $1 * tab.y FROM tab;
```

```
$$ LANGUAGE SQL;
```

It is not allowed to use explicit OUT or INOUT parameters with the RETURNS TABLE notation — you must put all the output columns in the TABLE list.

## 36.5.10. Polymorphic SQL Functions

SQL functions can be declared to accept and return the polymorphic types described in Section 36.2.5. Here is a polymorphic function `make_array` that builds up an array from two arbitrary data type elements:

```
CREATE FUNCTION make_array(anyelement, anyelement) RETURNS anyarray
AS $$
    SELECT ARRAY[$1, $2];
$$ LANGUAGE SQL;
```

```
SELECT make_array(1, 2) AS intarray, make_array('a'::text, 'b') AS
    textarray;
intarray | textarray
-----+-----
{1,2}   | {a,b}
(1 row)
```

Notice the use of the typecast `'a'::text` to specify that the argument is of type `text`. This is required if the argument is just a string literal, since otherwise it would be treated as type `unknown`, and array of `unknown` is not a valid type. Without the typecast, you will get errors like this:

```
ERROR: could not determine polymorphic type because input has type
unknown
```

With `make_array` declared as above, you must provide two arguments that are of exactly the same data type; the system will not attempt to resolve any type differences. Thus for example this does not work:

```
SELECT make_array(1, 2.5) AS numericarray;
ERROR: function make_array(integer, numeric) does not exist
```

An alternative approach is to use the “common” family of polymorphic types, which allows the system to try to identify a suitable common type:

```
CREATE FUNCTION make_array2(anycompatible, anycompatible)
RETURNS anycompatiblearray AS $$
    SELECT ARRAY[$1, $2];
$$ LANGUAGE SQL;
```

```
SELECT make_array2(1, 2.5) AS numericarray;
numericarray
-----
{1,2.5}
(1 row)
```

Because the rules for common type resolution default to choosing type `text` when all inputs are of unknown types, this also works:

```
SELECT make_array2('a', 'b') AS textarray;
```

```

textarray
-----
{a,b}
(1 row)

```

It is permitted to have polymorphic arguments with a fixed return type, but the converse is not. For example:

```

CREATE FUNCTION is_greater(anyelement, anyelement) RETURNS boolean
AS $$
    SELECT $1 > $2;
$$ LANGUAGE SQL;

```

```

SELECT is_greater(1, 2);
 is_greater
-----
f
(1 row)

```

```

CREATE FUNCTION invalid_func() RETURNS anyelement AS $$
    SELECT 1;
$$ LANGUAGE SQL;

```

```

ERROR:  cannot determine result data type
DETAIL:  A result of type anyelement requires at least one input of
         type anyelement, anyarray, anynonarray, anyenum, or anyrange.

```

Polymorphism can be used with functions that have output arguments. For example:

```

CREATE FUNCTION dup (f1 anyelement, OUT f2 anyelement, OUT f3
anyarray)
AS 'select $1, array[$1,$1]' LANGUAGE SQL;

```

```

SELECT * FROM dup(22);
 f2 |  f3
----+-----
 22 | {22,22}
(1 row)

```

Polymorphism can also be used with variadic functions. For example:

```

CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS
$$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;

```

```

SELECT anyleast(10, -1, 5, 4);
 anyleast
-----
      -1
(1 row)

```

```

SELECT anyleast('abc'::text, 'def');
 anyleast
-----
abc
(1 row)

```

```
CREATE FUNCTION concat_values(text, VARIADIC anyarray) RETURNS text
AS $$
    SELECT array_to_string($2, $1);
$$ LANGUAGE SQL;

SELECT concat_values('|', 1, 4, 2);
concat_values
-----
1|4|2
(1 row)
```

### 36.5.11. SQL Functions with Collations

When a SQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 21.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly. This will affect the behavior of collation-sensitive operations within the function. For example, using the `anyleast` function described above, the result of

```
SELECT anyleast('abc'::text, 'ABC');
```

will depend on the database's default collation. In C locale the result will be ABC, but in many other locales it will be abc. The collation to use can be forced by adding a `COLLATE` clause to any of the arguments, for example

```
SELECT anyleast('abc'::text, 'ABC' COLLATE "C");
```

Alternatively, if you wish a function to operate with a particular collation regardless of what it is called with, insert `COLLATE` clauses as needed in the function definition. This version of `anyleast` would always use `en_US` locale to compare strings:

```
CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS
$$
    SELECT min($1[i] COLLATE "en_US") FROM generate_subscripts($1,
1) g(i);
$$ LANGUAGE SQL;
```

But note that this will throw an error if applied to a non-collatable data type.

If no common collation can be identified among the actual arguments, then a SQL function treats its parameters as having their data types' default collation (which is usually the database's default collation, but could be different for parameters of domain types).

The behavior of collatable parameters can be thought of as a limited form of polymorphism, applicable only to textual data types.

## 36.6. Function Overloading

More than one function can be defined with the same SQL name, so long as the arguments they take are different. In other words, function names can be *overloaded*. Whether or not you use it, this capability entails security precautions when calling functions in databases where some users mistrust other users; see Section 10.3. When a query is executed, the server will determine which function to call from the data types and the number of the provided arguments. Overloading can also be used to simulate functions with a variable number of arguments, up to a finite maximum number.

When creating a family of overloaded functions, one should be careful not to create ambiguities. For instance, given the functions:

```
CREATE FUNCTION test(int, real) RETURNS ...
CREATE FUNCTION test(smallint, double precision) RETURNS ...
```

it is not immediately clear which function would be called with some trivial input like `test(1, 1.5)`. The currently implemented resolution rules are described in Chapter 10, but it is unwise to design a system that subtly relies on this behavior.

A function that takes a single argument of a composite type should generally not have the same name as any attribute (field) of that type. Recall that `attribute(table)` is considered equivalent to `table.attribute`. In the case that there is an ambiguity between a function on a composite type and an attribute of the composite type, the attribute will always be used. It is possible to override that choice by schema-qualifying the function name (that is, `schema.func(table)`) but it's better to avoid the problem by not choosing conflicting names.

Another possible conflict is between variadic and non-variadic functions. For instance, it is possible to create both `foo(numeric)` and `foo(VARIADIC numeric[])`. In this case it is unclear which one should be matched to a call providing a single numeric argument, such as `foo(10.1)`. The rule is that the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

When overloading C-language functions, there is an additional constraint: The C name of each function in the family of overloaded functions must be different from the C names of all other functions, either internal or dynamically loaded. If this rule is violated, the behavior is not portable. You might get a run-time linker error, or one of the functions will get called (usually the internal one). The alternative form of the AS clause for the SQL `CREATE FUNCTION` command decouples the SQL function name from the function name in the C source code. For instance:

```
CREATE FUNCTION test(int) RETURNS int
  AS 'filename', 'test_larg'
  LANGUAGE C;
CREATE FUNCTION test(int, int) RETURNS int
  AS 'filename', 'test_2arg'
  LANGUAGE C;
```

The names of the C functions here reflect one of many possible conventions.

## 36.7. Function Volatility Categories

Every function has a *volatility* classification, with the possibilities being `VOLATILE`, `STABLE`, or `IMMUTABLE`. `VOLATILE` is the default if the `CREATE FUNCTION` command does not specify a category. The volatility category is a promise to the optimizer about the behavior of the function:

- A `VOLATILE` function can do anything, including modifying the database. It can return different results on successive calls with the same arguments. The optimizer makes no assumptions about the behavior of such functions. A query using a volatile function will re-evaluate the function at every row where its value is needed.
- A `STABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments for all rows within a single statement. This category allows the optimizer to optimize multiple calls of the function to a single call. In particular, it is safe to use an expression containing such a function in an index scan condition. (Since an index scan will evaluate the comparison value only once, not once at each row, it is not valid to use a `VOLATILE` function in an index scan condition.)

- An `IMMUTABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments forever. This category allows the optimizer to pre-evaluate the function when a query calls it with constant arguments. For example, a query like `SELECT . . . WHERE x = 2 + 2` can be simplified on sight to `SELECT . . . WHERE x = 4`, because the function underlying the integer addition operator is marked `IMMUTABLE`.

For best optimization results, you should label your functions with the strictest volatility category that is valid for them.

Any function with side-effects *must* be labeled `VOLATILE`, so that calls to it cannot be optimized away. Even a function with no side-effects needs to be labeled `VOLATILE` if its value can change within a single query; some examples are `random()`, `currval()`, `timeofday()`.

Another important example is that the `current_timestamp` family of functions qualify as `STABLE`, since their values do not change within a transaction.

There is relatively little difference between `STABLE` and `IMMUTABLE` categories when considering simple interactive queries that are planned and immediately executed: it doesn't matter a lot whether a function is executed once during planning or once during query execution startup. But there is a big difference if the plan is saved and reused later. Labeling a function `IMMUTABLE` when it really isn't might allow it to be prematurely folded to a constant during planning, resulting in a stale value being re-used during subsequent uses of the plan. This is a hazard when using prepared statements or when using function languages that cache plans (such as PL/pgSQL).

For functions written in SQL or in any of the standard procedural languages, there is a second important property determined by the volatility category, namely the visibility of any data changes that have been made by the SQL command that is calling the function. A `VOLATILE` function will see such changes, a `STABLE` or `IMMUTABLE` function will not. This behavior is implemented using the snapshotting behavior of MVCC (see Chapter 13): `STABLE` and `IMMUTABLE` functions use a snapshot established as of the start of the calling query, whereas `VOLATILE` functions obtain a fresh snapshot at the start of each query they execute.

**Note**

Functions written in C can manage snapshots however they want, but it's usually a good idea to make C functions work this way too.

Because of this snapshotting behavior, a function containing only `SELECT` commands can safely be marked `STABLE`, even if it selects from tables that might be undergoing modifications by concurrent queries. LightDB will execute all commands of a `STABLE` function using the snapshot established for the calling query, and so it will see a fixed view of the database throughout that query.

The same snapshotting behavior is used for `SELECT` commands within `IMMUTABLE` functions. It is generally unwise to select from database tables within an `IMMUTABLE` function at all, since the immutability will be broken if the table contents ever change. However, LightDB does not enforce that you do not do that.

A common error is to label a function `IMMUTABLE` when its results depend on a configuration parameter. For example, a function that manipulates timestamps might well have results that depend on the `TimeZone` setting. For safety, such functions should be labeled `STABLE` instead.

**Note**

LightDB requires that `STABLE` and `IMMUTABLE` functions contain no SQL commands other than `SELECT` to prevent data modification. (This is not a completely bulletproof test, since such functions could still call `VOLATILE` functions that modify the database. If you do that, you will find that the `STABLE` or `IMMUTABLE` function



does not notice the database changes applied by the called function, since they are hidden from its snapshot.)

## 36.8. Procedural Language Functions

LightDB allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). Procedural languages aren't built into the LightDB server; they are offered by loadable modules. See Chapter 40 and following chapters for more information.

## 36.9. Internal Functions

Internal functions are functions written in C that have been statically linked into the LightDB server. The “body” of the function definition specifies the C-language name of the function, which need not be the same as the name being declared for SQL use. (For reasons of backward compatibility, an empty body is accepted as meaning that the C-language function name is the same as the SQL name.)

Normally, all internal functions present in the server are declared during the initialization of the database cluster (see Section 16.2), but a user could use `CREATE FUNCTION` to create additional alias names for an internal function. Internal functions are declared in `CREATE FUNCTION` with language name `internal`. For instance, to create an alias for the `sqrt` function:

```
CREATE FUNCTION square_root(double precision) RETURNS double
precision
AS 'dsqrt'
LANGUAGE internal
STRICT;
```

(Most internal functions expect to be declared “strict”).

### Note

Not all “predefined” functions are “internal” in the above sense. Some predefined functions are written in SQL.

## 36.10. C-Language Functions

User-defined functions can be written in C (or a language that can be made compatible with C, such as C++). Such functions are compiled into dynamically loadable objects (also called shared libraries) and are loaded by the server on demand. The dynamic loading feature is what distinguishes “C language” functions from “internal” functions — the actual coding conventions are essentially the same for both. (Hence, the standard internal function library is a rich source of coding examples for user-defined C functions.)

Currently only one calling convention is used for C functions (“version 1”). Support for that calling convention is indicated by writing a `PG_FUNCTION_INFO_V1 ( )` macro call for the function, as illustrated below.

### 36.10.1. Dynamic Loading

The first time a user-defined function in a particular loadable object file is called in a session, the dynamic loader loads that object file into memory so that the function can be called. The `CREATE`

FUNCTION for a user-defined C function must therefore specify two pieces of information for the function: the name of the loadable object file, and the C name (link symbol) of the specific function to call within that object file. If the C name is not explicitly specified then it is assumed to be the same as the SQL function name.

The following algorithm is used to locate the shared object file based on the name given in the CREATE FUNCTION command:

1. If the name is an absolute path, the given file is loaded.
2. If the name starts with the string `$libdir`, that part is replaced by the LightDB package library directory name, which is determined at build time.
3. If the name does not contain a directory part, the file is searched for in the path specified by the configuration variable `dynamic_library_path`.
4. Otherwise (the file was not found in the path, or it contains a non-absolute directory part), the dynamic loader will try to take the name as given, which will most likely fail. (It is unreliable to depend on the current working directory.)

If this sequence does not work, the platform-specific shared library file name extension (often `.so`) is appended to the given name and this sequence is tried again. If that fails as well, the load will fail.

It is recommended to locate shared libraries either relative to `$libdir` or through the dynamic library path. This simplifies version upgrades if the new installation is at a different location. The actual directory that `$libdir` stands for can be found out with the command `lt_config --pkglibdir`.

The user ID the LightDB server runs as must be able to traverse the path to the file you intend to load. Making the file or a higher-level directory not readable and/or not executable by the `lightdb` user is a common mistake.

In any case, the file name that is given in the CREATE FUNCTION command is recorded literally in the system catalogs, so if the file needs to be loaded again the same procedure is applied.

**Note**

LightDB will not compile a C function automatically. The object file must be compiled before it is referenced in a CREATE FUNCTION command. See Section 36.10.5 for additional information.

To ensure that a dynamically loaded object file is not loaded into an incompatible server, LightDB checks that the file contains a “magic block” with the appropriate contents. This allows the server to detect obvious incompatibilities, such as code compiled for a different major version of LightDB. To include a magic block, write this in one (and only one) of the module source files, after having included the header `fmgr.h`:

```
PG_MODULE_MAGIC;
```

After it is used for the first time, a dynamically loaded object file is retained in memory. Future calls in the same session to the function(s) in that file will only incur the small overhead of a symbol table lookup. If you need to force a reload of an object file, for example after recompiling it, begin a fresh session.

Optionally, a dynamically loaded file can contain initialization and finalization functions. If the file includes a function named `_PG_init`, that function will be called immediately after loading the file.

The function receives no parameters and should return void. If the file includes a function named `_PG_fini`, that function will be called immediately before unloading the file. Likewise, the function receives no parameters and should return void. Note that `_PG_fini` will only be called during an unload of the file, not during process termination. (Presently, unloads are disabled and will never occur, but this may change in the future.)

## 36.10.2. Base Types in C-Language Functions

To know how to write C-language functions, you need to know how LightDB internally represents base data types and how they can be passed to and from functions. Internally, LightDB regards a base type as a “blob of memory”. The user-defined functions that you define over a type in turn define the way that LightDB can operate on it. That is, LightDB will only store and retrieve the data from disk and use your user-defined functions to input, process, and output the data.

Base types can have one of three internal formats:

- pass by value, fixed-length
- pass by reference, fixed-length
- pass by reference, variable-length

By-value types can only be 1, 2, or 4 bytes in length (also 8 bytes, if `sizeof(Datum)` is 8 on your machine). You should be careful to define your types such that they will be the same size (in bytes) on all architectures. For example, the `long` type is dangerous because it is 4 bytes on some machines and 8 bytes on others, whereas `int` type is 4 bytes on most Unix machines. A reasonable implementation of the `int4` type on Unix machines might be:

```
/* 4-byte integer, passed by value */
typedef int int4;
```

(The actual LightDB C code calls this type `int32`, because it is a convention in C that `intXX` means `XX bits`. Note therefore also that the C type `int8` is 1 byte in size. The SQL type `int8` is called `int64` in C. See also Table 36.2.)

On the other hand, fixed-length types of any size can be passed by-reference. For example, here is a sample implementation of a LightDB type:

```
/* 16-byte structure, passed by reference */
typedef struct
{
    double x, y;
} Point;
```

Only pointers to such types can be used when passing them in and out of LightDB functions. To return a value of such a type, allocate the right amount of memory with `palloc`, fill in the allocated memory, and return a pointer to it. (Also, if you just want to return the same value as one of your input arguments that's of the same data type, you can skip the extra `palloc` and just return the pointer to the input value.)

Finally, all variable-length types must also be passed by reference. All variable-length types must begin with an opaque length field of exactly 4 bytes, which will be set by `SET_VARSIZE`; never set this field directly! All data to be stored within that type must be located in the memory immediately following that length field. The length field contains the total length of the structure, that is, it includes the size of the length field itself.

Another important point is to avoid leaving any uninitialized bits within data type values; for example, take care to zero out any alignment padding bytes that might be present in structs. Without this,

logically-equivalent constants of your data type might be seen as unequal by the planner, leading to inefficient (though not incorrect) plans.

**Warning**

*Never* modify the contents of a pass-by-reference input value. If you do so you are likely to corrupt on-disk data, since the pointer you are given might point directly into a disk buffer. The sole exception to this rule is explained in Section 36.12.

As an example, we can define the type `text` as follows:

```
typedef struct {
    int32 length;
    char data[FLEXIBLE_ARRAY_MEMBER];
} text;
```

The `[FLEXIBLE_ARRAY_MEMBER]` notation means that the actual length of the data part is not specified by this declaration.

When manipulating variable-length types, we must be careful to allocate the correct amount of memory and set the length field correctly. For example, if we wanted to store 40 bytes in a `text` structure, we might use a code fragment like this:

```
#include "postgres.h"
...
char buffer[40]; /* our source data */
...
text *destination = (text *) palloc(VARHDRSZ + 40);
SET_VARSIZE(destination, VARHDRSZ + 40);
memcpy(destination->data, buffer, 40);
...

```

`VARHDRSZ` is the same as `sizeof(int32)`, but it's considered good style to use the macro `VARHDRSZ` to refer to the size of the overhead for a variable-length type. Also, the length field *must* be set using the `SET_VARSIZE` macro, not by simple assignment.

Table 36.2 shows the C types corresponding to many of the built-in SQL data types of LightDB. The “Defined In” column gives the header file that needs to be included to get the type definition. (The actual definition might be in a different file that is included by the listed file. It is recommended that users stick to the defined interface.) Note that you should always include `postgres.h` first in any source file of server code, because it declares a number of things that you will need anyway, and because including other headers first can cause portability issues.

**Table 36.2. Equivalent C Types for Built-in SQL Types**

SQL Type	C Type	Defined In
boolean	bool	postgres.h (maybe compiler built-in)
box	BOX*	utils/geo_decls.h
bytea	bytea*	postgres.h
"char"	char	(compiler built-in)
character	BpChar*	postgres.h
cid	CommandId	postgres.h

SQL Type	C Type	Defined In
date	DateADT	utils/date.h
float4 (real)	float4	postgres.h
float8 (double precision)	float8	postgres.h
int2 (smallint)	int16	postgres.h
int4 (integer)	int32	postgres.h
int8 (bigint)	int64	postgres.h
interval	Interval*	datatype/timestamp.h
lseg	LSEG*	utils/geo_decls.h
name	Name	postgres.h
numeric	Numeric	utils/numeric.h
oid	Oid	postgres.h
oidvector	oidvector*	postgres.h
path	PATH*	utils/geo_decls.h
point	POINT*	utils/geo_decls.h
regproc	RegProcedure	postgres.h
text	text*	postgres.h
tid	ItemPointer	storage/itemptr.h
time	TimeADT	utils/date.h
time with time zone	TimeTzADT	utils/date.h
timestamp	Timestamp	datatype/timestamp.h
timestamp with time zone	TimestampTz	datatype/timestamp.h
varchar	VarChar*	postgres.h
xid	TransactionId	postgres.h

Now that we've gone over all of the possible structures for base types, we can show some examples of real functions.

### 36.10.3. Version 1 Calling Conventions

The version-1 calling convention relies on macros to suppress most of the complexity of passing arguments and results. The C declaration of a version-1 function is always:

```
Datum funcname ( PG_FUNCTION_ARGS )
```

In addition, the macro call:

```
PG_FUNCTION_INFO_V1 ( funcname ) ;
```

must appear in the same source file. (Conventionally, it's written just before the function itself.) This macro call is not needed for internal-language functions, since LightDB assumes that all internal functions use the version-1 convention. It is, however, required for dynamically-loaded functions.

In a version-1 function, each actual argument is fetched using a `PG_GETARG_xxx()` macro that corresponds to the argument's data type. (In non-strict functions there needs to be a previous check

about argument null-ness using `PG_ARGISNULL()`; see below.) The result is returned using a `PG_RETURN_xxx()` macro for the return type. `PG_GETARG_xxx()` takes as its argument the number of the function argument to fetch, where the count starts at 0. `PG_RETURN_xxx()` takes as its argument the actual value to return.

Here are some examples using the version-1 calling convention:

```
#include "postgres.h"
#include <string.h>
#include "fmgr.h"
#include "utils/geo_decls.h"

PG_MODULE_MAGIC;

/* by value */

PG_FUNCTION_INFO_V1(add_one);

Datum
add_one(PG_FUNCTION_ARGS)
{
    int32    arg = PG_GETARG_INT32(0);

    PG_RETURN_INT32(arg + 1);
}

/* by reference, fixed length */

PG_FUNCTION_INFO_V1(add_one_float8);

Datum
add_one_float8(PG_FUNCTION_ARGS)
{
    /* The macros for FLOAT8 hide its pass-by-reference nature. */
    float8   arg = PG_GETARG_FLOAT8(0);

    PG_RETURN_FLOAT8(arg + 1.0);
}

PG_FUNCTION_INFO_V1(makepoint);

Datum
makepoint(PG_FUNCTION_ARGS)
{
    /* Here, the pass-by-reference nature of Point is not hidden.
     */
    Point    *pointx = PG_GETARG_POINT_P(0);
    Point    *pointy = PG_GETARG_POINT_P(1);
    Point    *new_point = (Point *) palloc(sizeof(Point));

    new_point->x = pointx->x;
    new_point->y = pointy->y;

    PG_RETURN_POINT_P(new_point);
}

/* by reference, variable length */
```

```

PG_FUNCTION_INFO_V1(copytext);

Datum
copytext(PG_FUNCTION_ARGS)
{
    text      *t = PG_GETARG_TEXT_PP(0);

    /*
     * VARSIZE_ANY_EXHDR is the size of the struct in bytes, minus
     the
     * VARHDRSZ or VARHDRSZ_SHORT of its header. Construct the
     copy with a
     * full-length header.
     */
    text      *new_t = (text *) palloc(VARSIZE_ANY_EXHDR(t) +
VARHDRSZ);
    SET_VARSIZE(new_t, VARSIZE_ANY_EXHDR(t) + VARHDRSZ);

    /*
     * VARDATA is a pointer to the data region of the new struct.
     The source
     * could be a short datum, so retrieve its data through
     VARDATA_ANY.
     */
    memcpy((void *) VARDATA(new_t), /* destination */
           (void *) VARDATA_ANY(t), /* source */
           VARSIZE_ANY_EXHDR(t)); /* how many bytes */
    PG_RETURN_TEXT_P(new_t);
}

PG_FUNCTION_INFO_V1(concat_text);

Datum
concat_text(PG_FUNCTION_ARGS)
{
    text  *arg1 = PG_GETARG_TEXT_PP(0);
    text  *arg2 = PG_GETARG_TEXT_PP(1);
    int32 arg1_size = VARSIZE_ANY_EXHDR(arg1);
    int32 arg2_size = VARSIZE_ANY_EXHDR(arg2);
    int32 new_text_size = arg1_size + arg2_size + VARHDRSZ;
    text *new_text = (text *) palloc(new_text_size);

    SET_VARSIZE(new_text, new_text_size);
    memcpy(VARDATA(new_text), VARDATA_ANY(arg1), arg1_size);
    memcpy(VARDATA(new_text) + arg1_size, VARDATA_ANY(arg2),
arg2_size);
    PG_RETURN_TEXT_P(new_text);
}

```

Supposing that the above code has been prepared in file `funcs.c` and compiled into a shared object, we could define the functions to LightDB with commands like this:

```

CREATE FUNCTION add_one(integer) RETURNS integer
AS 'DIRECTORY/funcs', 'add_one'
LANGUAGE C STRICT;

```

```
-- note overloading of SQL function name "add_one"
CREATE FUNCTION add_one(double precision) RETURNS double precision
    AS 'DIRECTORY/funcs', 'add_one_float8'
    LANGUAGE C STRICT;

CREATE FUNCTION makepoint(point, point) RETURNS point
    AS 'DIRECTORY/funcs', 'makepoint'
    LANGUAGE C STRICT;

CREATE FUNCTION copytext(text) RETURNS text
    AS 'DIRECTORY/funcs', 'copytext'
    LANGUAGE C STRICT;

CREATE FUNCTION concat_text(text, text) RETURNS text
    AS 'DIRECTORY/funcs', 'concat_text'
    LANGUAGE C STRICT;
```

Here, *DIRECTORY* stands for the directory of the shared library file (for instance the LightDB tutorial directory, which contains the code for the examples used in this section). (Better style would be to use just 'funcs' in the AS clause, after having added *DIRECTORY* to the search path. In any case, we can omit the system-specific extension for a shared library, commonly .so.)

Notice that we have specified the functions as “strict”, meaning that the system should automatically assume a null result if any input value is null. By doing this, we avoid having to check for null inputs in the function code. Without this, we'd have to check for null values explicitly, using `PG_ARGISNULL()`.

The macro `PG_ARGISNULL(n)` allows a function to test whether each input is null. (Of course, doing this is only necessary in functions not declared “strict”.) As with the `PG_GETARG_xxx()` macros, the input arguments are counted beginning at zero. Note that one should refrain from executing `PG_GETARG_xxx()` until one has verified that the argument isn't null. To return a null result, execute `PG_RETURN_NULL()`; this works in both strict and nonstrict functions.

At first glance, the version-1 coding conventions might appear to be just pointless obscurantism, compared to using plain C calling conventions. They do however allow us to deal with NULLable arguments/return values, and “toasted” (compressed or out-of-line) values.

Other options provided by the version-1 interface are two variants of the `PG_GETARG_xxx()` macros. The first of these, `PG_GETARG_xxx_COPY()`, guarantees to return a copy of the specified argument that is safe for writing into. (The normal macros will sometimes return a pointer to a value that is physically stored in a table, which must not be written to. Using the `PG_GETARG_xxx_COPY()` macros guarantees a writable result.) The second variant consists of the `PG_GETARG_xxx_SLICE()` macros which take three arguments. The first is the number of the function argument (as above). The second and third are the offset and length of the segment to be returned. Offsets are counted from zero, and a negative length requests that the remainder of the value be returned. These macros provide more efficient access to parts of large values in the case where they have storage type “external”. (The storage type of a column can be specified using `ALTER TABLE tablename ALTER COLUMN colname SET STORAGE storagetype`. *storagetype* is one of plain, external, extended, or main.)

Finally, the version-1 function call conventions make it possible to return set results (Section 36.10.8) and implement trigger functions (Chapter 37) and procedural-language call handlers (Chapter 52). For more details see `src/backend/utils/fmgr/README` in the source distribution.

## 36.10.4. Writing Code

Before we turn to the more advanced topics, we should discuss some coding rules for LightDB C-language functions. While it might be possible to load functions written in languages other than C into



LightDB, this is usually difficult (when it is possible at all) because other languages, such as C++, FORTRAN, or Pascal often do not follow the same calling convention as C. That is, other languages do not pass argument and return values between functions in the same way. For this reason, we will assume that your C-language functions are actually written in C.

The basic rules for writing and building C functions are as follows:

- Use `lt_config --includedir-server` to find out where the LightDB server header files are installed on your system (or the system that your users will be running on).
- Compiling and linking your code so that it can be dynamically loaded into LightDB always requires special flags. See Section 36.10.5 for a detailed explanation of how to do it for your particular operating system.
- Remember to define a “magic block” for your shared library, as described in Section 36.10.1.
- When allocating memory, use the LightDB functions `palloc` and `pfree` instead of the corresponding C library functions `malloc` and `free`. The memory allocated by `palloc` will be freed automatically at the end of each transaction, preventing memory leaks.
- Always zero the bytes of your structures using `memset` (or allocate them with `palloc0` in the first place). Even if you assign to each field of your structure, there might be alignment padding (holes in the structure) that contain garbage values. Without this, it's difficult to support hash indexes or hash joins, as you must pick out only the significant bits of your data structure to compute a hash. The planner also sometimes relies on comparing constants via bitwise equality, so you can get undesirable planning results if logically-equivalent values aren't bitwise equal.
- Most of the internal LightDB types are declared in `postgres.h`, while the function manager interfaces (`PG_FUNCTION_ARGS`, etc.) are in `fmgr.h`, so you will need to include at least these two files. For portability reasons it's best to include `postgres.h` first, before any other system or user header files. Including `postgres.h` will also include `elog.h` and `palloc.h` for you.
- Symbol names defined within object files must not conflict with each other or with symbols defined in the LightDB server executable. You will have to rename your functions or variables if you get error messages to this effect.

## 36.10.5. Compiling and Linking Dynamically-Loaded Functions

Before you are able to use your LightDB extension functions written in C, they must be compiled and linked in a special way to produce a file that can be dynamically loaded by the server. To be precise, a *shared library* needs to be created.

For information beyond what is contained in this section you should read the documentation of your operating system, in particular the manual pages for the C compiler, `cc`, and the link editor, `ld`. In addition, the LightDB source code contains several working examples in the `contrib` directory. If you rely on these examples you will make your modules dependent on the availability of the LightDB source code, however.

Creating shared libraries is generally analogous to linking executables: first the source files are compiled into object files, then the object files are linked together. The object files need to be created as *position-independent code* (PIC), which conceptually means that they can be placed at an arbitrary location in memory when they are loaded by the executable. (Object files intended for executables are usually not compiled that way.) The command to link a shared library contains special flags to distinguish it from linking an executable (at least in theory — on some systems the practice is much uglier).

In the following examples we assume that your source code is in a file `foo.c` and we will create a shared library `foo.so`. The intermediate object file will be called `foo.o` unless otherwise noted. A shared library can contain more than one object file, but we only use one here.

### FreeBSD

The compiler flag to create PIC is `-fPIC`. To create shared libraries the compiler flag is `-shared`.

```
gcc -fPIC -c foo.c
gcc -shared -o foo.so foo.o
```

This is applicable as of version 3.0 of FreeBSD.

### HP-UX

The compiler flag of the system compiler to create PIC is `+z`. When using GCC it's `-fPIC`. The linker flag for shared libraries is `-b`. So:

```
cc +z -c foo.c

or:

gcc -fPIC -c foo.c
```

and then:

```
ld -b -o foo.sl foo.o
```

HP-UX uses the extension `.sl` for shared libraries, unlike most other systems.

### Linux

The compiler flag to create PIC is `-fPIC`. The compiler flag to create a shared library is `-shared`. A complete example looks like this:

```
cc -fPIC -c foo.c
cc -shared -o foo.so foo.o
```

### macOS

Here is an example. It assumes the developer tools are installed.

```
cc -c foo.c
cc -bundle -flat_namespace -undefined suppress -o foo.so foo.o
```

### NetBSD

The compiler flag to create PIC is `-fPIC`. For ELF systems, the compiler with the flag `-shared` is used to link shared libraries. On the older non-ELF systems, `ld -Bshareable` is used.

```
gcc -fPIC -c foo.c
gcc -shared -o foo.so foo.o
```

### OpenBSD

The compiler flag to create PIC is `-fPIC`. `ld -Bshareable` is used to link shared libraries.

```
gcc -fPIC -c foo.c
ld -Bshareable -o foo.so foo.o
```

#### Solaris

The compiler flag to create PIC is `-KPIC` with the Sun compiler and `-fPIC` with GCC. To link shared libraries, the compiler option is `-G` with either compiler or alternatively `-shared` with GCC.

```
cc -KPIC -c foo.c
cc -G -o foo.so foo.o
```

or

```
gcc -fPIC -c foo.c
gcc -G -o foo.so foo.o
```

### Tip

If this is too complicated for you, you should consider using GNU Libtool<sup>1</sup>, which hides the platform differences behind a uniform interface.

The resulting shared library file can then be loaded into LightDB. When specifying the file name to the `CREATE FUNCTION` command, one must give it the name of the shared library file, not the intermediate object file. Note that the system's standard shared-library extension (usually `.so` or `.sl`) can be omitted from the `CREATE FUNCTION` command, and normally should be omitted for best portability.

Refer back to Section 36.10.1 about where the server expects to find the shared library files.

## 36.10.6. Composite-Type Arguments

Composite types do not have a fixed layout like C structures. Instances of a composite type can contain null fields. In addition, composite types that are part of an inheritance hierarchy can have different fields than other members of the same inheritance hierarchy. Therefore, LightDB provides a function interface for accessing fields of composite types from C.

Suppose we want to write a function to answer the query:

```
SELECT name, c_overpaid(emp, 1500) AS overpaid
FROM emp
WHERE name = 'Bill' OR name = 'Sam';
```

Using the version-1 calling conventions, we can define `c_overpaid` as:

```
#include "postgres.h"
#include "executor/executor.h" /* for GetAttributeByName() */

PG_MODULE_MAGIC;
```

---

<sup>1</sup> <https://www.gnu.org/software/libtool/>

```

PG_FUNCTION_INFO_V1(c_overpaid);

Datum
c_overpaid(PG_FUNCTION_ARGS)
{
    HeapTupleHeader t = PG_GETARG_HEAPTUPLEHEADER(0);
    int32          limit = PG_GETARG_INT32(1);
    bool isnull;
    Datum salary;

    salary = GetAttributeByName(t, "salary", &isnull);
    if (isnull)
        PG_RETURN_BOOL(false);
    /* Alternatively, we might prefer to do PG_RETURN_NULL() for
    null salary. */

    PG_RETURN_BOOL(DatumGetInt32(salary) > limit);
}

```

`GetAttributeByName` is the LightDB system function that returns attributes out of the specified row. It has three arguments: the argument of type `HeapTupleHeader` passed into the function, the name of the desired attribute, and a return parameter that tells whether the attribute is null. `GetAttributeByName` returns a `Datum` value that you can convert to the proper data type by using the appropriate `DatumGetXXX()` macro. Note that the return value is meaningless if the null flag is set; always check the null flag before trying to do anything with the result.

There is also `GetAttributeByNum`, which selects the target attribute by column number instead of name.

The following command declares the function `c_overpaid` in SQL:

```

CREATE FUNCTION c_overpaid(emp, integer) RETURNS boolean
AS 'DIRECTORY/funcs', 'c_overpaid'
LANGUAGE C STRICT;

```

Notice we have used `STRICT` so that we did not have to check whether the input arguments were `NULL`.

## 36.10.7. Returning Rows (Composite Types)

To return a row or composite-type value from a C-language function, you can use a special API that provides macros and functions to hide most of the complexity of building composite data types. To use this API, the source file must include:

```
#include "funcapi.h"
```

There are two ways you can build a composite data value (henceforth a “tuple”): you can build it from an array of `Datum` values, or from an array of C strings that can be passed to the input conversion functions of the tuple's column data types. In either case, you first need to obtain or construct a `TupleDesc` descriptor for the tuple structure. When working with `Datums`, you pass the `TupleDesc` to `BlessTupleDesc`, and then call `heap_form_tuple` for each row. When working with C strings, you pass the `TupleDesc` to `TupleDescGetAttInMetadata`, and then call `BuildTupleFromCStrings` for each row. In the case of a function returning a set of tuples, the setup steps can all be done once during the first call of the function.

Several helper functions are available for setting up the needed `TupleDesc`. The recommended way to do this in most functions returning composite values is to call:

```
TypeFuncClass get_call_result_type(FunctionCallInfo fcinfo,
                                   Oid *resultTypeId,
                                   TupleDesc *resultTupleDesc)
```

passing the same `fcinfo` struct passed to the calling function itself. (This of course requires that you use the version-1 calling conventions.) `resultTypeId` can be specified as `NULL` or as the address of a local variable to receive the function's result type OID. `resultTupleDesc` should be the address of a local `TupleDesc` variable. Check that the result is `TYPEFUNC_COMPOSITE`; if so, `resultTupleDesc` has been filled with the needed `TupleDesc`. (If it is not, you can report an error along the lines of “function returning record called in context that cannot accept type record”.)

**Tip**

`get_call_result_type` can resolve the actual type of a polymorphic function result; so it is useful in functions that return scalar polymorphic results, not only functions that return composites. The `resultTypeId` output is primarily useful for functions returning polymorphic scalars.

**Note**

`get_call_result_type` has a sibling `get_expr_result_type`, which can be used to resolve the expected output type for a function call represented by an expression tree. This can be used when trying to determine the result type from outside the function itself. There is also `get_func_result_type`, which can be used when only the function's OID is available. However these functions are not able to deal with functions declared to return `record`, and `get_func_result_type` cannot resolve polymorphic types, so you should preferentially use `get_call_result_type`.

Older, now-deprecated functions for obtaining `TupleDesc`s are:

```
TupleDesc RelationNameGetTupleDesc(const char *relname)
```

to get a `TupleDesc` for the row type of a named relation, and:

```
TupleDesc TypeGetTupleDesc(Oid typeoid, List *colaliases)
```

to get a `TupleDesc` based on a type OID. This can be used to get a `TupleDesc` for a base or composite type. It will not work for a function that returns `record`, however, and it cannot resolve polymorphic types.

Once you have a `TupleDesc`, call:

```
TupleDesc BlessTupleDesc(TupleDesc tupdesc)
```

if you plan to work with `Datums`, or:

```
AttInMetadata *TupleDescGetAttInMetadata(TupleDesc tupdesc)
```

if you plan to work with C strings. If you are writing a function returning set, you can save the results of these functions in the `FuncCallContext` structure — use the `tuple_desc` or `attinmeta` field respectively.

When working with Datums, use:

```
HeapTuple heap_form_tuple(TupleDesc tupdesc, Datum *values, bool
    *isnull)
```

to build a `HeapTuple` given user data in Datum form.

When working with C strings, use:

```
HeapTuple BuildTupleFromCStrings(AttInMetadata *attinmeta, char
    **values)
```

to build a `HeapTuple` given user data in C string form. *values* is an array of C strings, one for each attribute of the return row. Each C string should be in the form expected by the input function of the attribute data type. In order to return a null value for one of the attributes, the corresponding pointer in the *values* array should be set to `NULL`. This function will need to be called again for each row you return.

Once you have built a tuple to return from your function, it must be converted into a Datum. Use:

```
HeapTupleGetDatum(HeapTuple tuple)
```

to convert a `HeapTuple` into a valid Datum. This Datum can be returned directly if you intend to return just a single row, or it can be used as the current return value in a set-returning function.

An example appears in the next section.

## 36.10.8. Returning Sets

C-language functions have two options for returning sets (multiple rows). In one method, called *ValuePerCall* mode, a set-returning function is called repeatedly (passing the same arguments each time) and it returns one new row on each call, until it has no more rows to return and signals that by returning `NULL`. The set-returning function (SRF) must therefore save enough state across calls to remember what it was doing and return the correct next item on each call. In the other method, called *Materialize* mode, a SRF fills and returns a tuplestore object containing its entire result; then only one call occurs for the whole result, and no inter-call state is needed.

When using *ValuePerCall* mode, it is important to remember that the query is not guaranteed to be run to completion; that is, due to options such as `LIMIT`, the executor might stop making calls to the set-returning function before all rows have been fetched. This means it is not safe to perform cleanup activities in the last call, because that might not ever happen. It's recommended to use *Materialize* mode for functions that need access to external resources, such as file descriptors.

The remainder of this section documents a set of helper macros that are commonly used (though not required to be used) for SRFs using *ValuePerCall* mode. Additional details about *Materialize* mode can be found in `src/backend/utils/fmgr/README`. Also, the `contrib` modules in the `LightDB` source distribution contain many examples of SRFs using both *ValuePerCall* and *Materialize* mode.

To use the *ValuePerCall* support macros described here, include `funcapi.h`. These macros work with a structure `FuncCallContext` that contains the state that needs to be saved across calls. Within the calling SRF, `fcinfo->flinfo->fn_extra` is used to hold a pointer to `FuncCallContext`

across calls. The macros automatically fill that field on first use, and expect to find the same pointer there on subsequent uses.

```
typedef struct FuncCallContext
{
    /*
     * Number of times we've been called before
     *
     * call_cntr is initialized to 0 for you by
     SRF_FIRSTCALL_INIT(), and
     * incremented for you every time SRF_RETURN_NEXT() is called.
     */
    uint64 call_cntr;

    /*
     * OPTIONAL maximum number of calls
     *
     * max_calls is here for convenience only and setting it is
     optional.
     * If not set, you must provide alternative means to know when
     the
     * function is done.
     */
    uint64 max_calls;

    /*
     * OPTIONAL pointer to miscellaneous user-provided context
     information
     *
     * user_fctx is for use as a pointer to your own data to retain
     * arbitrary context information between calls of your
     function.
     */
    void *user_fctx;

    /*
     * OPTIONAL pointer to struct containing attribute type input
     metadata
     *
     * attinmeta is for use when returning tuples (i.e., composite
     data types)
     * and is not used when returning base data types. It is only
     needed
     * if you intend to use BuildTupleFromCStrings() to create the
     return
     * tuple.
     */
    AttInMetadata *attinmeta;

    /*
     * memory context used for structures that must live for
     multiple calls
     *
     * multi_call_memory_ctx is set by SRF_FIRSTCALL_INIT() for
     you, and used
     * by SRF_RETURN_DONE() for cleanup. It is the most appropriate
     memory
    */

```

```

    * context for any memory that is to be reused across multiple
calls
    * of the SRF.
    */
MemoryContext multi_call_memory_ctx;

/*
 * OPTIONAL pointer to struct containing tuple description
 *
 * tuple_desc is for use when returning tuples (i.e., composite
data types)
 * and is only needed if you are going to build the tuples with
 * heap_form_tuple() rather than with BuildTupleFromCStrings().
Note that
 * the TupleDesc pointer stored here should usually have been
run through
 * BlessTupleDesc() first.
 */
TupleDesc tuple_desc;

} FuncCallContext;

```

The macros to be used by an SRF using this infrastructure are:

`SRF_IS_FIRSTCALL()`

Use this to determine if your function is being called for the first or a subsequent time. On the first call (only), call:

`SRF_FIRSTCALL_INIT()`

to initialize the `FuncCallContext`. On every function call, including the first, call:

`SRF_PERCALL_SETUP()`

to set up for using the `FuncCallContext`.

If your function has data to return in the current call, use:

`SRF_RETURN_NEXT(funcctx, result)`

to return it to the caller. (`result` must be of type `Datum`, either a single value or a tuple prepared as described above.) Finally, when your function is finished returning data, use:

`SRF_RETURN_DONE(funcctx)`

to clean up and end the SRF.

The memory context that is current when the SRF is called is a transient context that will be cleared between calls. This means that you do not need to call `pfree` on everything you allocated using `palloc`; it will go away anyway. However, if you want to allocate any data structures to live across calls, you need to put them somewhere else. The memory context referenced by `multi_call_memory_ctx` is a suitable location for any data that needs to survive until the SRF is finished running. In most cases, this means that you should switch into `multi_call_memory_ctx` while doing the first-call setup. Use `funcctx->user_fctx` to hold a pointer to any such cross-call data structures. (Data you allocate in `multi_call_memory_ctx` will go away automatically when the query ends, so it is not necessary to free that data manually, either.)



### Warning

While the actual arguments to the function remain unchanged between calls, if you detoast the argument values (which is normally done transparently by the `PG_GETARG_xxx` macro) in the transient context then the detoasted copies will be freed on each cycle. Accordingly, if you keep references to such values in your `user_fctx`, you must either copy them into the `multi_call_memory_ctx` after detoasting, or ensure that you detoast the values only in that context.

A complete pseudo-code example looks like the following:

```
Datum
my_set_returning_function(PG_FUNCTION_ARGS)
{
    FuncCallContext *funcctx;
    Datum          result;
    further declarations as needed

    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext oldcontext;

        funcctx = SRF_FIRSTCALL_INIT();
        oldcontext = MemoryContextSwitchTo(funcctx->
>multi_call_memory_ctx);
        /* One-time setup code appears here: */
        user code
        if returning composite
            build TupleDesc, and perhaps AttInMetadata
        endif returning composite
        user code
        MemoryContextSwitchTo(oldcontext);
    }

    /* Each-time setup code appears here: */
    user code
    funcctx = SRF_PERCALL_SETUP();
    user code

    /* this is just one way we might test whether we are done: */
    if (funcctx->call_cntr < funcctx->max_calls)
    {
        /* Here we want to return another item: */
        user code
        obtain result Datum
        SRF_RETURN_NEXT(funcctx, result);
    }
    else
    {
        /* Here we are done returning items, so just report that
fact. */
        /* (Resist the temptation to put cleanup code here.) */
        SRF_RETURN_DONE(funcctx);
    }
}
```

A complete example of a simple SRF returning a composite type looks like:

```

PG_FUNCTION_INFO_V1(retcomposite);

Datum
retcomposite(PG_FUNCTION_ARGS)
{
    FuncCallContext    *funcctx;
    int                 call_cntr;
    int                 max_calls;
    TupleDesc           tupdesc;
    AttInMetadata       *attinmeta;

    /* stuff done only on the first call of the function */
    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext    oldcontext;

        /* create a function context for cross-call persistence */
        funcctx = SRF_FIRSTCALL_INIT();

        /* switch to memory context appropriate for multiple
        function calls */
        oldcontext = MemoryContextSwitchTo(funcctx->multi_call_memory_ctx);

        /* total number of tuples to be returned */
        funcctx->max_calls = PG_GETARG_UINT32(0);

        /* Build a tuple descriptor for our result type */
        if (get_call_result_type(fcinfo, NULL, &tupdesc) !=
            TYPEFUNC_COMPOSITE)
            ereport(ERROR,
                    (errcode(ERRCODE_FEATURE_NOT_SUPPORTED),
                     errmsg("function returning record called in
context "
                            "that cannot accept type record")));

        /*
         * generate attribute metadata needed later to produce
         tuples from raw
         * C strings
         */
        attinmeta = TupleDescGetAttInMetadata(tupdesc);
        funcctx->attinmeta = attinmeta;

        MemoryContextSwitchTo(oldcontext);
    }

    /* stuff done on every call of the function */
    funcctx = SRF_PERCALL_SETUP();

    call_cntr = funcctx->call_cntr;
    max_calls = funcctx->max_calls;
    attinmeta = funcctx->attinmeta;

```

```

    if (call_cntr < max_calls)      /* do when there is more left to
send */
    {
        char          **values;
        HeapTuple     tuple;
        Datum         result;

        /*
         * Prepare a values array for building the returned tuple.
         * This should be an array of C strings which will
         * be processed later by the type input functions.
         */
        values = (char **) palloc(3 * sizeof(char *));
        values[0] = (char *) palloc(16 * sizeof(char));
        values[1] = (char *) palloc(16 * sizeof(char));
        values[2] = (char *) palloc(16 * sizeof(char));

        snprintf(values[0], 16, "%d", 1 * PG_GETARG_INT32(1));
        snprintf(values[1], 16, "%d", 2 * PG_GETARG_INT32(1));
        snprintf(values[2], 16, "%d", 3 * PG_GETARG_INT32(1));

        /* build a tuple */
        tuple = BuildTupleFromCStrings(atts, values);

        /* make the tuple into a datum */
        result = HeapTupleGetDatum(tuple);

        /* clean up (this is not really necessary) */
        pfree(values[0]);
        pfree(values[1]);
        pfree(values[2]);
        pfree(values);

        SRF_RETURN_NEXT(funcctx, result);
    }
    else /* do when there is no more left */
    {
        SRF_RETURN_DONE(funcctx);
    }
}

```

One way to declare this function in SQL is:

```

CREATE TYPE __retcomposite AS (f1 integer, f2 integer, f3 integer);

CREATE OR REPLACE FUNCTION retcomposite(integer, integer)
    RETURNS SETOF __retcomposite
    AS 'filename', 'retcomposite'
    LANGUAGE C IMMUTABLE STRICT;

```

A different way is to use OUT parameters:

```

CREATE OR REPLACE FUNCTION retcomposite(IN integer, IN integer,
    OUT f1 integer, OUT f2 integer, OUT f3 integer)
    RETURNS SETOF record
    AS 'filename', 'retcomposite'

```

```
LANGUAGE C IMMUTABLE STRICT;
```

Notice that in this method the output type of the function is formally an anonymous record type.

## 36.10.9. Polymorphic Arguments and Return Types

C-language functions can be declared to accept and return the polymorphic types described in Section 36.2.5. When a function's arguments or return types are defined as polymorphic types, the function author cannot know in advance what data type it will be called with, or need to return. There are two routines provided in `fmgr.h` to allow a version-1 C function to discover the actual data types of its arguments and the type it is expected to return. The routines are called `get_fn_expr_rettype(FmgrInfo *flinfo)` and `get_fn_expr_argtype(FmgrInfo *flinfo, int argnum)`. They return the result or argument type OID, or `InvalidOid` if the information is not available. The structure `flinfo` is normally accessed as `fcinfo->flinfo`. The parameter `argnum` is zero based. `get_call_result_type` can also be used as an alternative to `get_fn_expr_rettype`. There is also `get_fn_expr_variadic`, which can be used to find out whether variadic arguments have been merged into an array. This is primarily useful for `VARIADIC "any"` functions, since such merging will always have occurred for variadic functions taking ordinary array types.

For example, suppose we want to write a function to accept a single element of any type, and return a one-dimensional array of that type:

```
PG_FUNCTION_INFO_V1(make_array);
Datum
make_array(PG_FUNCTION_ARGS)
{
    ArrayType *result;
    Oid        element_type = get_fn_expr_argtype(fcinfo->flinfo,
0);
    Datum      element;
    bool       isnull;
    int16      typlen;
    bool       typbyval;
    char       typalign;
    int        ndims;
    int        dims[MAXDIM];
    int        lbs[MAXDIM];

    if (!OidIsValid(element_type))
        elog(ERROR, "could not determine data type of input");

    /* get the provided element, being careful in case it's NULL */
    isnull = PG_ARGISNULL(0);
    if (isnull)
        element = (Datum) 0;
    else
        element = PG_GETARG_DATUM(0);

    /* we have one dimension */
    ndims = 1;
    /* and one element */
    dims[0] = 1;
    /* and lower bound is 1 */
    lbs[0] = 1;

    /* get required info about the element type */
```

```

    get_typlenbyvalalign(element_type, &typlen, &typbyval,
    &typalign);

    /* now build the array */
    result = construct_md_array(&element, &isnull, ndims, dims,
    lbs,
                                element_type, typlen, typbyval,
    typalign);

    PG_RETURN_ARRAYTYPE_P(result);
}

```

The following command declares the function `make_array` in SQL:

```

CREATE FUNCTION make_array(anyelement) RETURNS anyarray
AS 'DIRECTORY/funcs', 'make_array'
LANGUAGE C IMMUTABLE;

```

There is a variant of polymorphism that is only available to C-language functions: they can be declared to take parameters of type "any". (Note that this type name must be double-quoted, since it's also a SQL reserved word.) This works like `anyelement` except that it does not constrain different "any" arguments to be the same type, nor do they help determine the function's result type. A C-language function can also declare its final parameter to be `VARIADIC "any"`. This will match one or more actual arguments of any type (not necessarily the same type). These arguments will *not* be gathered into an array as happens with normal variadic functions; they will just be passed to the function separately. The `PG_NARGS()` macro and the methods described above must be used to determine the number of actual arguments and their types when using this feature. Also, users of such a function might wish to use the `VARIADIC` keyword in their function call, with the expectation that the function would treat the array elements as separate arguments. The function itself must implement that behavior if wanted, after using `get_fn_expr_variadic` to detect that the actual argument was marked with `VARIADIC`.

## 36.10.10. Shared Memory and LWLocks

Add-ins can reserve LWLocks and an allocation of shared memory on server startup. The add-in's shared library must be preloaded by specifying it in `shared_preload_libraries`. Shared memory is reserved by calling:

```
void RequestAddinShmemSpace(int size)
```

from your `_PG_init` function.

LWLocks are reserved by calling:

```
void RequestNamedLWLockTranche(const char *tranche_name, int
    num_lwlocks)
```

from `_PG_init`. This will ensure that an array of `num_lwlocks` LWLocks is available under the name `tranche_name`. Use `GetNamedLWLockTranche` to get a pointer to this array.

To avoid possible race-conditions, each backend should use the LWLock `AddinShmemInitLock` when connecting to and initializing its allocation of shared memory, as shown here:

```
static mystruct *ptr = NULL;
```

```

if (!ptr)
{
    bool    found;

    LWLockAcquire(AddinShmemInitLock, LW_EXCLUSIVE);
    ptr = ShmemInitStruct("my struct name", size, &found);
    if (!found)
    {
        initialize contents of shmem area;
        acquire any requested LWLocks using:
        ptr->locks = GetNamedLWLockTranche("my tranche
name");
    }
    LWLockRelease(AddinShmemInitLock);
}

```

### 36.10.11. Using C++ for Extensibility

Although the LightDB backend is written in C, it is possible to write extensions in C++ if these guidelines are followed:

- All functions accessed by the backend must present a C interface to the backend; these C functions can then call C++ functions. For example, `extern C` linkage is required for backend-accessed functions. This is also necessary for any functions that are passed as pointers between the backend and C++ code.
- Free memory using the appropriate deallocation method. For example, most backend memory is allocated using `palloc()`, so use `pfree()` to free it. Using C++ `delete` in such cases will fail.
- Prevent exceptions from propagating into the C code (use a catch-all block at the top level of all `extern C` functions). This is necessary even if the C++ code does not explicitly throw any exceptions, because events like out-of-memory can still throw exceptions. Any exceptions must be caught and appropriate errors passed back to the C interface. If possible, compile C++ with `-fno-exceptions` to eliminate exceptions entirely; in such cases, you must check for failures in your C++ code, e.g., check for NULL returned by `new()`.
- If calling backend functions from C++ code, be sure that the C++ call stack contains only plain old data structures (POD). This is necessary because backend errors generate a distant `longjmp()` that does not properly unroll a C++ call stack with non-POD objects.

In summary, it is best to place C++ code behind a wall of `extern C` functions that interface to the backend, and avoid exception, memory, and call stack leakage.

## 36.11. Function Optimization Information

By default, a function is just a “black box” that the database system knows very little about the behavior of. However, that means that queries using the function may be executed much less efficiently than they could be. It is possible to supply additional knowledge that helps the planner optimize function calls.

Some basic facts can be supplied by declarative annotations provided in the `CREATE FUNCTION` command. Most important of these is the function's volatility category (`IMMUTABLE`, `STABLE`, or `VOLATILE`); one should always be careful to specify this correctly when defining a function. The parallel safety property (`PARALLEL UNSAFE`, `PARALLEL RESTRICTED`, or `PARALLEL SAFE`) must also be specified if you hope to use the function in parallelized queries. It can also be useful to specify the function's estimated execution cost, and/or the number of rows a set-returning function is estimated to return. However, the declarative way of specifying those two facts only allows specifying a constant value, which is often inadequate.

It is also possible to attach a *planner support function* to a SQL-callable function (called its *target function*), and thereby provide knowledge about the target function that is too complex to be represented declaratively. Planner support functions have to be written in C (although their target functions might not be), so this is an advanced feature that relatively few people will use.

A planner support function must have the SQL signature

```
supportfn(internal) returns internal
```

It is attached to its target function by specifying the `SUPPORT` clause when creating the target function.

The details of the API for planner support functions can be found in file `src/include/nodes/supportnodes.h` in the LightDB source code. Here we provide just an overview of what planner support functions can do. The set of possible requests to a support function is extensible, so more things might be possible in future versions.

Some function calls can be simplified during planning based on properties specific to the function. For example, `int4mul(n, 1)` could be simplified to just `n`. This type of transformation can be performed by a planner support function, by having it implement the `SupportRequestSimplify` request type. The support function will be called for each instance of its target function found in a query parse tree. If it finds that the particular call can be simplified into some other form, it can build and return a parse tree representing that expression. This will automatically work for operators based on the function, too — in the example just given, `n * 1` would also be simplified to `n`. (But note that this is just an example; this particular optimization is not actually performed by standard LightDB.) We make no guarantee that LightDB will never call the target function in cases that the support function could simplify. Ensure rigorous equivalence between the simplified expression and an actual execution of the target function.

For target functions that return `boolean`, it is often useful to estimate the fraction of rows that will be selected by a `WHERE` clause using that function. This can be done by a support function that implements the `SupportRequestSelectivity` request type.

If the target function's run time is highly dependent on its inputs, it may be useful to provide a non-constant cost estimate for it. This can be done by a support function that implements the `SupportRequestCost` request type.

For target functions that return sets, it is often useful to provide a non-constant estimate for the number of rows that will be returned. This can be done by a support function that implements the `SupportRequestRows` request type.

For target functions that return `boolean`, it may be possible to convert a function call appearing in `WHERE` into an indexable operator clause or clauses. The converted clauses might be exactly equivalent to the function's condition, or they could be somewhat weaker (that is, they might accept some values that the function condition does not). In the latter case the index condition is said to be *lossy*; it can still be used to scan an index, but the function call will have to be executed for each row returned by the index to see if it really passes the `WHERE` condition or not. To create such conditions, the support function must implement the `SupportRequestIndexCondition` request type.

## 36.12. User-Defined Aggregates

Aggregate functions in LightDB are defined in terms of *state values* and *state transition functions*. That is, an aggregate operates using a state value that is updated as each successive input row is processed. To define a new aggregate function, one selects a data type for the state value, an initial value for the state, and a state transition function. The state transition function takes the previous state value and the aggregate's input value(s) for the current row, and returns a new state value. A *final function* can also be specified, in case the desired result of the aggregate is different from the data that needs to be kept in the running state value. The final function takes the ending state value and returns whatever is wanted as the aggregate result. In principle, the transition and final functions are

just ordinary functions that could also be used outside the context of the aggregate. (In practice, it's often helpful for performance reasons to create specialized transition functions that can only work when called as part of an aggregate.)

Thus, in addition to the argument and result data types seen by a user of the aggregate, there is an internal state-value data type that might be different from both the argument and result types.

If we define an aggregate that does not use a final function, we have an aggregate that computes a running function of the column values from each row. `sum` is an example of this kind of aggregate. `sum` starts at zero and always adds the current row's value to its running total. For example, if we want to make a `sum` aggregate to work on a data type for complex numbers, we only need the addition function for that data type. The aggregate definition would be:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)'
);
```

which we might use like this:

```
SELECT sum(a) FROM test_complex;

      sum
-----
(34,53.9)
```

(Notice that we are relying on function overloading: there is more than one aggregate named `sum`, but LightDB can figure out which kind of `sum` applies to a column of type `complex`.)

The above definition of `sum` will return zero (the initial state value) if there are no nonnull input values. Perhaps we want to return null in that case instead — the SQL standard expects `sum` to behave that way. We can do this simply by omitting the `initcond` phrase, so that the initial state value is null. Ordinarily this would mean that the `sfunc` would need to check for a null state-value input. But for `sum` and some other simple aggregates like `max` and `min`, it is sufficient to insert the first nonnull input value into the state variable and then start applying the transition function at the second nonnull input value. LightDB will do that automatically if the initial state value is null and the transition function is marked “strict” (i.e., not to be called for null inputs).

Another bit of default behavior for a “strict” transition function is that the previous state value is retained unchanged whenever a null input value is encountered. Thus, null values are ignored. If you need some other behavior for null inputs, do not declare your transition function as `strict`; instead code it to test for null inputs and do whatever is needed.

`avg` (average) is a more complex example of an aggregate. It requires two pieces of running state: the sum of the inputs and the count of the number of inputs. The final result is obtained by dividing these quantities. Average is typically implemented by using an array as the state value. For example, the built-in implementation of `avg(float8)` looks like:

```
CREATE AGGREGATE avg (float8)
(
    sfunc = float8_accum,
    stype = float8[],
    finalfunc = float8_avg,
    initcond = '{0,0,0}'
);
```



**Note**

`float8_accum` requires a three-element array, not just two elements, because it accumulates the sum of squares as well as the sum and count of the inputs. This is so that it can be used for some other aggregates as well as `avg`.

Aggregate function calls in SQL allow `DISTINCT` and `ORDER BY` options that control which rows are fed to the aggregate's transition function and in what order. These options are implemented behind the scenes and are not the concern of the aggregate's support functions.

For further details see the `CREATE AGGREGATE` command.

### 36.12.1. Moving-Aggregate Mode

Aggregate functions can optionally support *moving-aggregate mode*, which allows substantially faster execution of aggregate functions within windows with moving frame starting points. (See Section 3.5 and Section 4.2.8 for information about use of aggregate functions as window functions.) The basic idea is that in addition to a normal “forward” transition function, the aggregate provides an *inverse transition function*, which allows rows to be removed from the aggregate's running state value when they exit the window frame. For example a `sum` aggregate, which uses addition as the forward transition function, would use subtraction as the inverse transition function. Without an inverse transition function, the window function mechanism must recalculate the aggregate from scratch each time the frame starting point moves, resulting in run time proportional to the number of input rows times the average frame length. With an inverse transition function, the run time is only proportional to the number of input rows.

The inverse transition function is passed the current state value and the aggregate input value(s) for the earliest row included in the current state. It must reconstruct what the state value would have been if the given input row had never been aggregated, but only the rows following it. This sometimes requires that the forward transition function keep more state than is needed for plain aggregation mode. Therefore, the moving-aggregate mode uses a completely separate implementation from the plain mode: it has its own state data type, its own forward transition function, and its own final function if needed. These can be the same as the plain mode's data type and functions, if there is no need for extra state.

As an example, we could extend the `sum` aggregate given above to support moving-aggregate mode like this:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)',
    msfunc = complex_add,
    minvfunc = complex_sub,
    mstype = complex,
    minitcond = '(0,0)'
);
```

The parameters whose names begin with `m` define the moving-aggregate implementation. Except for the inverse transition function `minvfunc`, they correspond to the plain-aggregate parameters without `m`.

The forward transition function for moving-aggregate mode is not allowed to return null as the new state value. If the inverse transition function returns null, this is taken as an indication that the inverse

function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value. The inverse transition function can “punt” on these cases, and yet still come out ahead so long as it can work for most cases. As an example, an aggregate working with floating-point numbers might choose to punt when a NaN (not a number) input has to be removed from the running state value.

When writing moving-aggregate support functions, it is important to be sure that the inverse transition function can reconstruct the correct state value exactly. Otherwise there might be user-visible differences in results depending on whether the moving-aggregate mode is used. An example of an aggregate for which adding an inverse transition function seems easy at first, yet where this requirement cannot be met is `sum` over `float4` or `float8` inputs. A naive declaration of `sum(float8)` could be

```
CREATE AGGREGATE unsafe_sum (float8)
(
    stype = float8,
    sfunc = float8pl,
    mstype = float8,
    msfunc = float8pl,
    minvfunc = float8mi
);
```

This aggregate, however, can give wildly different results than it would have without the inverse transition function. For example, consider

```
SELECT
    unsafe_sum(x) OVER (ORDER BY n ROWS BETWEEN CURRENT ROW AND 1
        FOLLOWING)
FROM (VALUES (1, 1.0e20::float8),
        (2, 1.0::float8)) AS v (n,x);
```

This query returns 0 as its second result, rather than the expected answer of 1. The cause is the limited precision of floating-point values: adding 1 to `1e20` results in `1e20` again, and so subtracting `1e20` from that yields 0, not 1. Note that this is a limitation of floating-point arithmetic in general, not a limitation of LightDB.

## 36.12.2. Polymorphic and Variadic Aggregates

Aggregate functions can use polymorphic state transition functions or final functions, so that the same functions can be used to implement multiple aggregates. See Section 36.2.5 for an explanation of polymorphic functions. Going a step further, the aggregate function itself can be specified with polymorphic input type(s) and state type, allowing a single aggregate definition to serve for multiple input data types. Here is an example of a polymorphic aggregate:

```
CREATE AGGREGATE array_accum (anyelement)
(
    sfunc = array_append,
    stype = anyarray,
    initcond = '{} '
);
```

Here, the actual state type for any given aggregate call is the array type having the actual input type as elements. The behavior of the aggregate is to concatenate all the inputs into an array of that type. (Note:

the built-in aggregate `array_agg` provides similar functionality, with better performance than this definition would have.)

Here's the output using two different actual data types as arguments:

```
SELECT attrelid::regclass, array_accum(attname)
   FROM pg_attribute
   WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
   GROUP BY attrelid;
```

```
   attrelid   |          array_accum
-----+-----
pg_tablespace | {spcname,spcowner,spcacl,spcoptions}
(1 row)
```

```
SELECT attrelid::regclass, array_accum(atttypeid::regtype)
   FROM pg_attribute
   WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
   GROUP BY attrelid;
```

```
   attrelid   |          array_accum
-----+-----
pg_tablespace | {name,oid,aclitem[],text[]}
(1 row)
```

Ordinarily, an aggregate function with a polymorphic result type has a polymorphic state type, as in the above example. This is necessary because otherwise the final function cannot be declared sensibly: it would need to have a polymorphic result type but no polymorphic argument type, which `CREATE FUNCTION` will reject on the grounds that the result type cannot be deduced from a call. But sometimes it is inconvenient to use a polymorphic state type. The most common case is where the aggregate support functions are to be written in C and the state type should be declared as `internal` because there is no SQL-level equivalent for it. To address this case, it is possible to declare the final function as taking extra “dummy” arguments that match the input arguments of the aggregate. Such dummy arguments are always passed as null values since no specific value is available when the final function is called. Their only use is to allow a polymorphic final function's result type to be connected to the aggregate's input type(s). For example, the definition of the built-in aggregate `array_agg` is equivalent to

```
CREATE FUNCTION array_agg_transfn(internal, anynonarray)
   RETURNS internal ...;
CREATE FUNCTION array_agg_finalfn(internal, anynonarray)
   RETURNS anyarray ...;

CREATE AGGREGATE array_agg (anynonarray)
(
   sfunc = array_agg_transfn,
   stype = internal,
   finalfunc = array_agg_finalfn,
   finalfunc_extra
);
```

Here, the `finalfunc_extra` option specifies that the final function receives, in addition to the state value, extra dummy argument(s) corresponding to the aggregate's input argument(s). The extra `anynonarray` argument allows the declaration of `array_agg_finalfn` to be valid.

An aggregate function can be made to accept a varying number of arguments by declaring its last argument as a `VARIADIC` array, in much the same fashion as for regular functions; see Section 36.5.5.

The aggregate's transition function(s) must have the same array type as their last argument. The transition function(s) typically would also be marked `VARIADIC`, but this is not strictly required.

**Note**

Variadic aggregates are easily misused in connection with the `ORDER BY` option (see Section 4.2.7), since the parser cannot tell whether the wrong number of actual arguments have been given in such a combination. Keep in mind that everything to the right of `ORDER BY` is a sort key, not an argument to the aggregate. For example, in

```
SELECT myaggregate(a ORDER BY a, b, c) FROM ...
```

the parser will see this as a single aggregate function argument and three sort keys. However, the user might have intended

```
SELECT myaggregate(a, b, c ORDER BY a) FROM ...
```

If `myaggregate` is variadic, both these calls could be perfectly valid.

For the same reason, it's wise to think twice before creating aggregate functions with the same names and different numbers of regular arguments.

### 36.12.3. Ordered-Set Aggregates

The aggregates we have been describing so far are “normal” aggregates. LightDB also supports *ordered-set aggregates*, which differ from normal aggregates in two key ways. First, in addition to ordinary aggregated arguments that are evaluated once per input row, an ordered-set aggregate can have “direct” arguments that are evaluated only once per aggregation operation. Second, the syntax for the ordinary aggregated arguments specifies a sort ordering for them explicitly. An ordered-set aggregate is usually used to implement a computation that depends on a specific row ordering, for instance rank or percentile, so that the sort ordering is a required aspect of any call. For example, the built-in definition of `percentile_disc` is equivalent to:

```
CREATE FUNCTION ordered_set_transition(internal, anyelement)
  RETURNS internal ...;
CREATE FUNCTION percentile_disc_final(internal, float8, anyelement)
  RETURNS anyelement ...;

CREATE AGGREGATE percentile_disc (float8 ORDER BY anyelement)
(
  sfunc = ordered_set_transition,
  stype = internal,
  finalfunc = percentile_disc_final,
  finalfunc_extra
);
```

This aggregate takes a `float8` direct argument (the percentile fraction) and an aggregated input that can be of any sortable data type. It could be used to obtain a median household income like this:

```
SELECT percentile_disc(0.5) WITHIN GROUP (ORDER BY income) FROM
households;
percentile_disc
```

-----  
50489

Here, `0.5` is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

Unlike the case for normal aggregates, the sorting of input rows for an ordered-set aggregate is *not* done behind the scenes, but is the responsibility of the aggregate's support functions. The typical implementation approach is to keep a reference to a “tuplesort” object in the aggregate's state value, feed the incoming rows into that object, and then complete the sorting and read out the data in the final function. This design allows the final function to perform special operations such as injecting additional “hypothetical” rows into the data to be sorted. While normal aggregates can often be implemented with support functions written in PL/pgSQL or another PL language, ordered-set aggregates generally have to be written in C, since their state values aren't definable as any SQL data type. (In the above example, notice that the state value is declared as type `internal` — this is typical.) Also, because the final function performs the sort, it is not possible to continue adding input rows by executing the transition function again later. This means the final function is not `READ_ONLY`; it must be declared in `CREATE AGGREGATE` as `READ_WRITE`, or as `SHAREABLE` if it's possible for additional final-function calls to make use of the already-sorted state.

The state transition function for an ordered-set aggregate receives the current state value plus the aggregated input values for each row, and returns the updated state value. This is the same definition as for normal aggregates, but note that the direct arguments (if any) are not provided. The final function receives the last state value, the values of the direct arguments if any, and (if `finalfunc_extra` is specified) null values corresponding to the aggregated input(s). As with normal aggregates, `finalfunc_extra` is only really useful if the aggregate is polymorphic; then the extra dummy argument(s) are needed to connect the final function's result type to the aggregate's input type(s).

Currently, ordered-set aggregates cannot be used as window functions, and therefore there is no need for them to support moving-aggregate mode.

## 36.12.4. Partial Aggregation

Optionally, an aggregate function can support *partial aggregation*. The idea of partial aggregation is to run the aggregate's state transition function over different subsets of the input data independently, and then to combine the state values resulting from those subsets to produce the same state value that would have resulted from scanning all the input in a single operation. This mode can be used for parallel aggregation by having different worker processes scan different portions of a table. Each worker produces a partial state value, and at the end those state values are combined to produce a final state value. (In the future this mode might also be used for purposes such as combining aggregations over local and remote tables; but that is not implemented yet.)

To support partial aggregation, the aggregate definition must provide a *combine function*, which takes two values of the aggregate's state type (representing the results of aggregating over two subsets of the input rows) and produces a new value of the state type, representing what the state would have been after aggregating over the combination of those sets of rows. It is unspecified what the relative order of the input rows from the two sets would have been. This means that it's usually impossible to define a useful combine function for aggregates that are sensitive to input row order.

As simple examples, `MAX` and `MIN` aggregates can be made to support partial aggregation by specifying the combine function as the same greater-of-two or lesser-of-two comparison function that is used as their transition function. `SUM` aggregates just need an addition function as combine function. (Again, this is the same as their transition function, unless the state value is wider than the input data type.)

The combine function is treated much like a transition function that happens to take a value of the state type, not of the underlying input type, as its second argument. In particular, the rules for dealing with null values and strict functions are similar. Also, if the aggregate definition specifies a non-null `initcond`, keep in mind that that will be used not only as the initial state for each partial aggregation

run, but also as the initial state for the combine function, which will be called to combine each partial result into that state.

If the aggregate's state type is declared as `internal`, it is the combine function's responsibility that its result is allocated in the correct memory context for aggregate state values. This means in particular that when the first input is `NULL` it's invalid to simply return the second input, as that value will be in the wrong context and will not have sufficient lifespan.

When the aggregate's state type is declared as `internal`, it is usually also appropriate for the aggregate definition to provide a *serialization function* and a *deserialization function*, which allow such a state value to be copied from one process to another. Without these functions, parallel aggregation cannot be performed, and future applications such as local/remote aggregation will probably not work either.

A serialization function must take a single argument of type `internal` and return a result of type `bytea`, which represents the state value packaged up into a flat blob of bytes. Conversely, a deserialization function reverses that conversion. It must take two arguments of types `bytea` and `internal`, and return a result of type `internal`. (The second argument is unused and is always zero, but it is required for type-safety reasons.) The result of the deserialization function should simply be allocated in the current memory context, as unlike the combine function's result, it is not long-lived.

Worth noting also is that for an aggregate to be executed in parallel, the aggregate itself must be marked `PARALLEL SAFE`. The parallel-safety markings on its support functions are not consulted.

## 36.12.5. Support Functions for Aggregates

A function written in C can detect that it is being called as an aggregate support function by calling `AggCheckCallContext`, for example:

```
if (AggCheckCallContext(fcinfo, NULL))
```

One reason for checking this is that when it is true, the first input must be a temporary state value and can therefore safely be modified in-place rather than allocating a new copy. See `int8inc()` for an example. (While aggregate transition functions are always allowed to modify the transition value in-place, aggregate final functions are generally discouraged from doing so; if they do so, the behavior must be declared when creating the aggregate. See `CREATE AGGREGATE` for more detail.)

The second argument of `AggCheckCallContext` can be used to retrieve the memory context in which aggregate state values are being kept. This is useful for transition functions that wish to use “expanded” objects (see Section 36.13.1) as their state values. On first call, the transition function should return an expanded object whose memory context is a child of the aggregate state context, and then keep returning the same expanded object on subsequent calls. See `array_append()` for an example. (`array_append()` is not the transition function of any built-in aggregate, but it is written to behave efficiently when used as transition function of a custom aggregate.)

Another support routine available to aggregate functions written in C is `AggGetAggref`, which returns the `Aggref` parse node that defines the aggregate call. This is mainly useful for ordered-set aggregates, which can inspect the substructure of the `Aggref` node to find out what sort ordering they are supposed to implement. Examples can be found in `orderedsetaggs.c` in the `LightDB` source code.

## 36.13. User-Defined Types

As described in Section 36.2, `LightDB` can be extended to support new data types. This section describes how to define new base types, which are data types defined below the level of the SQL language. Creating a new base type requires implementing functions to operate on the type in a low-level language, usually C.

The examples in this section can be found in `complex.sql` and `complex.c` in the `src/tutorial` directory of the source distribution. See the `README` file in that directory for instructions about running the examples.

A user-defined type must always have input and output functions. These functions determine how the type appears in strings (for input by the user and output to the user) and how the type is organized in memory. The input function takes a null-terminated character string as its argument and returns the internal (in memory) representation of the type. The output function takes the internal representation of the type as argument and returns a null-terminated character string. If we want to do anything more with the type than merely store it, we must provide additional functions to implement whatever operations we'd like to have for the type.

Suppose we want to define a type `complex` that represents complex numbers. A natural way to represent a complex number in memory would be the following C structure:

```
typedef struct Complex {
    double    x;
    double    y;
} Complex;
```

We will need to make this a pass-by-reference type, since it's too large to fit into a single `Datum` value.

As the external string representation of the type, we choose a string of the form `(x,y)`.

The input and output functions are usually not hard to write, especially the output function. But when defining the external string representation of the type, remember that you must eventually write a complete and robust parser for that representation as your input function. For instance:

```
PG_FUNCTION_INFO_V1(complex_in);

Datum
complex_in(PG_FUNCTION_ARGS)
{
    char        *str = PG_GETARG_CSTRING(0);
    double      x,
               y;
    Complex     *result;

    if (sscanf(str, " ( %lf , %lf )", &x, &y) != 2)
        ereport(ERROR,
                (errcode(ERRCODE_INVALID_TEXT_REPRESENTATION),
                 errmsg("invalid input syntax for type %s: \"%s\"",
                        "complex", str)));

    result = (Complex *) palloc(sizeof(Complex));
    result->x = x;
    result->y = y;
    PG_RETURN_POINTER(result);
}
```

The output function can simply be:

```
PG_FUNCTION_INFO_V1(complex_out);

Datum
complex_out(PG_FUNCTION_ARGS)
```

```

{
    Complex    *complex = (Complex *) PG_GETARG_POINTER(0);
    char       *result;

    result = psprintf("(%g,%g)", complex->x, complex->y);
    PG_RETURN_CSTRING(result);
}

```

You should be careful to make the input and output functions inverses of each other. If you do not, you will have severe problems when you need to dump your data into a file and then read it back in. This is a particularly common problem when floating-point numbers are involved.

Optionally, a user-defined type can provide binary input and output routines. Binary I/O is normally faster but less portable than textual I/O. As with textual I/O, it is up to you to define exactly what the external binary representation is. Most of the built-in data types try to provide a machine-independent binary representation. For `complex`, we will piggy-back on the binary I/O converters for type `float8`:

```
PG_FUNCTION_INFO_V1(complex_recv);
```

```

Datum
complex_recv(PG_FUNCTION_ARGS)
{
    StringInfo buf = (StringInfo) PG_GETARG_POINTER(0);
    Complex    *result;

    result = (Complex *) palloc(sizeof(Complex));
    result->x = pq_getmsgfloat8(buf);
    result->y = pq_getmsgfloat8(buf);
    PG_RETURN_POINTER(result);
}

```

```
PG_FUNCTION_INFO_V1(complex_send);
```

```

Datum
complex_send(PG_FUNCTION_ARGS)
{
    Complex    *complex = (Complex *) PG_GETARG_POINTER(0);
    StringInfoData buf;

    pq_begintypsend(&buf);
    pq_sendfloat8(&buf, complex->x);
    pq_sendfloat8(&buf, complex->y);
    PG_RETURN_BYTEA_P(pq_endtypsend(&buf));
}

```

Once we have written the I/O functions and compiled them into a shared library, we can define the `complex` type in SQL. First we declare it as a shell type:

```
CREATE TYPE complex;
```

This serves as a placeholder that allows us to reference the type while defining its I/O functions. Now we can define the I/O functions:



```

CREATE FUNCTION complex_in(cstring)
    RETURNS complex
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_out(complex)
    RETURNS cstring
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_recv(internal)
    RETURNS complex
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_send(complex)
    RETURNS bytea
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

```

Finally, we can provide the full definition of the data type:

```

CREATE TYPE complex (
    internallength = 16,
    input = complex_in,
    output = complex_out,
    receive = complex_recv,
    send = complex_send,
    alignment = double
);

```

When you define a new base type, LightDB automatically provides support for arrays of that type. The array type typically has the same name as the base type with the underscore character (`_`) prepended.

Once the data type exists, we can declare additional functions to provide useful operations on the data type. Operators can then be defined atop the functions, and if needed, operator classes can be created to support indexing of the data type. These additional layers are discussed in following sections.

If the internal representation of the data type is variable-length, the internal representation must follow the standard layout for variable-length data: the first four bytes must be a `char[4]` field which is never accessed directly (customarily named `vl_len_`). You must use the `SET_VARSIZE()` macro to store the total size of the datum (including the length field itself) in this field and `VARSIZE()` to retrieve it. (These macros exist because the length field may be encoded depending on platform.)

For further details see the description of the `CREATE TYPE` command.

### 36.13.1. TOAST Considerations

If the values of your data type vary in size (in internal form), it's usually desirable to make the data type TOAST-able (see Section 64.2). You should do this even if the values are always too small to be compressed or stored externally, because TOAST can save space on small data too, by reducing header overhead.

To support TOAST storage, the C functions operating on the data type must always be careful to unpack any toasted values they are handed by using `PG_DETOAST_DATUM`. (This detail is customarily hidden by defining type-specific `GETARG_DATATYPE_P` macros.) Then, when running the `CREATE TYPE` command, specify the internal length as `variable` and select some appropriate storage option other than `plain`.

If data alignment is unimportant (either just for a specific function or because the data type specifies byte alignment anyway) then it's possible to avoid some of the overhead of `PG_DETOAST_DATUM`. You can use `PG_DETOAST_DATUM_PACKED` instead (customarily hidden by defining a `GETARG_DATATYPE_PP` macro) and using the macros `VARSIZE_ANY_EXHDR` and `VARDATA_ANY` to access a potentially-packed datum. Again, the data returned by these macros is not aligned even if the data type definition specifies an alignment. If the alignment is important you must go through the regular `PG_DETOAST_DATUM` interface.

### Note

Older code frequently declares `vl_len_` as an `int32` field instead of `char[4]`. This is OK as long as the struct definition has other fields that have at least `int32` alignment. But it is dangerous to use such a struct definition when working with a potentially unaligned datum; the compiler may take it as license to assume the datum actually is aligned, leading to core dumps on architectures that are strict about alignment.

Another feature that's enabled by TOAST support is the possibility of having an *expanded* in-memory data representation that is more convenient to work with than the format that is stored on disk. The regular or “flat” varlena storage format is ultimately just a blob of bytes; it cannot for example contain pointers, since it may get copied to other locations in memory. For complex data types, the flat format may be quite expensive to work with, so LightDB provides a way to “expand” the flat format into a representation that is more suited to computation, and then pass that format in-memory between functions of the data type.

To use expanded storage, a data type must define an expanded format that follows the rules given in `src/include/utils/expandeddatum.h`, and provide functions to “expand” a flat varlena value into expanded format and “flatten” the expanded format back to the regular varlena representation. Then ensure that all C functions for the data type can accept either representation, possibly by converting one into the other immediately upon receipt. This does not require fixing all existing functions for the data type at once, because the standard `PG_DETOAST_DATUM` macro is defined to convert expanded inputs into regular flat format. Therefore, existing functions that work with the flat varlena format will continue to work, though slightly inefficiently, with expanded inputs; they need not be converted until and unless better performance is important.

C functions that know how to work with an expanded representation typically fall into two categories: those that can only handle expanded format, and those that can handle either expanded or flat varlena inputs. The former are easier to write but may be less efficient overall, because converting a flat input to expanded form for use by a single function may cost more than is saved by operating on the expanded format. When only expanded format need be handled, conversion of flat inputs to expanded form can be hidden inside an argument-fetching macro, so that the function appears no more complex than one working with traditional varlena input. To handle both types of input, write an argument-fetching function that will detoast external, short-header, and compressed varlena inputs, but not expanded inputs. Such a function can be defined as returning a pointer to a union of the flat varlena format and the expanded format. Callers can use the `VARATT_IS_EXPANDED_HEADER( )` macro to determine which format they received.

The TOAST infrastructure not only allows regular varlena values to be distinguished from expanded values, but also distinguishes “read-write” and “read-only” pointers to expanded values. C functions that only need to examine an expanded value, or will only change it in safe and non-semantically-visible ways, need not care which type of pointer they receive. C functions that produce a modified version of an input value are allowed to modify an expanded input value in-place if they receive a read-write pointer, but must not modify the input if they receive a read-only pointer; in that case they have to copy the value first, producing a new value to modify. A C function that has constructed a new expanded value should always return a read-write pointer to it. Also, a C function that is modifying a read-write expanded value in-place should take care to leave the value in a sane state if it fails partway through.

For examples of working with expanded values, see the standard array infrastructure, particularly `src/backend/utils/adt/array_expanded.c`.

## 36.14. User-Defined Operators

Every operator is “syntactic sugar” for a call to an underlying function that does the real work; so you must first create the underlying function before you can create the operator. However, an operator is *not merely* syntactic sugar, because it carries additional information that helps the query planner optimize queries that use the operator. The next section will be devoted to explaining that additional information.

LightDB supports left unary, right unary, and binary operators. Operators can be overloaded; that is, the same operator name can be used for different operators that have different numbers and types of operands. When a query is executed, the system determines the operator to call from the number and types of the provided operands.

Here is an example of creating an operator for adding two complex numbers. We assume we've already created the definition of type `complex` (see Section 36.13). First we need a function that does the work, then we can define the operator:

```
CREATE FUNCTION complex_add(complex, complex)
    RETURNS complex
    AS 'filename', 'complex_add'
    LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR + (
    leftarg = complex,
    rightarg = complex,
    function = complex_add,
    commutator = +
);
```

Now we could execute a query like this:

```
SELECT (a + b) AS c FROM test_complex;

      c
-----
(5.2,6.05)
(133.42,144.95)
```

We've shown how to create a binary operator here. To create unary operators, just omit one of `leftarg` (for left unary) or `rightarg` (for right unary). The `function` clause and the argument clauses are the only required items in `CREATE OPERATOR`. The `commutator` clause shown in the example is an optional hint to the query optimizer. Further details about `commutator` and other optimizer hints appear in the next section.

## 36.15. Operator Optimization Information

A LightDB operator definition can include several optional clauses that tell the system useful things about how the operator behaves. These clauses should be provided whenever appropriate, because they can make for considerable speedups in execution of queries that use the operator. But if you provide them, you must be sure that they are right! Incorrect use of an optimization clause can result in slow queries, subtly wrong output, or other Bad Things. You can always leave out an optimization clause if you are not sure about it; the only consequence is that queries might run slower than they need to.

Additional optimization clauses might be added in future versions of LightDB. The ones described here are all the ones that release 13.8-23.4 understands.

It is also possible to attach a planner support function to the function that underlies an operator, providing another way of telling the system about the behavior of the operator. See Section 36.11 for more information.

### 36.15.1. COMMUTATOR

The `COMMUTATOR` clause, if provided, names an operator that is the commutator of the operator being defined. We say that operator *A* is the commutator of operator *B* if  $(x \ A \ y)$  equals  $(y \ B \ x)$  for all possible input values *x*, *y*. Notice that *B* is also the commutator of *A*. For example, operators `<` and `>` for a particular data type are usually each others' commutators, and operator `+` is usually commutative with itself. But operator `-` is usually not commutative with anything.

The left operand type of a commutable operator is the same as the right operand type of its commutator, and vice versa. So the name of the commutator operator is all that LightDB needs to be given to look up the commutator, and that's all that needs to be provided in the `COMMUTATOR` clause.

It's critical to provide commutator information for operators that will be used in indexes and join clauses, because this allows the query optimizer to “flip around” such a clause to the forms needed for different plan types. For example, consider a query with a `WHERE` clause like `tab1.x = tab2.y`, where `tab1.x` and `tab2.y` are of a user-defined type, and suppose that `tab2.y` is indexed. The optimizer cannot generate an index scan unless it can determine how to flip the clause around to `tab2.y = tab1.x`, because the index-scan machinery expects to see the indexed column on the left of the operator it is given. LightDB will *not* simply assume that this is a valid transformation — the creator of the `=` operator must specify that it is valid, by marking the operator with commutator information.

When you are defining a self-commutative operator, you just do it. When you are defining a pair of commutative operators, things are a little trickier: how can the first one to be defined refer to the other one, which you haven't defined yet? There are two solutions to this problem:

- One way is to omit the `COMMUTATOR` clause in the first operator that you define, and then provide one in the second operator's definition. Since LightDB knows that commutative operators come in pairs, when it sees the second definition it will automatically go back and fill in the missing `COMMUTATOR` clause in the first definition.
- The other, more straightforward way is just to include `COMMUTATOR` clauses in both definitions. When LightDB processes the first definition and realizes that `COMMUTATOR` refers to a nonexistent operator, the system will make a dummy entry for that operator in the system catalog. This dummy entry will have valid data only for the operator name, left and right operand types, and result type, since that's all that LightDB can deduce at this point. The first operator's catalog entry will link to this dummy entry. Later, when you define the second operator, the system updates the dummy entry with the additional information from the second definition. If you try to use the dummy operator before it's been filled in, you'll just get an error message.

### 36.15.2. NEGATOR

The `NEGATOR` clause, if provided, names an operator that is the negator of the operator being defined. We say that operator *A* is the negator of operator *B* if both return Boolean results and  $(x \ A \ y)$  equals `NOT (x \ B \ y)` for all possible inputs *x*, *y*. Notice that *B* is also the negator of *A*. For example, `<` and `>=` are a negator pair for most data types. An operator can never validly be its own negator.

Unlike commutators, a pair of unary operators could validly be marked as each other's negators; that would mean  $(A \ x)$  equals `NOT (B \ x)` for all *x*, or the equivalent for right unary operators.

An operator's negator must have the same left and/or right operand types as the operator to be defined, so just as with `COMMUTATOR`, only the operator name need be given in the `NEGATOR` clause.

Providing a negator is very helpful to the query optimizer since it allows expressions like `NOT (x = y)` to be simplified into `x <> y`. This comes up more often than you might think, because `NOT` operations can be inserted as a consequence of other rearrangements.

Pairs of negator operators can be defined using the same methods explained above for commutator pairs.

### 36.15.3. RESTRICT

The `RESTRICT` clause, if provided, names a restriction selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `RESTRICT` clauses only make sense for binary operators that return `boolean`. The idea behind a restriction selectivity estimator is to guess what fraction of the rows in a table will satisfy a `WHERE`-clause condition of the form:

```
column OP constant
```

for the current operator and a particular constant value. This assists the optimizer by giving it some idea of how many rows will be eliminated by `WHERE` clauses that have this form. (What happens if the constant is on the left, you might be wondering? Well, that's one of the things that `COMMUTATOR` is for...)

Writing new restriction selectivity estimation functions is far beyond the scope of this chapter, but fortunately you can usually just use one of the system's standard estimators for many of your own operators. These are the standard restriction estimators:

```
eqsel for =
neqsel for <>
scalarltsel for <
scalarlesel for <=
scalargtsel for >
scalargesel for >=
```

You can frequently get away with using either `eqsel` or `neqsel` for operators that have very high or very low selectivity, even if they aren't really equality or inequality. For example, the approximate-equality geometric operators use `eqsel` on the assumption that they'll usually only match a small fraction of the entries in a table.

You can use `scalarltsel`, `scalarlesel`, `scalargtsel` and `scalargesel` for comparisons on data types that have some sensible means of being converted into numeric scalars for range comparisons. If possible, add the data type to those understood by the function `convert_to_scalar()` in `src/backend/utils/adt/selfuncs.c`. (Eventually, this function should be replaced by per-data-type functions identified through a column of the `pg_type` system catalog; but that hasn't happened yet.) If you do not do this, things will still work, but the optimizer's estimates won't be as good as they could be.

Another useful built-in selectivity estimation function is `matchingsel`, which will work for almost any binary operator, if standard `MCV` and/or histogram statistics are collected for the input data type(s). Its default estimate is set to twice the default estimate used in `eqsel`, making it most suitable for comparison operators that are somewhat less strict than equality. (Or you could call the underlying `generic_restriction_selectivity` function, providing a different default estimate.)

There are additional selectivity estimation functions designed for geometric operators in `src/backend/utils/adt/geo_selfuncs.c`: `areasel`, `positionsel`, and `contsel`. At this writing these are just stubs, but you might want to use them (or even better, improve them) anyway.

### 36.15.4. JOIN

The `JOIN` clause, if provided, names a join selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `JOIN` clauses only make sense for binary operators

that return `boolean`. The idea behind a join selectivity estimator is to guess what fraction of the rows in a pair of tables will satisfy a `WHERE`-clause condition of the form:

```
table1.column1 OP table2.column2
```

for the current operator. As with the `RESTRICT` clause, this helps the optimizer very substantially by letting it figure out which of several possible join sequences is likely to take the least work.

As before, this chapter will make no attempt to explain how to write a join selectivity estimator function, but will just suggest that you use one of the standard estimators if one is applicable:

```
eqjoinselect for =
neqjoinselect for <>
scalartjoinselect for <
scalartlejoinselect for <=
scalartgjoinselect for >
scalartgejoinselect for >=
matchingjoinselect for generic matching operators
areajoinselect for 2D area-based comparisons
positionjoinselect for 2D position-based comparisons
contjoinselect for 2D containment-based comparisons
```

## 36.15.5. HASHES

The `HASHES` clause, if present, tells the system that it is permissible to use the hash join method for a join based on this operator. `HASHES` only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

The assumption underlying hash join is that the join operator can only return true for pairs of left and right values that hash to the same hash code. If two values get put in different hash buckets, the join will never compare them at all, implicitly assuming that the result of the join operator must be false. So it never makes sense to specify `HASHES` for operators that do not represent some form of equality. In most cases it is only practical to support hashing for operators that take the same data type on both sides. However, sometimes it is possible to design compatible hash functions for two or more data types; that is, functions that will generate the same hash codes for “equal” values, even though the values have different representations. For example, it’s fairly simple to arrange this property when hashing integers of different widths.

To be marked `HASHES`, the join operator must appear in a hash index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn’t exist yet. But attempts to use the operator in hash joins will fail at run time if no such operator family exists. The system needs the operator family to find the data-type-specific hash function(s) for the operator’s input data type(s). Of course, you must also create suitable hash functions before you can create the operator family.

Care should be exercised when preparing a hash function, because there are machine-dependent ways in which it might fail to do the right thing. For example, if your data type is a structure in which there might be uninteresting pad bits, you cannot simply pass the whole structure to `hash_any`. (Unless you write your other operators and functions to ensure that the unused bits are always zero, which is the recommended strategy.) Another example is that on machines that meet the IEEE floating-point standard, negative zero and positive zero are different values (different bit patterns) but they are defined to compare equal. If a float value might contain negative zero then extra steps are needed to ensure it generates the same hash value as positive zero.

A hash-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a hash operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

**Note**

The function underlying a hash-joinable operator must be marked immutable or stable. If it is volatile, the system will never attempt to use the operator for a hash join.

**Note**

If a hash-joinable operator has an underlying function that is marked strict, the function must also be complete: that is, it should return true or false, never null, for any two nonnull inputs. If this rule is not followed, hash-optimization of IN operations might generate wrong results. (Specifically, IN might return false where the correct answer according to the standard would be null; or it might yield an error complaining that it wasn't prepared for a null result.)

## 36.15.6. MERGES

The MERGES clause, if present, tells the system that it is permissible to use the merge-join method for a join based on this operator. MERGES only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. So, both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at the “same place” in the sort order. In practice this means that the join operator must behave like equality. But it is possible to merge-join two distinct data types so long as they are logically compatible. For example, the `smallint-versus-integer` equality operator is merge-joinable. We only need sorting operators that will bring both data types into a logically compatible sequence.

To be marked MERGES, the join operator must appear as an equality member of a `btree` index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn't exist yet. But the operator will not actually be used for merge joins unless a matching operator family can be found. The MERGES flag thus acts as a hint to the planner that it's worth looking for a matching operator family.

A merge-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a `btree` operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

**Note**

The function underlying a merge-joinable operator must be marked immutable or stable. If it is volatile, the system will never attempt to use the operator for a merge join.

## 36.16. Interfacing Extensions to Indexes

The procedures described thus far let you define new types, new functions, and new operators. However, we cannot yet define an index on a column of a new data type. To do this, we must define an *operator class* for the new data type. Later in this section, we will illustrate this concept in an example: a new operator class for the B-tree index method that stores and sorts complex numbers in ascending absolute value order.

Operator classes can be grouped into *operator families* to show the relationships between semantically compatible classes. When only a single data type is involved, an operator class is sufficient, so we'll focus on that case first and then return to operator families.

### 36.16.1. Index Methods and Operator Classes

The `pg_am` table contains one row for every index method (internally known as access method). Support for regular access to tables is built into LightDB, but all index methods are described in `pg_am`. It is possible to add a new index access method by writing the necessary code and then creating an entry in `pg_am` — but that is beyond the scope of this chapter (see Chapter 58).

The routines for an index method do not directly know anything about the data types that the index method will operate on. Instead, an *operator class* identifies the set of operations that the index method needs to use to work with a particular data type. Operator classes are so called because one thing they specify is the set of WHERE-clause operators that can be used with an index (i.e., can be converted into an index-scan qualification). An operator class can also specify some *support function* that are needed by the internal operations of the index method, but do not directly correspond to any WHERE-clause operator that can be used with the index.

It is possible to define multiple operator classes for the same data type and index method. By doing this, multiple sets of indexing semantics can be defined for a single data type. For example, a B-tree index requires a sort ordering to be defined for each data type it works on. It might be useful for a complex-number data type to have one B-tree operator class that sorts the data by complex absolute value, another that sorts by real part, and so on. Typically, one of the operator classes will be deemed most commonly useful and will be marked as the default operator class for that data type and index method.

The same operator class name can be used for several different index methods (for example, both B-tree and hash index methods have operator classes named `int4_ops`), but each such class is an independent entity and must be defined separately.

### 36.16.2. Index Method Strategies

The operators associated with an operator class are identified by “strategy numbers”, which serve to identify the semantics of each operator within the context of its operator class. For example, B-trees impose a strict ordering on keys, lesser to greater, and so operators like “less than” and “greater than or equal to” are interesting with respect to a B-tree. Because LightDB allows the user to define operators, LightDB cannot look at the name of an operator (e.g., `<` or `>=`) and tell what kind of comparison it is. Instead, the index method defines a set of “strategies”, which can be thought of as generalized operators. Each operator class specifies which actual operator corresponds to each strategy for a particular data type and interpretation of the index semantics.

The B-tree index method defines five strategies, shown in Table 36.3.

**Table 36.3. B-Tree Strategies**

Operation	Strategy Number
less than	1
less than or equal	2
equal	3
greater than or equal	4
greater than	5

Hash indexes support only equality comparisons, and so they use only one strategy, shown in Table 36.4.



**Table 36.4. Hash Strategies**

Operation	Strategy Number
equal	1

GiST indexes are more flexible: they do not have a fixed set of strategies at all. Instead, the “consistency” support routine of each particular GiST operator class interprets the strategy numbers however it likes. As an example, several of the built-in GiST index operator classes index two-dimensional geometric objects, providing the “R-tree” strategies shown in Table 36.5. Four of these are true two-dimensional tests (overlaps, same, contains, contained by); four of them consider only the X direction; and the other four provide the same tests in the Y direction.

**Table 36.5. GiST Two-Dimensional “R-tree” Strategies**

Operation	Strategy Number
strictly left of	1
does not extend to right of	2
overlaps	3
does not extend to left of	4
strictly right of	5
same	6
contains	7
contained by	8
does not extend above	9
strictly below	10
strictly above	11
does not extend below	12

GIN indexes are similar to GiST indexes, in that they don't have a fixed set of strategies either. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in operator class for arrays are shown in Table 36.6.

**Table 36.6. GIN Array Strategies**

Operation	Strategy Number
overlap	1
contains	2
is contained by	3
equal	4

Notice that all the operators listed above return Boolean values. In practice, all operators defined as index method search operators must return type `boolean`, since they must appear at the top level of a `WHERE` clause to be used with an index. (Some index access methods also support *ordering operators*, which typically don't return Boolean values; that feature is discussed in Section 36.16.7.)

### 36.16.3. Index Method Support Routines

Strategies aren't usually enough information for the system to figure out how to use an index. In practice, the index methods require additional support routines in order to work. For example, the B-tree index method must be able to compare two keys and determine whether one is greater than, equal to, or less than the other. Similarly, the hash index method must be able to compute hash codes for

key values. These operations do not correspond to operators used in qualifications in SQL commands; they are administrative routines used by the index methods, internally.

Just as with strategies, the operator class identifies which specific functions should play each of these roles for a given data type and semantic interpretation. The index method defines the set of functions it needs, and the operator class identifies the correct functions to use by assigning them to the “support function numbers” specified by the index method.

Additionally, some opclasses allow users to specify parameters which control their behavior. Each builtin index access method has an optional `options` support function, which defines a set of opclass-specific parameters.

B-trees require a comparison support function, and allow four additional support functions to be supplied at the operator class author's option, as shown in Table 36.7. The requirements for these support functions are explained further in Section 60.3.

**Table 36.7. B-Tree Support Functions**

Function	Support Number
Compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
Return the addresses of C-callable sort support function(s) (optional)	2
Compare a test value to a base value plus/minus an offset, and return true or false according to the comparison result (optional)	3
Determine if it is safe for indexes that use the operator class to apply the btree deduplication optimization (optional)	4
Defines a set of options that are specific to this operator class (optional)	5

Hash indexes require one support function, and allow two additional ones to be supplied at the operator class author's option, as shown in Table 36.8.

**Table 36.8. Hash Support Functions**

Function	Support Number
Compute the 32-bit hash value for a key	1
Compute the 64-bit hash value for a key given a 64-bit salt; if the salt is 0, the low 32 bits of the result must match the value that would have been computed by function 1 (optional)	2
Defines a set of options that are specific to this operator class (optional)	3

GiST indexes have ten support functions, three of which are optional, as shown in Table 36.9. (For more information see Chapter 61.)

**Table 36.9. GiST Support Functions**

Function	Description	Support Number
<code>consistent</code>	determine whether key satisfies the query qualifier	1
<code>union</code>	compute union of a set of keys	2
<code>compress</code>	compute a compressed representation of a key or value to be indexed	3
<code>decompress</code>	compute a decompressed representation of a compressed key	4

Function	Description	Support Number
penalty	compute penalty for inserting new key into subtree with given subtree's key	5
picksplit	determine which entries of a page are to be moved to the new page and compute the union keys for resulting pages	6
equal	compare two keys and return true if they are equal	7
distance	determine distance from key to query value (optional)	8
fetch	compute original representation of a compressed key for index-only scans (optional)	9
options	Defines a set of options that are specific to this operator class (optional)	10

GIN indexes have seven support functions, four of which are optional, as shown in Table 36.10. (For more information see Chapter 62.)

**Table 36.10. GIN Support Functions**

Function	Description	Support Number
compare	compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
extractValue	extract keys from a value to be indexed	2
extractQuery	extract keys from a query condition	3
consistent	determine whether value matches query condition (Boolean variant) (optional if support function 6 is present)	4
comparePartial	compare partial key from query and key from index, and return an integer less than zero, zero, or greater than zero, indicating whether GIN should ignore this index entry, treat the entry as a match, or stop the index scan (optional)	5
triConsistent	determine whether value matches query condition (ternary variant) (optional if support function 4 is present)	6
options	Defines a set of options that are specific to this operator class (optional)	7

Unlike search operators, support functions return whichever data type the particular index method expects; for example in the case of the comparison function for B-trees, a signed integer. The number and types of the arguments to each support function are likewise dependent on the index method. For B-tree and hash the comparison and hashing support functions take the same input data types as do the operators included in the operator class, but this is not the case for most GiST, GIN support functions.

### 36.16.4. An Example

Now that we have seen the ideas, here is the promised example of creating a new operator class. (You can find a working copy of this example in `src/tutorial/complex.c` and `src/tutorial/`

`complex.sql` in the source distribution.) The operator class encapsulates operators that sort complex numbers in absolute value order, so we choose the name `complex_abs_ops`. First, we need a set of operators. The procedure for defining operators was discussed in Section 36.14. For an operator class on B-trees, the operators we require are:

- absolute-value less-than (strategy 1)
- absolute-value less-than-or-equal (strategy 2)
- absolute-value equal (strategy 3)
- absolute-value greater-than-or-equal (strategy 4)
- absolute-value greater-than (strategy 5)

The least error-prone way to define a related set of comparison operators is to write the B-tree comparison support function first, and then write the other functions as one-line wrappers around the support function. This reduces the odds of getting inconsistent results for corner cases. Following this approach, we first write:

```
#define Mag(c)  ((c)->x*(c)->x + (c)->y*(c)->y)

static int
complex_abs_cmp_internal(Complex *a, Complex *b)
{
    double      amag = Mag(a),
               bmag = Mag(b);

    if (amag < bmag)
        return -1;
    if (amag > bmag)
        return 1;
    return 0;
}
```

Now the less-than function looks like:

```
PG_FUNCTION_INFO_V1(complex_abs_lt);

Datum
complex_abs_lt(PG_FUNCTION_ARGS)
{
    Complex      *a = (Complex *) PG_GETARG_POINTER(0);
    Complex      *b = (Complex *) PG_GETARG_POINTER(1);

    PG_RETURN_BOOL(complex_abs_cmp_internal(a, b) < 0);
}
```

The other four functions differ only in how they compare the internal function's result to zero.

Next we declare the functions and the operators based on the functions to SQL:

```
CREATE FUNCTION complex_abs_lt(complex, complex) RETURNS bool
AS 'filename', 'complex_abs_lt'
LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR < (
    leftarg = complex, rightarg = complex, procedure =
    complex_abs_lt,
```

```

    commutator = > , negator = >= ,
    restrict = scalarltsel, join = scalarltjoinsel
);

```

It is important to specify the correct commutator and negator operators, as well as suitable restriction and join selectivity functions, otherwise the optimizer will be unable to make effective use of the index.

Other things worth noting are happening here:

- There can only be one operator named, say, = and taking type `complex` for both operands. In this case we don't have any other operator = for `complex`, but if we were building a practical data type we'd probably want = to be the ordinary equality operation for complex numbers (and not the equality of the absolute values). In that case, we'd need to use some other operator name for `complex_abs_eq`.
- Although LightDB can cope with functions having the same SQL name as long as they have different argument data types, C can only cope with one global function having a given name. So we shouldn't name the C function something simple like `abs_eq`. Usually it's a good practice to include the data type name in the C function name, so as not to conflict with functions for other data types.
- We could have made the SQL name of the function `abs_eq`, relying on LightDB to distinguish it by argument data types from any other SQL function of the same name. To keep the example simple, we make the function have the same names at the C level and SQL level.

The next step is the registration of the support routine required by B-trees. The example C code that implements this is in the same file that contains the operator functions. This is how we declare the function:

```

CREATE FUNCTION complex_abs_cmp(complex, complex)
    RETURNS integer
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

```

Now that we have the required operators and support routine, we can finally create the operator class:

```

CREATE OPERATOR CLASS complex_abs_ops
    DEFAULT FOR TYPE complex USING btree AS
    OPERATOR          1          < ,
    OPERATOR          2          <= ,
    OPERATOR          3          = ,
    OPERATOR          4          >= ,
    OPERATOR          5          > ,
    FUNCTION          1          complex_abs_cmp(complex, complex);

```

And we're done! It should now be possible to create and use B-tree indexes on `complex` columns.

We could have written the operator entries more verbosely, as in:

```

OPERATOR          1          < (complex, complex) ,

```

but there is no need to do so when the operators take the same data type we are defining the operator class for.

The above example assumes that you want to make this new operator class the default B-tree operator class for the `complex` data type. If you don't, just leave out the word `DEFAULT`.

## 36.16.5. Operator Classes and Operator Families

So far we have implicitly assumed that an operator class deals with only one data type. While there certainly can be only one data type in a particular index column, it is often useful to index operations that compare an indexed column to a value of a different data type. Also, if there is use for a cross-data-type operator in connection with an operator class, it is often the case that the other data type has a related operator class of its own. It is helpful to make the connections between related classes explicit, because this can aid the planner in optimizing SQL queries (particularly for B-tree operator classes, since the planner contains a great deal of knowledge about how to work with them).

To handle these needs, LightDB uses the concept of an *operator family*. An operator family contains one or more operator classes, and can also contain indexable operators and corresponding support functions that belong to the family as a whole but not to any single class within the family. We say that such operators and functions are “loose” within the family, as opposed to being bound into a specific class. Typically each operator class contains single-data-type operators while cross-data-type operators are loose in the family.

All the operators and functions in an operator family must have compatible semantics, where the compatibility requirements are set by the index method. You might therefore wonder why bother to single out particular subsets of the family as operator classes; and indeed for many purposes the class divisions are irrelevant and the family is the only interesting grouping. The reason for defining operator classes is that they specify how much of the family is needed to support any particular index. If there is an index using an operator class, then that operator class cannot be dropped without dropping the index — but other parts of the operator family, namely other operator classes and loose operators, could be dropped. Thus, an operator class should be specified to contain the minimum set of operators and functions that are reasonably needed to work with an index on a specific data type, and then related but non-essential operators can be added as loose members of the operator family.

As an example, LightDB has a built-in B-tree operator family `integer_ops`, which includes operator classes `int8_ops`, `int4_ops`, and `int2_ops` for indexes on `bigint (int8)`, `integer (int4)`, and `smallint (int2)` columns respectively. The family also contains cross-data-type comparison operators allowing any two of these types to be compared, so that an index on one of these types can be searched using a comparison value of another type. The family could be duplicated by these definitions:

```
CREATE OPERATOR FAMILY integer_ops USING btree;
```

```
CREATE OPERATOR CLASS int8_ops
DEFAULT FOR TYPE int8 USING btree FAMILY integer_ops AS
  -- standard int8 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint8cmp(int8, int8) ,
  FUNCTION 2 btint8sortsupport(internal) ,
  FUNCTION 3 in_range(int8, int8, int8, boolean, boolean) ,
  FUNCTION 4 btequalimage(oid) ;
```

```
CREATE OPERATOR CLASS int4_ops
DEFAULT FOR TYPE int4 USING btree FAMILY integer_ops AS
  -- standard int4 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
```

```

FUNCTION 1 btint4cmp(int4, int4) ,
FUNCTION 2 btint4sortsupport(internal) ,
FUNCTION 3 in_range(int4, int4, int4, boolean, boolean) ,
FUNCTION 4 btequalimage(oid) ;

CREATE OPERATOR CLASS int2_ops
DEFAULT FOR TYPE int2 USING btree FAMILY integer_ops AS
-- standard int2 comparisons
OPERATOR 1 < ,
OPERATOR 2 <= ,
OPERATOR 3 = ,
OPERATOR 4 >= ,
OPERATOR 5 > ,
FUNCTION 1 btint2cmp(int2, int2) ,
FUNCTION 2 btint2sortsupport(internal) ,
FUNCTION 3 in_range(int2, int2, int2, boolean, boolean) ,
FUNCTION 4 btequalimage(oid) ;

ALTER OPERATOR FAMILY integer_ops USING btree ADD
-- cross-type comparisons int8 vs int2
OPERATOR 1 < (int8, int2) ,
OPERATOR 2 <= (int8, int2) ,
OPERATOR 3 = (int8, int2) ,
OPERATOR 4 >= (int8, int2) ,
OPERATOR 5 > (int8, int2) ,
FUNCTION 1 btint82cmp(int8, int2) ,

-- cross-type comparisons int8 vs int4
OPERATOR 1 < (int8, int4) ,
OPERATOR 2 <= (int8, int4) ,
OPERATOR 3 = (int8, int4) ,
OPERATOR 4 >= (int8, int4) ,
OPERATOR 5 > (int8, int4) ,
FUNCTION 1 btint84cmp(int8, int4) ,

-- cross-type comparisons int4 vs int2
OPERATOR 1 < (int4, int2) ,
OPERATOR 2 <= (int4, int2) ,
OPERATOR 3 = (int4, int2) ,
OPERATOR 4 >= (int4, int2) ,
OPERATOR 5 > (int4, int2) ,
FUNCTION 1 btint42cmp(int4, int2) ,

-- cross-type comparisons int4 vs int8
OPERATOR 1 < (int4, int8) ,
OPERATOR 2 <= (int4, int8) ,
OPERATOR 3 = (int4, int8) ,
OPERATOR 4 >= (int4, int8) ,
OPERATOR 5 > (int4, int8) ,
FUNCTION 1 btint48cmp(int4, int8) ,

-- cross-type comparisons int2 vs int8
OPERATOR 1 < (int2, int8) ,
OPERATOR 2 <= (int2, int8) ,
OPERATOR 3 = (int2, int8) ,
OPERATOR 4 >= (int2, int8) ,
OPERATOR 5 > (int2, int8) ,
FUNCTION 1 btint28cmp(int2, int8) ,

```

```

-- cross-type comparisons int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ,

-- cross-type in_range functions
FUNCTION 3 in_range(int4, int4, int8, boolean, boolean) ,
FUNCTION 3 in_range(int4, int4, int2, boolean, boolean) ,
FUNCTION 3 in_range(int2, int2, int8, boolean, boolean) ,
FUNCTION 3 in_range(int2, int2, int4, boolean, boolean) ;

```

Notice that this definition “overloads” the operator strategy and support function numbers: each number occurs multiple times within the family. This is allowed so long as each instance of a particular number has distinct input data types. The instances that have both input types equal to an operator class's input type are the primary operators and support functions for that operator class, and in most cases should be declared as part of the operator class rather than as loose members of the family.

In a B-tree operator family, all the operators in the family must sort compatibly, as is specified in detail in Section 60.2. For each operator in the family there must be a support function having the same two input data types as the operator. It is recommended that a family be complete, i.e., for each combination of data types, all operators are included. Each operator class should include just the non-cross-type operators and support function for its data type.

To build a multiple-data-type hash operator family, compatible hash support functions must be created for each data type supported by the family. Here compatibility means that the functions are guaranteed to return the same hash code for any two values that are considered equal by the family's equality operators, even when the values are of different types. This is usually difficult to accomplish when the types have different physical representations, but it can be done in some cases. Furthermore, casting a value from one data type represented in the operator family to another data type also represented in the operator family via an implicit or binary coercion cast must not change the computed hash value. Notice that there is only one support function per data type, not one per equality operator. It is recommended that a family be complete, i.e., provide an equality operator for each combination of data types. Each operator class should include just the non-cross-type equality operator and the support function for its data type.

GiST and GIN indexes do not have any explicit notion of cross-data-type operations. The set of operators supported is just whatever the primary support functions for a given operator class can handle.

### Note

Prior to LightDB 8.3, there was no concept of operator families, and so any cross-data-type operators intended to be used with an index had to be bound directly into the index's operator class. While this approach still works, it is deprecated because it makes an index's dependencies too broad, and because the planner can handle cross-data-type comparisons more effectively when both data types have operators in the same operator family.

## 36.16.6. System Dependencies on Operator Classes



LightDB uses operator classes to infer the properties of operators in more ways than just whether they can be used with indexes. Therefore, you might want to create operator classes even if you have no intention of indexing any columns of your data type.

In particular, there are SQL features such as `ORDER BY` and `DISTINCT` that require comparison and sorting of values. To implement these features on a user-defined data type, LightDB looks for the default B-tree operator class for the data type. The “equals” member of this operator class defines the system’s notion of equality of values for `GROUP BY` and `DISTINCT`, and the sort ordering imposed by the operator class defines the default `ORDER BY` ordering.

If there is no default B-tree operator class for a data type, the system will look for a default hash operator class. But since that kind of operator class only provides equality, it is only able to support grouping not sorting.

When there is no default operator class for a data type, you will get errors like “could not identify an ordering operator” if you try to use these SQL features with the data type.

**Note**

In LightDB versions before 7.4, sorting and grouping operations would implicitly use operators named `=`, `<`, and `>`. The new behavior of relying on default operator classes avoids having to make any assumption about the behavior of operators with particular names.

Sorting by a non-default B-tree operator class is possible by specifying the class’s less-than operator in a `USING` option, for example

```
SELECT * FROM mytable ORDER BY somecol USING ~<~;
```

Alternatively, specifying the class’s greater-than operator in `USING` selects a descending-order sort.

Comparison of arrays of a user-defined type also relies on the semantics defined by the type’s default B-tree operator class. If there is no default B-tree operator class, but there is a default hash operator class, then array equality is supported, but not ordering comparisons.

Another SQL feature that requires even more data-type-specific knowledge is the `RANGE offset PRECEDING/FOLLOWING` framing option for window functions (see Section 4.2.8). For a query such as

```
SELECT sum(x) OVER (ORDER BY x RANGE BETWEEN 5 PRECEDING AND 10
    FOLLOWING)
    FROM mytable;
```

it is not sufficient to know how to order by `x`; the database must also understand how to “subtract 5” or “add 10” to the current row’s value of `x` to identify the bounds of the current window frame. Comparing the resulting bounds to other rows’ values of `x` is possible using the comparison operators provided by the B-tree operator class that defines the `ORDER BY` ordering — but addition and subtraction operators are not part of the operator class, so which ones should be used? Hard-wiring that choice would be undesirable, because different sort orders (different B-tree operator classes) might need different behavior. Therefore, a B-tree operator class can specify an *in\_range* support function that encapsulates the addition and subtraction behaviors that make sense for its sort order. It can even provide more than one *in\_range* support function, in case there is more than one data type that makes sense to use as the offset in `RANGE` clauses. If the B-tree operator class associated with the window’s `ORDER BY` clause does not have a matching *in\_range* support function, the `RANGE offset PRECEDING/FOLLOWING` option is not supported.

Another important point is that an equality operator that appears in a hash operator family is a candidate for hash joins, hash aggregation, and related optimizations. The hash operator family is essential here since it identifies the hash function(s) to use.

## 36.16.7. Ordering Operators

Some index access methods (currently, only GiST) support the concept of *ordering operators*. What we have been discussing so far are *search operators*. A search operator is one for which the index can be searched to find all rows satisfying `WHERE indexed_column operator constant`. Note that nothing is promised about the order in which the matching rows will be returned. In contrast, an ordering operator does not restrict the set of rows that can be returned, but instead determines their order. An ordering operator is one for which the index can be scanned to return rows in the order represented by `ORDER BY indexed_column operator constant`. The reason for defining ordering operators that way is that it supports nearest-neighbor searches, if the operator is one that measures distance. For example, a query like

```
SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT
10;
```

finds the ten places closest to a given target point. A GiST index on the location column can do this efficiently because `<->` is an ordering operator.

While search operators have to return Boolean results, ordering operators usually return some other type, such as float or numeric for distances. This type is normally not the same as the data type being indexed. To avoid hard-wiring assumptions about the behavior of different data types, the definition of an ordering operator is required to name a B-tree operator family that specifies the sort ordering of the result data type. As was stated in the previous section, B-tree operator families define LightDB's notion of ordering, so this is a natural representation. Since the point `<->` operator returns `float8`, it could be specified in an operator class creation command like this:

```
OPERATOR 15 <-> (point, point) FOR ORDER BY float_ops
```

where `float_ops` is the built-in operator family that includes operations on `float8`. This declaration states that the index is able to return rows in order of increasing values of the `<->` operator.

## 36.16.8. Special Features of Operator Classes

There are two special features of operator classes that we have not discussed yet, mainly because they are not useful with the most commonly used index methods.

Normally, declaring an operator as a member of an operator class (or family) means that the index method can retrieve exactly the set of rows that satisfy a `WHERE` condition using the operator. For example:

```
SELECT * FROM table WHERE integer_column < 4;
```

can be satisfied exactly by a B-tree index on the integer column. But there are cases where an index is useful as an inexact guide to the matching rows. For example, if a GiST index stores only bounding boxes for geometric objects, then it cannot exactly satisfy a `WHERE` condition that tests overlap between nonrectangular objects such as polygons. Yet we could use the index to find objects whose bounding box overlaps the bounding box of the target object, and then do the exact overlap test only on the objects found by the index. If this scenario applies, the index is said to be “lossy” for the operator. Lossy index searches are implemented by having the index method return a *recheck* flag when a row might or might not really satisfy the query condition. The core system will then test the

original query condition on the retrieved row to see whether it should be returned as a valid match. This approach works if the index is guaranteed to return all the required rows, plus perhaps some additional rows, which can be eliminated by performing the original operator invocation. The index methods that support lossy searches (currently, GiST and GIN) allow the support functions of individual operator classes to set the recheck flag, and so this is essentially an operator-class feature.

Consider again the situation where we are storing in the index only the bounding box of a complex object such as a polygon. In this case there's not much value in storing the whole polygon in the index entry — we might as well store just a simpler object of type `box`. This situation is expressed by the `STORAGE` option in `CREATE OPERATOR CLASS`: we'd write something like:

```
CREATE OPERATOR CLASS polygon_ops
    DEFAULT FOR TYPE polygon USING gist AS
    ...
    STORAGE box;
```

At present, only the GiST, GIN index methods support a `STORAGE` type that's different from the column data type. The GiST `compress` and `decompress` support routines must deal with data-type conversion when `STORAGE` is used. In GIN, the `STORAGE` type identifies the type of the “key” values, which normally is different from the type of the indexed column — for example, an operator class for integer-array columns might have keys that are just integers. The GIN `extractValue` and `extractQuery` support routines are responsible for extracting keys from indexed values.

## 36.17. Packaging Related Objects into an Extension

A useful extension to LightDB typically includes multiple SQL objects; for example, a new data type will require new functions, new operators, and probably new index operator classes. It is helpful to collect all these objects into a single package to simplify database management. LightDB calls such a package an *extension*. To define an extension, you need at least a *script file* that contains the SQL commands to create the extension's objects, and a *control file* that specifies a few basic properties of the extension itself. If the extension includes C code, there will typically also be a shared library file into which the C code has been built. Once you have these files, a simple `CREATE EXTENSION` command loads the objects into your database.

The main advantage of using an extension, rather than just running the SQL script to load a bunch of “loose” objects into your database, is that LightDB will then understand that the objects of the extension go together. You can drop all the objects with a single `DROP EXTENSION` command (no need to maintain a separate “uninstall” script). Even more useful, `lt_dump` knows that it should not dump the individual member objects of the extension — it will just include a `CREATE EXTENSION` command in dumps, instead. This vastly simplifies migration to a new version of the extension that might contain more or different objects than the old version. Note however that you must have the extension's control, script, and other files available when loading such a dump into a new database.

LightDB will not let you drop an individual object contained in an extension, except by dropping the whole extension. Also, while you can change the definition of an extension member object (for example, via `CREATE OR REPLACE FUNCTION` for a function), bear in mind that the modified definition will not be dumped by `lt_dump`. Such a change is usually only sensible if you concurrently make the same change in the extension's script file. (But there are special provisions for tables containing configuration data; see Section 36.17.3.) In production situations, it's generally better to create an extension update script to perform changes to extension member objects.

The extension script may set privileges on objects that are part of the extension, using `GRANT` and `REVOKE` statements. The final set of privileges for each object (if any are set) will be stored in the `pg_init_privs` system catalog. When `lt_dump` is used, the `CREATE EXTENSION` command will be included in the dump, followed by the set of `GRANT` and `REVOKE` statements necessary to set the privileges on the objects to what they were at the time the dump was taken.

LightDB does not currently support extension scripts issuing `CREATE POLICY` or `SECURITY LABEL` statements. These are expected to be set after the extension has been created. All RLS policies and security labels on extension objects will be included in dumps created by `lt_dump`.

The extension mechanism also has provisions for packaging modification scripts that adjust the definitions of the SQL objects contained in an extension. For example, if version 1.1 of an extension adds one function and changes the body of another function compared to 1.0, the extension author can provide an *update script* that makes just those two changes. The `ALTER EXTENSION UPDATE` command can then be used to apply these changes and track which version of the extension is actually installed in a given database.

The kinds of SQL objects that can be members of an extension are shown in the description of `ALTER EXTENSION`. Notably, objects that are database-cluster-wide, such as databases, roles, and tablespaces, cannot be extension members since an extension is only known within one database. (Although an extension script is not prohibited from creating such objects, if it does so they will not be tracked as part of the extension.) Also notice that while a table can be a member of an extension, its subsidiary objects such as indexes are not directly considered members of the extension. Another important point is that schemas can belong to extensions, but not vice versa: an extension as such has an unqualified name and does not exist “within” any schema. The extension's member objects, however, will belong to schemas whenever appropriate for their object types. It may or may not be appropriate for an extension to own the schema(s) its member objects are within.

If an extension's script creates any temporary objects (such as temp tables), those objects are treated as extension members for the remainder of the current session, but are automatically dropped at session end, as any temporary object would be. This is an exception to the rule that extension member objects cannot be dropped without dropping the whole extension.

## 36.17.1. Extension Files

The `CREATE EXTENSION` command relies on a control file for each extension, which must be named the same as the extension with a suffix of `.control`, and must be placed in the installation's `SHAREDIR/extension` directory. There must also be at least one SQL script file, which follows the naming pattern `extension--version.sql` (for example, `foo--1.0.sql` for version 1.0 of extension `foo`). By default, the script file(s) are also placed in the `SHAREDIR/extension` directory; but the control file can specify a different directory for the script file(s).

The file format for an extension control file is the same as for the `lightdb.conf` file, namely a list of `parameter_name = value` assignments, one per line. Blank lines and comments introduced by `#` are allowed. Be sure to quote any value that is not a single word or number.

A control file can set the following parameters:

`directory (string)`

The directory containing the extension's SQL script file(s). Unless an absolute path is given, the name is relative to the installation's `SHAREDIR` directory. The default behavior is equivalent to specifying `directory = 'extension'`.

`default_version (string)`

The default version of the extension (the one that will be installed if no version is specified in `CREATE EXTENSION`). Although this can be omitted, that will result in `CREATE EXTENSION` failing if no `VERSION` option appears, so you generally don't want to do that.

`comment (string)`

A comment (any string) about the extension. The comment is applied when initially creating an extension, but not during extension updates (since that might override user-added comments). Alternatively, the extension's comment can be set by writing a `COMMENT` command in the script file.

`encoding (string)`

The character set encoding used by the script file(s). This should be specified if the script files contain any non-ASCII characters. Otherwise the files will be assumed to be in the database encoding.

`module_pathname (string)`

The value of this parameter will be substituted for each occurrence of `MODULE_PATHNAME` in the script file(s). If it is not set, no substitution is made. Typically, this is set to `$libdir/shared_library_name` and then `MODULE_PATHNAME` is used in `CREATE FUNCTION` commands for C-language functions, so that the script files do not need to hard-wire the name of the shared library.

`requires (string)`

A list of names of extensions that this extension depends on, for example `requires = 'foo, bar'`. Those extensions must be installed before this one can be installed.

`superuser (boolean)`

If this parameter is `true` (which is the default), only superusers can create the extension or update it to a new version (but see also `trusted`, below). If it is set to `false`, just the privileges required to execute the commands in the installation or update script are required. This should normally be set to `true` if any of the script commands require superuser privileges. (Such commands would fail anyway, but it's more user-friendly to give the error up front.)

`trusted (boolean)`

This parameter, if set to `true` (which is not the default), allows some non-superusers to install an extension that has `superuser` set to `true`. Specifically, installation will be permitted for anyone who has `CREATE` privilege on the current database. When the user executing `CREATE EXTENSION` is not a superuser but is allowed to install by virtue of this parameter, then the installation or update script is run as the bootstrap superuser, not as the calling user. This parameter is irrelevant if `superuser` is `false`. Generally, this should not be set true for extensions that could allow access to otherwise-superuser-only abilities, such as file system access. Also, marking an extension `trusted` requires significant extra effort to write the extension's installation and update script(s) securely; see Section 36.17.6.

`relocatable (boolean)`

An extension is *relocatable* if it is possible to move its contained objects into a different schema after initial creation of the extension. The default is `false`, i.e., the extension is not relocatable. See Section 36.17.2 for more information.

`schema (string)`

This parameter can only be set for non-relocatable extensions. It forces the extension to be loaded into exactly the named schema and not any other. The `schema` parameter is consulted only when initially creating an extension, not during extension updates. See Section 36.17.2 for more information.

In addition to the primary control file `extension.control`, an extension can have secondary control files named in the style `extension--version.control`. If supplied, these must be located in the script file directory. Secondary control files follow the same format as the primary control file. Any parameters set in a secondary control file override the primary control file when installing or updating to that version of the extension. However, the parameters `directory` and `default_version` cannot be set in a secondary control file.

An extension's SQL script files can contain any SQL commands, except for transaction control commands (`BEGIN`, `COMMIT`, etc) and commands that cannot be executed inside a transaction block (such as `VACUUM`). This is because the script files are implicitly executed within a transaction block.

An extension's SQL script files can also contain lines beginning with `\echo`, which will be ignored (treated as comments) by the extension mechanism. This provision is commonly used to throw an error if the script file is fed to `ltsql` rather than being loaded via `CREATE EXTENSION` (see example script in Section 36.17.7). Without that, users might accidentally load the extension's contents as “loose” objects rather than as an extension, a state of affairs that's a bit tedious to recover from.

If the extension script contains the string `@extowner@`, that string is replaced with the (suitably quoted) name of the user calling `CREATE EXTENSION` or `ALTER EXTENSION`. Typically this feature is used by extensions that are marked trusted to assign ownership of selected objects to the calling user rather than the bootstrap superuser. (One should be careful about doing so, however. For example, assigning ownership of a C-language function to a non-superuser would create a privilege escalation path for that user.)

While the script files can contain any characters allowed by the specified encoding, control files should contain only plain ASCII, because there is no way for LightDB to know what encoding a control file is in. In practice this is only an issue if you want to use non-ASCII characters in the extension's comment. Recommended practice in that case is to not use the control file `comment` parameter, but instead use `COMMENT ON EXTENSION` within a script file to set the comment.

## 36.17.2. Extension Relocatability

Users often wish to load the objects contained in an extension into a different schema than the extension's author had in mind. There are three supported levels of relocatability:

- A fully relocatable extension can be moved into another schema at any time, even after it's been loaded into a database. This is done with the `ALTER EXTENSION SET SCHEMA` command, which automatically renames all the member objects into the new schema. Normally, this is only possible if the extension contains no internal assumptions about what schema any of its objects are in. Also, the extension's objects must all be in one schema to begin with (ignoring objects that do not belong to any schema, such as procedural languages). Mark a fully relocatable extension by setting `relocatable = true` in its control file.
- An extension might be relocatable during installation but not afterwards. This is typically the case if the extension's script file needs to reference the target schema explicitly, for example in setting `search_path` properties for SQL functions. For such an extension, set `relocatable = false` in its control file, and use `@extschema@` to refer to the target schema in the script file. All occurrences of this string will be replaced by the actual target schema's name before the script is executed. The user can set the target schema using the `SCHEMA` option of `CREATE EXTENSION`.
- If the extension does not support relocation at all, set `relocatable = false` in its control file, and also set `schema` to the name of the intended target schema. This will prevent use of the `SCHEMA` option of `CREATE EXTENSION`, unless it specifies the same schema named in the control file. This choice is typically necessary if the extension contains internal assumptions about schema names that can't be replaced by uses of `@extschema@`. The `@extschema@` substitution mechanism is available in this case too, although it is of limited use since the schema name is determined by the control file.

In all cases, the script file will be executed with `search_path` initially set to point to the target schema; that is, `CREATE EXTENSION` does the equivalent of this:

```
SET LOCAL search_path TO @extschema@, pg_temp;
```

This allows the objects created by the script file to go into the target schema. The script file can change `search_path` if it wishes, but that is generally undesirable. `search_path` is restored to its previous setting upon completion of `CREATE EXTENSION`.

The target schema is determined by the `schema` parameter in the control file if that is given, otherwise by the `SCHEMA` option of `CREATE EXTENSION` if that is given, otherwise the current default

object creation schema (the first one in the caller's `search_path`). When the control file schema parameter is used, the target schema will be created if it doesn't already exist, but in the other two cases it must already exist.

If any prerequisite extensions are listed in `requires` in the control file, their target schemas are added to the initial setting of `search_path`, following the new extension's target schema. This allows their objects to be visible to the new extension's script file.

For security, `pg_temp` is automatically appended to the end of `search_path` in all cases.

Although a non-relocatable extension can contain objects spread across multiple schemas, it is usually desirable to place all the objects meant for external use into a single schema, which is considered the extension's target schema. Such an arrangement works conveniently with the default setting of `search_path` during creation of dependent extensions.

### 36.17.3. Extension Configuration Tables

Some extensions include configuration tables, which contain data that might be added or changed by the user after installation of the extension. Ordinarily, if a table is part of an extension, neither the table's definition nor its content will be dumped by `lt_dump`. But that behavior is undesirable for a configuration table; any data changes made by the user need to be included in dumps, or the extension will behave differently after a dump and restore.

To solve this problem, an extension's script file can mark a table or a sequence it has created as a configuration relation, which will cause `lt_dump` to include the table's or the sequence's contents (not its definition) in dumps. To do that, call the function `pg_extension_config_dump(regclass, text)` after creating the table or the sequence, for example

```
CREATE TABLE my_config (key text, value text);
CREATE SEQUENCE my_config_seq;

SELECT pg_catalog.pg_extension_config_dump('my_config', '');
SELECT pg_catalog.pg_extension_config_dump('my_config_seq', '');
```

Any number of tables or sequences can be marked this way. Sequences associated with `serial` or `bigserial` columns can be marked as well.

When the second argument of `pg_extension_config_dump` is an empty string, the entire contents of the table are dumped by `lt_dump`. This is usually only correct if the table is initially empty as created by the extension script. If there is a mixture of initial data and user-provided data in the table, the second argument of `pg_extension_config_dump` provides a `WHERE` condition that selects the data to be dumped. For example, you might do

```
CREATE TABLE my_config (key text, value text, standard_entry
    boolean);

SELECT pg_catalog.pg_extension_config_dump('my_config', 'WHERE NOT
    standard_entry');
```

and then make sure that `standard_entry` is true only in the rows created by the extension's script.

For sequences, the second argument of `pg_extension_config_dump` has no effect.

More complicated situations, such as initially-provided rows that might be modified by users, can be handled by creating triggers on the configuration table to ensure that modified rows are marked correctly.

You can alter the filter condition associated with a configuration table by calling `pg_extension_config_dump` again. (This would typically be useful in an extension update script.) The only way to mark a table as no longer a configuration table is to dissociate it from the extension with `ALTER EXTENSION ... DROP TABLE`.

Note that foreign key relationships between these tables will dictate the order in which the tables are dumped out by `lt_dump`. Specifically, `lt_dump` will attempt to dump the referenced-by table before the referencing table. As the foreign key relationships are set up at `CREATE EXTENSION` time (prior to data being loaded into the tables) circular dependencies are not supported. When circular dependencies exist, the data will still be dumped out but the dump will not be able to be restored directly and user intervention will be required.

Sequences associated with `serial` or `bigserial` columns need to be directly marked to dump their state. Marking their parent relation is not enough for this purpose.

## 36.17.4. Extension Updates

One advantage of the extension mechanism is that it provides convenient ways to manage updates to the SQL commands that define an extension's objects. This is done by associating a version name or number with each released version of the extension's installation script. In addition, if you want users to be able to update their databases dynamically from one version to the next, you should provide *update scripts* that make the necessary changes to go from one version to the next. Update scripts have names following the pattern `extension--old_version--target_version.sql` (for example, `foo--1.0--1.1.sql` contains the commands to modify version 1.0 of extension `foo` into version 1.1).

Given that a suitable update script is available, the command `ALTER EXTENSION UPDATE` will update an installed extension to the specified new version. The update script is run in the same environment that `CREATE EXTENSION` provides for installation scripts: in particular, `search_path` is set up in the same way, and any new objects created by the script are automatically added to the extension. Also, if the script chooses to drop extension member objects, they are automatically dissociated from the extension.

If an extension has secondary control files, the control parameters that are used for an update script are those associated with the script's target (new) version.

`ALTER EXTENSION` is able to execute sequences of update script files to achieve a requested update. For example, if only `foo--1.0--1.1.sql` and `foo--1.1--2.0.sql` are available, `ALTER EXTENSION` will apply them in sequence if an update to version 2.0 is requested when 1.0 is currently installed.

LightDB doesn't assume anything about the properties of version names: for example, it does not know whether 1.1 follows 1.0. It just matches up the available version names and follows the path that requires applying the fewest update scripts. (A version name can actually be any string that doesn't contain `--` or leading or trailing `-`.)

Sometimes it is useful to provide “downgrade” scripts, for example `foo--1.1--1.0.sql` to allow reverting the changes associated with version 1.1. If you do that, be careful of the possibility that a downgrade script might unexpectedly get applied because it yields a shorter path. The risky case is where there is a “fast path” update script that jumps ahead several versions as well as a downgrade script to the fast path's start point. It might take fewer steps to apply the downgrade and then the fast path than to move ahead one version at a time. If the downgrade script drops any irreplaceable objects, this will yield undesirable results.

To check for unexpected update paths, use this command:

```
SELECT * FROM pg_extension_update_paths('extension_name');
```



This shows each pair of distinct known version names for the specified extension, together with the update path sequence that would be taken to get from the source version to the target version, or NULL if there is no available update path. The path is shown in textual form with `--` separators. You can use `regexp_split_to_array(path, '--')` if you prefer an array format.

## 36.17.5. Installing Extensions Using Update Scripts

An extension that has been around for awhile will probably exist in several versions, for which the author will need to write update scripts. For example, if you have released a `foo` extension in versions 1.0, 1.1, and 1.2, there should be update scripts `foo--1.0--1.1.sql` and `foo--1.1--1.2.sql`. Before LightDB 10, it was necessary to also create new script files `foo--1.1.sql` and `foo--1.2.sql` that directly build the newer extension versions, or else the newer versions could not be installed directly, only by installing 1.0 and then updating. That was tedious and duplicative, but now it's unnecessary, because `CREATE EXTENSION` can follow update chains automatically. For example, if only the script files `foo--1.0.sql`, `foo--1.0--1.1.sql`, and `foo--1.1--1.2.sql` are available then a request to install version 1.2 is honored by running those three scripts in sequence. The processing is the same as if you'd first installed 1.0 and then updated to 1.2. (As with `ALTER EXTENSION UPDATE`, if multiple pathways are available then the shortest is preferred.) Arranging an extension's script files in this style can reduce the amount of maintenance effort needed to produce small updates.

If you use secondary (version-specific) control files with an extension maintained in this style, keep in mind that each version needs a control file even if it has no stand-alone installation script, as that control file will determine how the implicit update to that version is performed. For example, if `foo--1.0.control` specifies `requires = 'bar'` but `foo`'s other control files do not, the extension's dependency on `bar` will be dropped when updating from 1.0 to another version.

## 36.17.6. Security Considerations for Extensions

Widely-distributed extensions should assume little about the database they occupy. Therefore, it's appropriate to write functions provided by an extension in a secure style that cannot be compromised by search-path-based attacks.

An extension that has the `superuser` property set to true must also consider security hazards for the actions taken within its installation and update scripts. It is not terribly difficult for a malicious user to create trojan-horse objects that will compromise later execution of a carelessly-written extension script, allowing that user to acquire superuser privileges.

If an extension is marked `trusted`, then its installation schema can be selected by the installing user, who might intentionally use an insecure schema in hopes of gaining superuser privileges. Therefore, a trusted extension is extremely exposed from a security standpoint, and all its script commands must be carefully examined to ensure that no compromise is possible.

Advice about writing functions securely is provided in Section 36.17.6.1 below, and advice about writing installation scripts securely is provided in Section 36.17.6.2.

### 36.17.6.1. Security Considerations for Extension Functions

SQL-language and PL-language functions provided by extensions are at risk of search-path-based attacks when they are executed, since parsing of these functions occurs at execution time not creation time.

The `CREATE FUNCTION` reference page contains advice about writing `SECURITY DEFINER` functions safely. It's good practice to apply those techniques for any function provided by an extension, since the function might be called by a high-privilege user.

If you cannot set the `search_path` to contain only secure schemas, assume that each unqualified name could resolve to an object that a malicious user has defined. Beware of constructs that depend

on `search_path` implicitly; for example, `IN` and `CASE expression WHEN` always select an operator using the search path. In their place, use `OPERATOR(schema.=) ANY` and `CASE WHEN expression`.

A general-purpose extension usually should not assume that it's been installed into a secure schema, which means that even schema-qualified references to its own objects are not entirely risk-free. For example, if the extension has defined a function `myschema.myfunc(bigint)` then a call such as `myschema.myfunc(42)` could be captured by a hostile function `myschema.myfunc(integer)`. Be careful that the data types of function and operator parameters exactly match the declared argument types, using explicit casts where necessary.

### 36.17.6.2. Security Considerations for Extension Scripts

An extension installation or update script should be written to guard against search-path-based attacks occurring when the script executes. If an object reference in the script can be made to resolve to some other object than the script author intended, then a compromise might occur immediately, or later when the mis-defined extension object is used.

DDL commands such as `CREATE FUNCTION` and `CREATE OPERATOR CLASS` are generally secure, but beware of any command having a general-purpose expression as a component. For example, `CREATE VIEW` needs to be vetted, as does a `DEFAULT` expression in `CREATE FUNCTION`.

Sometimes an extension script might need to execute general-purpose SQL, for example to make catalog adjustments that aren't possible via DDL. Be careful to execute such commands with a secure `search_path`; do *not* trust the path provided by `CREATE/ALTER EXTENSION` to be secure. Best practice is to temporarily set `search_path` to `'pg_catalog, pg_temp'` and insert references to the extension's installation schema explicitly where needed. (This practice might also be helpful for creating views.) Examples can be found in the `contrib` modules in the LightDB source code distribution.

Cross-extension references are extremely difficult to make fully secure, partially because of uncertainty about which schema the other extension is in. The hazards are reduced if both extensions are installed in the same schema, because then a hostile object cannot be placed ahead of the referenced extension in the installation-time `search_path`. However, no mechanism currently exists to require that. For now, best practice is to not mark an extension trusted if it depends on another one, unless that other one is always installed in `pg_catalog`.

### 36.17.7. Extension Example

Here is a complete example of an SQL-only extension, a two-element composite type that can store any type of value in its slots, which are named “k” and “v”. Non-text values are automatically coerced to text for storage.

The script file `pair--1.0.sql` looks like this:

```
-- complain if script is sourced in ltsql, rather than via CREATE
EXTENSION
\echo Use "CREATE EXTENSION pair" to load this file. \quit

CREATE TYPE pair AS ( k text, v text );

CREATE FUNCTION pair(text, text)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1,
    $2)::@extschema.pair;';

CREATE OPERATOR ~> (LEFTARG = text, RIGHTARG = text, FUNCTION =
    pair);
```

```
-- "SET search_path" is easy to get right, but qualified names
  perform better.
CREATE FUNCTION lower(pair)
RETURNS pair LANGUAGE SQL
AS 'SELECT ROW(lower($1.k), lower($1.v))::@extschema@.pair;'
SET search_path = pg_temp;

CREATE FUNCTION pair_concat(pair, pair)
RETURNS pair LANGUAGE SQL
AS 'SELECT ROW($1.k OPERATOR(pg_catalog.||) $2.k,
               $1.v OPERATOR(pg_catalog.||)
               $2.v)::@extschema@.pair;';
```

The control file `pair.control` looks like this:

```
# pair extension
comment = 'A key/value pair data type'
default_version = '1.0'
# cannot be relocatable because of use of @extschema@
relocatable = false
```

While you hardly need a makefile to install these two files into the correct directory, you could use a Makefile containing this:

```
EXTENSION = pair
DATA = pair--1.0.sql

PG_CONFIG = lt_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

This makefile relies on PGXS, which is described in Section 36.18. The command `make install` will install the control and script files into the correct directory as reported by `lt_config`.

Once the files are installed, use the `CREATE EXTENSION` command to load the objects into any particular database.

## 36.18. Extension Building Infrastructure

If you are thinking about distributing your LightDB extension modules, setting up a portable build system for them can be fairly difficult. Therefore the LightDB installation provides a build infrastructure for extensions, called PGXS, so that simple extension modules can be built simply against an already installed server. PGXS is mainly intended for extensions that include C code, although it can be used for pure-SQL extensions too. Note that PGXS is not intended to be a universal build system framework that can be used to build any software interfacing to LightDB; it simply automates common build rules for simple server extension modules. For more complicated packages, you might need to write your own build system.

To use the PGXS infrastructure for your extension, you must write a simple makefile. In the makefile, you need to set some variables and include the global PGXS makefile. Here is an example that builds an extension module named `isbn_issn`, consisting of a shared library containing some C code, an extension control file, a SQL script, an include file (only needed if other modules might need to access the extension functions without going via SQL), and a documentation text file:

```
MODULES = isbn_issn
```

```
EXTENSION = isbn_issn
DATA = isbn_issn--1.0.sql
DOCS = README.isbn_issn
HEADERS_isbn_issn = isbn_issn.h
```

```
PG_CONFIG = lt_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

The last three lines should always be the same. Earlier in the file, you assign variables or add custom make rules.

Set one of these three variables to specify what is built:

MODULES

list of shared-library objects to be built from source files with same stem (do not include library suffixes in this list)

MODULE\_big

a shared library to build from multiple source files (list object files in OBJS)

PROGRAM

an executable program to build (list object files in OBJS)

The following variables can also be set:

EXTENSION

extension name(s); for each name you must provide an *extension.control* file, which will be installed into *prefix/share/extension*

MODULEDIR

subdirectory of *prefix/share* into which DATA and DOCS files should be installed (if not set, default is *extension* if EXTENSION is set, or *contrib* if not)

DATA

random files to install into *prefix/share/\$MODULEDIR*

DATA\_built

random files to install into *prefix/share/\$MODULEDIR*, which need to be built first

DATA\_TSEARCH

random files to install under *prefix/share/tsearch\_data*

DOCS

random files to install under *prefix/doc/\$MODULEDIR*

HEADERS

HEADERS\_built

Files to (optionally build and) install under *prefix/include/server/\$MODULEDIR/\$MODULE\_big*.

Unlike DATA\_built, files in HEADERS\_built are not removed by the clean target; if you want them removed, also add them to EXTRA\_CLEAN or add your own rules to do it.

HEADERS\_\$MODULE  
HEADERS\_built\_\$MODULE

Files to install (after building if specified) under *prefix/include/server/\$MODULEDIR/\$MODULE*, where \$MODULE must be a module name used in MODULES or MODULE\_big.

Unlike DATA\_built, files in HEADERS\_built\_\$MODULE are not removed by the clean target; if you want them removed, also add them to EXTRA\_CLEAN or add your own rules to do it.

It is legal to use both variables for the same module, or any combination, unless you have two module names in the MODULES list that differ only by the presence of a prefix built\_, which would cause ambiguity. In that (hopefully unlikely) case, you should use only the HEADERS\_built\_\$MODULE variables.

SCRIPTS

script files (not binaries) to install into *prefix/bin*

SCRIPTS\_built

script files (not binaries) to install into *prefix/bin*, which need to be built first

REGRESS

list of regression test cases (without suffix), see below

REGRESS\_OPTS

additional switches to pass to pg\_regress

ISOLATION

list of isolation test cases, see below for more details

ISOLATION\_OPTS

additional switches to pass to pg\_isolation\_regress

TAP\_TESTS

switch defining if TAP tests need to be run, see below

NO\_INSTALLCHECK

don't define an installcheck target, useful e.g., if tests require special configuration, or don't use pg\_regress

EXTRA\_CLEAN

extra files to remove in make clean

PG\_CPPFLAGS

will be prepended to CPPFLAGS

PG\_CFLAGS

will be appended to CFLAGS

PG\_CXXFLAGS

will be appended to CXXFLAGS

PG\_LDFLAGS

will be prepended to LDFLAGS

PG\_LIBS

will be added to PROGRAM link line

SHLIB\_LINK

will be added to MODULE\_big link line

PG\_CONFIG

path to `lt_config` program for the LightDB installation to build against (typically just `lt_config` to use the first one in your PATH)

Put this makefile as `Makefile` in the directory which holds your extension. Then you can do `make` to compile, and then `make install` to install your module. By default, the extension is compiled and installed for the LightDB installation that corresponds to the first `pg_config` program found in your PATH. You can use a different installation by setting `PG_CONFIG` to point to its `lt_config` program, either within the makefile or on the `make` command line.

You can also run `make` in a directory outside the source tree of your extension, if you want to keep the build directory separate. This procedure is also called a *VPATH* build. Here's how:

```
mkdir build_dir
cd build_dir
make -f /path/to/extension/source/tree/Makefile
make -f /path/to/extension/source/tree/Makefile install
```

Alternatively, you can set up a directory for a *VPATH* build in a similar way to how it is done for the core code. One way to do this is using the core script `config/prep_buildtree`. Once this has been done you can build by setting the `make` variable `VPATH` like this:

```
make VPATH=/path/to/extension/source/tree
make VPATH=/path/to/extension/source/tree install
```

This procedure can work with a greater variety of directory layouts.

The scripts listed in the `REGRESS` variable are used for regression testing of your module, which can be invoked by `make installcheck` after doing `make install`. For this to work you must have a running LightDB server. The script files listed in `REGRESS` must appear in a subdirectory named `sql/` in your extension's directory. These files must have extension `.sql`, which must not be included in the `REGRESS` list in the makefile. For each test there should also be a file containing the expected output in a subdirectory named `expected/`, with the same stem and extension `.out`. `make installcheck` executes each test script with `ltsql`, and compares the resulting output to the matching expected file. Any differences will be written to the file `regression.diffs` in `diff -c` format. Note that trying to run a test that is missing its expected file will be reported as “trouble”, so make sure you have all expected files.

The scripts listed in the `ISOLATION` variable are used for tests stressing behavior of concurrent session with your module, which can be invoked by `make installcheck` after doing `make install`. For this to work you must have a running LightDB server. The script files listed in `ISOLATION` must appear in a subdirectory named `specs/` in your extension's directory. These files must have extension `.spec`, which must not be included in the `ISOLATION` list in the makefile. For each test there should also be a file containing the expected output in a subdirectory named `expected/`, with the same stem and extension `.out`. `make installcheck` executes each test script, and compares the resulting output to the matching expected file. Any differences will be written

to the file `output_iso/regression.diffs` in `diff -c` format. Note that trying to run a test that is missing its expected file will be reported as “trouble”, so make sure you have all expected files.

`TAP_TESTS` enables the use of TAP tests. Data from each run is present in a subdirectory named `tmp_check/`. See also Section 30.4 for more details.

**Tip**

The easiest way to create the expected files is to create empty files, then do a test run (which will of course report differences). Inspect the actual result files found in the `results/` directory (for tests in `REGRESS`), or `output_iso/results/` directory (for tests in `ISOLATION`), then copy them to `expected/` if they match what you expect from the test.

---

# Chapter 37. Triggers

This chapter provides general information about writing trigger functions. Trigger functions can be written in most of the available procedural languages, including PL/pgSQL (Chapter 41), PL/oraSQL (Chapter 42). After reading this chapter, you should consult the chapter for your favorite procedural language to find out the language-specific details of writing a trigger in it.

It is also possible to write a trigger function in C, although most people find it easier to use one of the procedural languages. It is not currently possible to write a trigger function in the plain SQL function language.

## 37.1. Overview of Trigger Behavior

A trigger is a specification that the database should automatically execute a particular function whenever a certain type of operation is performed. Triggers can be attached to tables (partitioned or not), views, and foreign tables.

On tables and foreign tables, triggers can be defined to execute either before or after any `INSERT`, `UPDATE`, or `DELETE` operation, either once per modified row, or once per SQL statement. `UPDATE` triggers can moreover be set to fire only if certain columns are mentioned in the `SET` clause of the `UPDATE` statement. Triggers can also fire for `TRUNCATE` statements. If a trigger event occurs, the trigger's function is called at the appropriate time to handle the event.

On views, triggers can be defined to execute instead of `INSERT`, `UPDATE`, or `DELETE` operations. Such `INSTEAD OF` triggers are fired once for each row that needs to be modified in the view. It is the responsibility of the trigger's function to perform the necessary modifications to the view's underlying base table(s) and, where appropriate, return the modified row as it will appear in the view. Triggers on views can also be defined to execute once per SQL statement, before or after `INSERT`, `UPDATE`, or `DELETE` operations. However, such triggers are fired only if there is also an `INSTEAD OF` trigger on the view. Otherwise, any statement targeting the view must be rewritten into a statement affecting its underlying base table(s), and then the triggers that will be fired are the ones attached to the base table(s).

The trigger function must be defined before the trigger itself can be created. The trigger function must be declared as a function taking no arguments and returning type `trigger`. (The trigger function receives its input through a specially-passed `TriggerData` structure, not in the form of ordinary function arguments.)

Once a suitable trigger function has been created, the trigger is established with `CREATE TRIGGER`. The same trigger function can be used for multiple triggers.

LightDB offers both *per-row* triggers and *per-statement* triggers. With a per-row trigger, the trigger function is invoked once for each row that is affected by the statement that fired the trigger. In contrast, a per-statement trigger is invoked only once when an appropriate statement is executed, regardless of the number of rows affected by that statement. In particular, a statement that affects zero rows will still result in the execution of any applicable per-statement triggers. These two types of triggers are sometimes called *row-level* triggers and *statement-level* triggers, respectively. Triggers on `TRUNCATE` may only be defined at statement level, not per-row.

Triggers are also classified according to whether they fire *before*, *after*, or *instead of* the operation. These are referred to as `BEFORE` triggers, `AFTER` triggers, and `INSTEAD OF` triggers respectively. Statement-level `BEFORE` triggers naturally fire before the statement starts to do anything, while statement-level `AFTER` triggers fire at the very end of the statement. These types of triggers may be defined on tables, views, or foreign tables. Row-level `BEFORE` triggers fire immediately before a particular row is operated on, while row-level `AFTER` triggers fire at the end of the statement (but before any statement-level `AFTER` triggers). These types of triggers may only be defined on tables and foreign tables, not views. `INSTEAD OF` triggers may only be defined on views, and only at row level; they fire immediately as each row in the view is identified as needing to be operated on.



A statement that targets a parent table in an inheritance or partitioning hierarchy does not cause the statement-level triggers of affected child tables to be fired; only the parent table's statement-level triggers are fired. However, row-level triggers of any affected child tables will be fired.

If an `INSERT` contains an `ON CONFLICT DO UPDATE` clause, it is possible that the effects of row-level `BEFORE INSERT` triggers and row-level `BEFORE UPDATE` triggers can both be applied in a way that is apparent from the final state of the updated row, if an `EXCLUDED` column is referenced. There need not be an `EXCLUDED` column reference for both sets of row-level `BEFORE` triggers to execute, though. The possibility of surprising outcomes should be considered when there are both `BEFORE INSERT` and `BEFORE UPDATE` row-level triggers that change a row being inserted/updated (this can be problematic even if the modifications are more or less equivalent, if they're not also idempotent). Note that statement-level `UPDATE` triggers are executed when `ON CONFLICT DO UPDATE` is specified, regardless of whether or not any rows were affected by the `UPDATE` (and regardless of whether the alternative `UPDATE` path was ever taken). An `INSERT` with an `ON CONFLICT DO UPDATE` clause will execute statement-level `BEFORE INSERT` triggers first, then statement-level `BEFORE UPDATE` triggers, followed by statement-level `AFTER UPDATE` triggers and finally statement-level `AFTER INSERT` triggers.

If an `UPDATE` on a partitioned table causes a row to move to another partition, it will be performed as a `DELETE` from the original partition followed by an `INSERT` into the new partition. In this case, all row-level `BEFORE UPDATE` triggers and all row-level `BEFORE DELETE` triggers are fired on the original partition. Then all row-level `BEFORE INSERT` triggers are fired on the destination partition. The possibility of surprising outcomes should be considered when all these triggers affect the row being moved. As far as `AFTER ROW` triggers are concerned, `AFTER DELETE` and `AFTER INSERT` triggers are applied; but `AFTER UPDATE` triggers are not applied because the `UPDATE` has been converted to a `DELETE` and an `INSERT`. As far as statement-level triggers are concerned, none of the `DELETE` or `INSERT` triggers are fired, even if row movement occurs; only the `UPDATE` triggers defined on the target table used in the `UPDATE` statement will be fired.

Trigger functions invoked by per-statement triggers should always return `NULL`. Trigger functions invoked by per-row triggers can return a table row (a value of type `HeapTuple`) to the calling executor, if they choose. A row-level trigger fired before an operation has the following choices:

- It can return `NULL` to skip the operation for the current row. This instructs the executor to not perform the row-level operation that invoked the trigger (the insertion, modification, or deletion of a particular table row).
- For row-level `INSERT` and `UPDATE` triggers only, the returned row becomes the row that will be inserted or will replace the row being updated. This allows the trigger function to modify the row being inserted or updated.

A row-level `BEFORE` trigger that does not intend to cause either of these behaviors must be careful to return as its result the same row that was passed in (that is, the `NEW` row for `INSERT` and `UPDATE` triggers, the `OLD` row for `DELETE` triggers).

A row-level `INSTEAD OF` trigger should either return `NULL` to indicate that it did not modify any data from the view's underlying base tables, or it should return the view row that was passed in (the `NEW` row for `INSERT` and `UPDATE` operations, or the `OLD` row for `DELETE` operations). A nonnull return value is used to signal that the trigger performed the necessary data modifications in the view. This will cause the count of the number of rows affected by the command to be incremented. For `INSERT` and `UPDATE` operations only, the trigger may modify the `NEW` row before returning it. This will change the data returned by `INSERT RETURNING` or `UPDATE RETURNING`, and is useful when the view will not show exactly the same data that was provided.

The return value is ignored for row-level triggers fired after an operation, and so they can return `NULL`.

Some considerations apply for generated columns. Stored generated columns are computed after `BEFORE` triggers and before `AFTER` triggers. Therefore, the generated value can be inspected in `AFTER` triggers. In `BEFORE` triggers, the `OLD` row contains the old generated value, as one would expect, but the `NEW` row does not yet contain the new generated value and should not be accessed. In the

C language interface, the content of the column is undefined at this point; a higher-level programming language should prevent access to a stored generated column in the `NEW` row in a `BEFORE` trigger. Changes to the value of a generated column in a `BEFORE` trigger are ignored and will be overwritten.

If more than one trigger is defined for the same event on the same relation, the triggers will be fired in alphabetical order by trigger name. In the case of `BEFORE` and `INSTEAD OF` triggers, the possibly-modified row returned by each trigger becomes the input to the next trigger. If any `BEFORE` or `INSTEAD OF` trigger returns `NULL`, the operation is abandoned for that row and subsequent triggers are not fired (for that row).

A trigger definition can also specify a Boolean `WHEN` condition, which will be tested to see whether the trigger should be fired. In row-level triggers the `WHEN` condition can examine the old and/or new values of columns of the row. (Statement-level triggers can also have `WHEN` conditions, although the feature is not so useful for them.) In a `BEFORE` trigger, the `WHEN` condition is evaluated just before the function is or would be executed, so using `WHEN` is not materially different from testing the same condition at the beginning of the trigger function. However, in an `AFTER` trigger, the `WHEN` condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an `AFTER` trigger's `WHEN` condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows. `INSTEAD OF` triggers do not support `WHEN` conditions.

Typically, row-level `BEFORE` triggers are used for checking or modifying the data that will be inserted or updated. For example, a `BEFORE` trigger might be used to insert the current time into a `timestamp` column, or to check that two elements of the row are consistent. Row-level `AFTER` triggers are most sensibly used to propagate the updates to other tables, or make consistency checks against other tables. The reason for this division of labor is that an `AFTER` trigger can be certain it is seeing the final value of the row, while a `BEFORE` trigger cannot; there might be other `BEFORE` triggers firing after it. If you have no specific reason to make a trigger `BEFORE` or `AFTER`, the `BEFORE` case is more efficient, since the information about the operation doesn't have to be saved until end of statement.

If a trigger function executes SQL commands then these commands might fire triggers again. This is known as cascading triggers. There is no direct limitation on the number of cascade levels. It is possible for cascades to cause a recursive invocation of the same trigger; for example, an `INSERT` trigger might execute a command that inserts an additional row into the same table, causing the `INSERT` trigger to be fired again. It is the trigger programmer's responsibility to avoid infinite recursion in such scenarios.

When a trigger is being defined, arguments can be specified for it. The purpose of including arguments in the trigger definition is to allow different triggers with similar requirements to call the same function. As an example, there could be a generalized trigger function that takes as its arguments two column names and puts the current user in one and the current time stamp in the other. Properly written, this trigger function would be independent of the specific table it is triggering on. So the same function could be used for `INSERT` events on any table with suitable columns, to automatically track creation of records in a transaction table for example. It could also be used to track last-update events if defined as an `UPDATE` trigger.

Each programming language that supports triggers has its own method for making the trigger input data available to the trigger function. This input data includes the type of trigger event (e.g., `INSERT` or `UPDATE`) as well as any arguments that were listed in `CREATE TRIGGER`. For a row-level trigger, the input data also includes the `NEW` row for `INSERT` and `UPDATE` triggers, and/or the `OLD` row for `UPDATE` and `DELETE` triggers.

By default, statement-level triggers do not have any way to examine the individual row(s) modified by the statement. But an `AFTER STATEMENT` trigger can request that *transition tables* be created to make the sets of affected rows available to the trigger. `AFTER ROW` triggers can also request transition tables, so that they can see the total changes in the table as well as the change in the individual row they are currently being fired for. The method for examining the transition tables again depends on the programming language that is being used, but the typical approach is to make the transition tables act like read-only temporary tables that can be accessed by SQL commands issued within the trigger function.

## 37.2. Visibility of Data Changes

If you execute SQL commands in your trigger function, and these commands access the table that the trigger is for, then you need to be aware of the data visibility rules, because they determine whether these SQL commands will see the data change that the trigger is fired for. Briefly:

- Statement-level triggers follow simple visibility rules: none of the changes made by a statement are visible to statement-level `BEFORE` triggers, whereas all modifications are visible to statement-level `AFTER` triggers.
- The data change (insertion, update, or deletion) causing the trigger to fire is naturally *not* visible to SQL commands executed in a row-level `BEFORE` trigger, because it hasn't happened yet.
- However, SQL commands executed in a row-level `BEFORE` trigger *will* see the effects of data changes for rows previously processed in the same outer command. This requires caution, since the ordering of these change events is not in general predictable; a SQL command that affects multiple rows can visit the rows in any order.
- Similarly, a row-level `INSTEAD OF` trigger will see the effects of data changes made by previous firings of `INSTEAD OF` triggers in the same outer command.
- When a row-level `AFTER` trigger is fired, all data changes made by the outer command are already complete, and are visible to the invoked trigger function.

If your trigger function is written in any of the standard procedural languages, then the above statements apply only if the function is declared `VOLATILE`. Functions that are declared `STABLE` or `IMMUTABLE` will not see changes made by the calling command in any case.

Further information about data visibility rules can be found in Section 43.5. The example in Section 37.4 contains a demonstration of these rules.

## 37.3. Writing Trigger Functions in C

This section describes the low-level details of the interface to a trigger function. This information is only needed when writing trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your triggers in C. The documentation of each procedural language explains how to write a trigger in that language.

Trigger functions must use the “version 1” function manager interface.

When a function is called by the trigger manager, it is not passed any normal arguments, but it is passed a “context” pointer pointing to a `TriggerData` structure. C functions can check whether they were called from the trigger manager or not by executing the macro:

```
CALLED_AS_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context, TriggerData))
```

If this returns true, then it is safe to cast `fcinfo->context` to type `TriggerData *` and make use of the pointed-to `TriggerData` structure. The function must *not* alter the `TriggerData` structure or any of the data it points to.

`struct TriggerData` is defined in `commands/trigger.h`:

```
typedef struct TriggerData
```

```

{
    NodeTag            type;
    TriggerEvent      tg_event;
    Relation           tg_relation;
    HeapTuple         tg_trigtuple;
    HeapTuple         tg_newtuple;
    Trigger            *tg_trigger;
    TupleTableSlot    *tg_trigslot;
    TupleTableSlot    *tg_newslot;
    Tuplestorestate   *tg_oldtable;
    Tuplestorestate   *tg_newtable;
    const Bitmapset   *tg_updatedcols;
} TriggerData;

```

where the members are defined as follows:

type

Always T\_TriggerData.

tg\_event

Describes the event for which the function is called. You can use the following macros to examine tg\_event:

TRIGGER\_FIRED\_BEFORE(tg\_event)

Returns true if the trigger fired before the operation.

TRIGGER\_FIRED\_AFTER(tg\_event)

Returns true if the trigger fired after the operation.

TRIGGER\_FIRED\_INSTEAD(tg\_event)

Returns true if the trigger fired instead of the operation.

TRIGGER\_FIRED\_FOR\_ROW(tg\_event)

Returns true if the trigger fired for a row-level event.

TRIGGER\_FIRED\_FOR\_STATEMENT(tg\_event)

Returns true if the trigger fired for a statement-level event.

TRIGGER\_FIRED\_BY\_INSERT(tg\_event)

Returns true if the trigger was fired by an INSERT command.

TRIGGER\_FIRED\_BY\_UPDATE(tg\_event)

Returns true if the trigger was fired by an UPDATE command.

TRIGGER\_FIRED\_BY\_DELETE(tg\_event)

Returns true if the trigger was fired by a DELETE command.

TRIGGER\_FIRED\_BY\_TRUNCATE(tg\_event)

Returns true if the trigger was fired by a TRUNCATE command.

tg\_relation

A pointer to a structure describing the relation that the trigger fired for. Look at `utils/rel.h` for details about this structure. The most interesting things are `tg_relation->rd_att`

(descriptor of the relation tuples) and `tg_relation->rd_rel->relname` (relation name; the type is not `char*` but `NameData`; use `SPI_getrelname(tg_relation)` to get a `char*` if you need a copy of the name).

`tg_trigtuple`

A pointer to the row for which the trigger was fired. This is the row being inserted, updated, or deleted. If this trigger was fired for an `INSERT` or `DELETE` then this is what you should return from the function if you don't want to replace the row with a different one (in the case of `INSERT`) or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_newtuple`

A pointer to the new version of the row, if the trigger was fired for an `UPDATE`, and `NULL` if it is for an `INSERT` or a `DELETE`. This is what you have to return from the function if the event is an `UPDATE` and you don't want to replace this row by a different one or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_trigger`

A pointer to a structure of type `Trigger`, defined in `utils/reltrigger.h`:

```
typedef struct Trigger
{
    Oid          tgoid;
    char        *tgname;
    Oid          tgfoid;
    int16       tgtype;
    char        tgenabled;
    bool        tgisinternal;
    Oid          tgconstrrelid;
    Oid          tgconstrindid;
    Oid          tgconstraint;
    bool        tgdeferrable;
    bool        tginitdeferred;
    int16       tgnargs;
    int16       tgnattr;
    int16       *tgattr;
    char        **tgargs;
    char        *tgqual;
    char        *tgoldtable;
    char        *tgnewtable;
} Trigger;
```

where `tgname` is the trigger's name, `tgnargs` is the number of arguments in `tgargs`, and `tgargs` is an array of pointers to the arguments specified in the `CREATE TRIGGER` statement. The other members are for internal use only.

`tg_trigslot`

The slot containing `tg_trigtuple`, or a `NULL` pointer if there is no such tuple.

`tg_newslot`

The slot containing `tg_newtuple`, or a `NULL` pointer if there is no such tuple.

`tg_oldtable`

A pointer to a structure of type `Tuplestorestate` containing zero or more rows in the format specified by `tg_relation`, or a `NULL` pointer if there is no `OLD TABLE` transition relation.

`tg_newtable`

A pointer to a structure of type `Tuplestorestate` containing zero or more rows in the format specified by `tg_relation`, or a `NULL` pointer if there is no `NEW TABLE` transition relation.

`tg_updatedcols`

For `UPDATE` triggers, a bitmap set indicating the columns that were updated by the triggering command. Generic trigger functions can use this to optimize actions by not having to deal with columns that were not changed.

As an example, to determine whether a column with attribute number `attnum` (1-based) is a member of this bitmap set, call `bms_is_member(attnum - FirstLowInvalidHeapAttributeNumber, trigdata->tg_updatedcols)`.

For triggers other than `UPDATE` triggers, this will be `NULL`.

To allow queries issued through SPI to reference transition tables, see `SPI_register_trigger_data`.

A trigger function must return either a `HeapTuple` pointer or a `NULL` pointer (*not* an SQL null value, that is, do not set `isNull` true). Be careful to return either `tg_trigtuple` or `tg_newtuple`, as appropriate, if you don't want to modify the row being operated on.

## 37.4. A Complete Trigger Example

Here is a very simple example of a trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `trigf` reports the number of rows in the table `ttest` and skips the actual operation if the command attempts to insert a null value into the column `x`. (So the trigger acts as a not-null constraint but doesn't abort the transaction.)

First, the table definition:

```
CREATE TABLE ttest (
    x integer
);
```

This is the source code of the trigger function:

```
#include "postgres.h"
#include "fmgr.h"
#include "executor/spi.h"      /* this is what you need to work
    with SPI */
#include "commands/trigger.h" /* ... triggers ... */
#include "utils/rel.h"        /* ... and relations */

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(trigf);

Datum
trigf(PG_FUNCTION_ARGS)
{
    TriggerData *trigdata = (TriggerData *) fcinfo->context;
    TupleDesc   tupdesc;
    HeapTuple   rettuple;
    char        *when;
    bool        checknull = false;
```

---

```

bool        isnull;
int         ret, i;

/* make sure it's called as a trigger at all */
if (!CALLED_AS_TRIGGER(fcinfo))
    elog(ERROR, "trigf: not called by trigger manager");

/* tuple to return to executor */
if (TRIGGER_FIRED_BY_UPDATE(trigdata->tg_event))
    rettuple = trigdata->tg_newtuple;
else
    rettuple = trigdata->tg_trigtuple;

/* check for null values */
if (!TRIGGER_FIRED_BY_DELETE(trigdata->tg_event)
    && TRIGGER_FIRED_BEFORE(trigdata->tg_event))
    checknull = true;

if (TRIGGER_FIRED_BEFORE(trigdata->tg_event))
    when = "before";
else
    when = "after ";

tupdesc = trigdata->tg_relation->rd_att;

/* connect to SPI manager */
if ((ret = SPI_connect()) < 0)
    elog(ERROR, "trigf (fired %s): SPI_connect returned %d",
when, ret);

/* get number of rows in table */
ret = SPI_exec("SELECT count(*) FROM ttest", 0);

if (ret < 0)
    elog(ERROR, "trigf (fired %s): SPI_exec returned %d", when,
ret);

/* count(*) returns int8, so be careful to convert */
i = DatumGetInt64(SPI_getbinval(SPI_tuptable->vals[0],
                                SPI_tuptable->tupdesc,
                                1,
                                &isnull));

    elog (INFO, "trigf (fired %s): there are %d rows in ttest",
when, i);

SPI_finish();

if (checknull)
{
    SPI_getbinval(rettuple, tupdesc, 1, &isnull);
    if (isnull)
        rettuple = NULL;
}

return PointerGetDatum(rettuple);
}

```

After you have compiled the source code (see Section 36.10.5), declare the function and the triggers:

```
CREATE FUNCTION trigf() RETURNS trigger
  AS 'filename'
  LANGUAGE C;

CREATE TRIGGER tbefore BEFORE INSERT OR UPDATE OR DELETE ON ttest
  FOR EACH ROW EXECUTE FUNCTION trigf();

CREATE TRIGGER tafter AFTER INSERT OR UPDATE OR DELETE ON ttest
  FOR EACH ROW EXECUTE FUNCTION trigf();
```

Now you can test the operation of the trigger:

```
=> INSERT INTO ttest VALUES (NULL);
INFO:  trigf (fired before): there are 0 rows in ttest
INSERT 0 0

-- Insertion skipped and AFTER trigger is not fired

=> SELECT * FROM ttest;
 x
---
(0 rows)

=> INSERT INTO ttest VALUES (1);
INFO:  trigf (fired before): there are 0 rows in ttest
INFO:  trigf (fired after ): there are 1 rows in ttest
          ^^^^^^^
          remember what we said about
visibility.
INSERT 167793 1
vac=> SELECT * FROM ttest;
 x
---
 1
(1 row)

=> INSERT INTO ttest SELECT x * 2 FROM ttest;
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ): there are 2 rows in ttest
          ^^^^^
          remember what we said about
visibility.
INSERT 167794 1
=> SELECT * FROM ttest;
 x
---
 1
 2
(2 rows)

=> UPDATE ttest SET x = NULL WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
UPDATE 0
=> UPDATE ttest SET x = 4 WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
```



```
INFO:  trigf (fired after ): there are 2 rows in ttest
UPDATE 1
vac=> SELECT * FROM ttest;
  x
---
  1
  4
(2 rows)
```

```
=> DELETE FROM ttest;
INFO:  trigf (fired before): there are 2 rows in ttest
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
                                ^^^^^^
```

remember what we said about

visibility.

```
DELETE 2
=> SELECT * FROM ttest;
  x
---
(0 rows)
```

There are more complex examples in `src/test/regress/regress.c` and in `spi`.

---

# Chapter 38. Event Triggers

To supplement the trigger mechanism discussed in Chapter 37, LightDB also provides event triggers. Unlike regular triggers, which are attached to a single table and capture only DML events, event triggers are global to a particular database and are capable of capturing DDL events.

Like regular triggers, event triggers can be written in any procedural language that includes event trigger support, or in C, but not in plain SQL.

## 38.1. Overview of Event Trigger Behavior

An event trigger fires whenever the event with which it is associated occurs in the database in which it is defined. Currently, the only supported events are `ddl_command_start`, `ddl_command_end`, `table_rewrite` and `sql_drop`. Support for additional events may be added in future releases.

The `ddl_command_start` event occurs just before the execution of a `CREATE`, `ALTER`, `DROP`, `SECURITY LABEL`, `COMMENT`, `GRANT` or `REVOKE` command. No check whether the affected object exists or doesn't exist is performed before the event trigger fires. As an exception, however, this event does not occur for DDL commands targeting shared objects — databases, roles, and tablespaces — or for commands targeting event triggers themselves. The event trigger mechanism does not support these object types. `ddl_command_start` also occurs just before the execution of a `SELECT INTO` command, since this is equivalent to `CREATE TABLE AS`.

The `ddl_command_end` event occurs just after the execution of this same set of commands. To obtain more details on the DDL operations that took place, use the set-returning function `pg_event_trigger_ddl_commands()` from the `ddl_command_end` event trigger code (see Section 9.29). Note that the trigger fires after the actions have taken place (but before the transaction commits), and thus the system catalogs can be read as already changed.

The `sql_drop` event occurs just before the `ddl_command_end` event trigger for any operation that drops database objects. To list the objects that have been dropped, use the set-returning function `pg_event_trigger_dropped_objects()` from the `sql_drop` event trigger code (see Section 9.29). Note that the trigger is executed after the objects have been deleted from the system catalogs, so it's not possible to look them up anymore.

The `table_rewrite` event occurs just before a table is rewritten by some actions of the commands `ALTER TABLE` and `ALTER TYPE`. While other control statements are available to rewrite a table, like `CLUSTER` and `VACUUM`, the `table_rewrite` event is not triggered by them.

Event triggers (like other functions) cannot be executed in an aborted transaction. Thus, if a DDL command fails with an error, any associated `ddl_command_end` triggers will not be executed. Conversely, if a `ddl_command_start` trigger fails with an error, no further event triggers will fire, and no attempt will be made to execute the command itself. Similarly, if a `ddl_command_end` trigger fails with an error, the effects of the DDL statement will be rolled back, just as they would be in any other case where the containing transaction aborts.

For a complete list of commands supported by the event trigger mechanism, see Section 38.2.

Event triggers are created using the command `CREATE EVENT TRIGGER`. In order to create an event trigger, you must first create a function with the special return type `event_trigger`. This function need not (and may not) return a value; the return type serves merely as a signal that the function is to be invoked as an event trigger.

If more than one event trigger is defined for a particular event, they will fire in alphabetical order by trigger name.

A trigger definition can also specify a `WHEN` condition so that, for example, a `ddl_command_start` trigger can be fired only for particular commands which the user wishes to intercept. A common use of such triggers is to restrict the range of DDL operations which users may perform.

## 38.2. Event Trigger Firing Matrix

Table 38.1 lists all commands for which event triggers are supported.

**Table 38.1. Event Trigger Support by Command Tag**

Command Tag	ddl_ command_ start	ddl_ command_ end	sql_drop	table_ rewrite	Notes
ALTER AGGREGATE	X	X	-	-	
ALTER COLLATION	X	X	-	-	
ALTER CONVERSION	X	X	-	-	
ALTER DOMAIN	X	X	-	-	
ALTER DEFAULT PRIVILEGES	X	X	-	-	
ALTER EXTENSION	X	X	-	-	
ALTER FOREIGN DATA WRAPPER	X	X	-	-	
ALTER FOREIGN TABLE	X	X	X	-	
ALTER FUNCTION	X	X	-	-	
ALTER LANGUAGE	X	X	-	-	
ALTER LARGE OBJECT	X	X	-	-	
ALTER MATERIALIZED VIEW	X	X	-	-	
ALTER OPERATOR	X	X	-	-	
ALTER OPERATOR CLASS	X	X	-	-	
ALTER OPERATOR FAMILY	X	X	-	-	
ALTER POLICY	X	X	-	-	
ALTER PROCEDURE	X	X	-	-	
ALTER PUBLICATION	X	X	-	-	
ALTER ROUTINE	X	X	-	-	
ALTER SCHEMA	X	X	-	-	
ALTER SEQUENCE	X	X	-	-	
ALTER SERVER	X	X	-	-	
ALTER STATISTICS	X	X	-	-	
ALTER SUBSCRIPTION	X	X	-	-	
ALTER TABLE	X	X	X	X	
ALTER TEXT SEARCH CONFIGURATION	X	X	-	-	
ALTER TEXT SEARCH DICTIONARY	X	X	-	-	
ALTER TEXT SEARCH PARSER	X	X	-	-	

Event Triggers

Command Tag	ddl_ command_ start	ddl_ command_ end	sql_drop	table_ rewrite	Notes
ALTER TEXT SEARCH TEMPLATE	X	X	-	-	
ALTER TRIGGER	X	X	-	-	
ALTER TYPE	X	X	-	X	
ALTER USER MAPPING	X	X	-	-	
ALTER VIEW	X	X	-	-	
COMMENT	X	X	-	-	Only for local objects
CREATE ACCESS METHOD	X	X	-	-	
CREATE AGGREGATE	X	X	-	-	
CREATE CAST	X	X	-	-	
CREATE COLLATION	X	X	-	-	
CREATE CONVERSION	X	X	-	-	
CREATE DOMAIN	X	X	-	-	
CREATE EXTENSION	X	X	-	-	
CREATE FOREIGN DATA WRAPPER	X	X	-	-	
CREATE FOREIGN TABLE	X	X	-	-	
CREATE FUNCTION	X	X	-	-	
CREATE INDEX	X	X	-	-	
CREATE LANGUAGE	X	X	-	-	
CREATE MATERIALIZED VIEW	X	X	-	-	
CREATE OPERATOR	X	X	-	-	
CREATE OPERATOR CLASS	X	X	-	-	
CREATE OPERATOR FAMILY	X	X	-	-	
CREATE POLICY	X	X	-	-	
CREATE PROCEDURE	X	X	-	-	
CREATE PUBLICATION	X	X	-	-	
CREATE RULE	X	X	-	-	
CREATE SCHEMA	X	X	-	-	
CREATE SEQUENCE	X	X	-	-	
CREATE SERVER	X	X	-	-	
CREATE STATISTICS	X	X	-	-	
CREATE SUBSCRIPTION	X	X	-	-	
CREATE TABLE	X	X	-	-	
CREATE TABLE AS	X	X	-	-	

Event Triggers

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
CREATE TEXT SEARCH CONFIGURATION	X	X	-	-	
CREATE TEXT SEARCH DICTIONARY	X	X	-	-	
CREATE TEXT SEARCH PARSER	X	X	-	-	
CREATE TEXT SEARCH TEMPLATE	X	X	-	-	
CREATE TRIGGER	X	X	-	-	
CREATE TYPE	X	X	-	-	
CREATE USER MAPPING	X	X	-	-	
CREATE VIEW	X	X	-	-	
DROP ACCESS METHOD	X	X	X	-	
DROP AGGREGATE	X	X	X	-	
DROP CAST	X	X	X	-	
DROP COLLATION	X	X	X	-	
DROP CONVERSION	X	X	X	-	
DROP DOMAIN	X	X	X	-	
DROP EXTENSION	X	X	X	-	
DROP FOREIGN DATA WRAPPER	X	X	X	-	
DROP FOREIGN TABLE	X	X	X	-	
DROP FUNCTION	X	X	X	-	
DROP INDEX	X	X	X	-	
DROP LANGUAGE	X	X	X	-	
DROP MATERIALIZED VIEW	X	X	X	-	
DROP OPERATOR	X	X	X	-	
DROP OPERATOR CLASS	X	X	X	-	
DROP OPERATOR FAMILY	X	X	X	-	
DROP OWNED	X	X	X	-	
DROP POLICY	X	X	X	-	
DROP PROCEDURE	X	X	X	-	
DROP PUBLICATION	X	X	X	-	
DROP ROUTINE	X	X	X	-	
DROP RULE	X	X	X	-	
DROP SCHEMA	X	X	X	-	
DROP SEQUENCE	X	X	X	-	
DROP SERVER	X	X	X	-	

Command Tag	ddl_ command_ start	ddl_ command_ end	sql_drop	table_ rewrite	Notes
DROP STATISTICS	X	X	X	-	
DROP SUBSCRIPTION	X	X	X	-	
DROP TABLE	X	X	X	-	
DROP TEXT SEARCH CONFIGURATION	X	X	X	-	
DROP TEXT SEARCH DICTIONARY	X	X	X	-	
DROP TEXT SEARCH PARSER	X	X	X	-	
DROP TEXT SEARCH TEMPLATE	X	X	X	-	
DROP TRIGGER	X	X	X	-	
DROP TYPE	X	X	X	-	
DROP USER MAPPING	X	X	X	-	
DROP VIEW	X	X	X	-	
GRANT	X	X	-	-	Only for local objects
IMPORT FOREIGN SCHEMA	X	X	-	-	
REFRESH MATERIALIZED VIEW	X	X	-	-	
REVOKE	X	X	-	-	Only for local objects
SECURITY LABEL	X	X	-	-	Only for local objects
SELECT INTO	X	X	-	-	

## 38.3. Writing Event Trigger Functions in C

This section describes the low-level details of the interface to an event trigger function. This information is only needed when writing event trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your event triggers in C. The documentation of each procedural language explains how to write an event trigger in that language.

Event trigger functions must use the “version 1” function manager interface.

When a function is called by the event trigger manager, it is not passed any normal arguments, but it is passed a “context” pointer pointing to a `EventTriggerData` structure. C functions can check whether they were called from the event trigger manager or not by executing the macro:

```
CALLED_AS_EVENT_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context,  
EventTriggerData))
```

If this returns true, then it is safe to cast `fcinfo->context` to type `EventTriggerData *` and make use of the pointed-to `EventTriggerData` structure. The function must *not* alter the `EventTriggerData` structure or any of the data it points to.

`struct EventTriggerData` is defined in `commands/event_trigger.h`:

```
typedef struct EventTriggerData
{
    NodeTag      type;
    const char *event;      /* event name */
    Node        *parsetree; /* parse tree */
    CommandTag  tag;       /* command tag */
} EventTriggerData;
```

where the members are defined as follows:

`type`

Always `T_EventTriggerData`.

`event`

Describes the event for which the function is called, one of `"ddl_command_start"`, `"ddl_command_end"`, `"sql_drop"`, `"table_rewrite"`. See Section 38.1 for the meaning of these events.

`parsetree`

A pointer to the parse tree of the command. Check the LightDB source code for details. The parse tree structure is subject to change without notice.

`tag`

The command tag associated with the event for which the event trigger is run, for example `"CREATE FUNCTION"`.

An event trigger function must return a NULL pointer (*not* an SQL null value, that is, do not set `isNull` true).

## 38.4. A Complete Event Trigger Example

Here is a very simple example of an event trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `nodd1` raises an exception each time it is called. The event trigger definition associated the function with the `ddl_command_start` event. The effect is that all DDL commands (with the exceptions mentioned in Section 38.1) are prevented from running.

This is the source code of the trigger function:

```
#include "postgres.h"
#include "commands/event_trigger.h"

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(nodd1);
```

```

Datum
nodd1(PG_FUNCTION_ARGS)
{
    EventTriggerData *trigdata;

    if (!CALLED_AS_EVENT_TRIGGER(fcinfo)) /* internal error */
        elog(ERROR, "not fired by event trigger manager");

    trigdata = (EventTriggerData *) fcinfo->context;

    ereport(ERROR,
            (errcode(ERRCODE_INSUFFICIENT_PRIVILEGE),
             errmsg("command \"%s\" denied", trigdata->tag)));

    PG_RETURN_NULL();
}

```

After you have compiled the source code (see Section 36.10.5), declare the function and the triggers:

```

CREATE FUNCTION nodd1() RETURNS event_trigger
AS 'nodd1' LANGUAGE C;

CREATE EVENT TRIGGER nodd1 ON ddl_command_start
EXECUTE FUNCTION nodd1();

```

Now you can test the operation of the trigger:

```

=# \dy
                                List of event triggers
  Name |          Event          | Owner | Enabled | Function | Tags
-----+-----+-----+-----+-----+-----
 nodd1 | ddl_command_start      | dim   | enabled | nodd1    |
(1 row)

=# CREATE TABLE foo(id serial);
ERROR:  command "CREATE TABLE" denied

```

In this situation, in order to be able to run some DDL commands when you need to do so, you have to either drop the event trigger or disable it. It can be convenient to disable the trigger for only the duration of a transaction:

```

BEGIN;
ALTER EVENT TRIGGER nodd1 DISABLE;
CREATE TABLE foo (id serial);
ALTER EVENT TRIGGER nodd1 ENABLE;
COMMIT;

```

(Recall that DDL commands on event triggers themselves are not affected by event triggers.)

## 38.5. A Table Rewrite Event Trigger Example

Thanks to the `table_rewrite` event, it is possible to implement a table rewriting policy only allowing the rewrite in maintenance windows.

Here's an example implementing such a policy.



```
CREATE OR REPLACE FUNCTION no_rewrite()
  RETURNS event_trigger
  LANGUAGE plpgsql AS
$$
---
--- Implement local Table Rewriting policy:
---   public.foo is not allowed rewriting, ever
---   other tables are only allowed rewriting between 1am and 6am
---   unless they have more than 100 blocks
---
DECLARE
  table_oid oid := pg_event_trigger_table_rewrite_oid();
  current_hour integer := extract('hour' from current_time);
  pages integer;
  max_pages integer := 100;
BEGIN
  IF pg_event_trigger_table_rewrite_oid() = 'public.foo'::regclass
  THEN
    RAISE EXCEPTION 'you're not allowed to rewrite the table
  %',
    table_oid::regclass;
  END IF;

  SELECT INTO pages relpages FROM pg_class WHERE oid = table_oid;
  IF pages > max_pages
  THEN
    RAISE EXCEPTION 'rewrites only allowed for table with less
  than % pages',
    max_pages;
  END IF;

  IF current_hour NOT BETWEEN 1 AND 6
  THEN
    RAISE EXCEPTION 'rewrites only allowed between 1am and
  6am';
  END IF;
END;
$$;

CREATE EVENT TRIGGER no_rewrite_allowed
  ON table_rewrite
  EXECUTE FUNCTION no_rewrite();
```

---

# Chapter 39. The Rule System

This chapter discusses the rule system in LightDB. Production rule systems are conceptually simple, but there are many subtle points involved in actually using them.

Some other database systems define active database rules, which are usually stored procedures and triggers. In LightDB, these can be implemented using functions and triggers as well.

The rule system (more precisely speaking, the query rewrite rule system) is totally different from stored procedures and triggers. It modifies queries to take rules into consideration, and then passes the modified query to the query planner for planning and execution. It is very powerful, and can be used for many things such as query language procedures, views, and versions. The theoretical foundations and the power of this rule system are also discussed in [ston90b] and [ong90].

## 39.1. The Query Tree

To understand how the rule system works it is necessary to know when it is invoked and what its input and results are.

The rule system is located between the parser and the planner. It takes the output of the parser, one query tree, and the user-defined rewrite rules, which are also query trees with some extra information, and creates zero or more query trees as result. So its input and output are always things the parser itself could have produced and thus, anything it sees is basically representable as an SQL statement.

Now what is a query tree? It is an internal representation of an SQL statement where the single parts that it is built from are stored separately. These query trees can be shown in the server log if you set the configuration parameters `debug_print_parse`, `debug_print_rewritten`, or `debug_print_plan`. The rule actions are also stored as query trees, in the system catalog `pg_rewrite`. They are not formatted like the log output, but they contain exactly the same information.

Reading a raw query tree requires some experience. But since SQL representations of query trees are sufficient to understand the rule system, this chapter will not teach how to read them.

When reading the SQL representations of the query trees in this chapter it is necessary to be able to identify the parts the statement is broken into when it is in the query tree structure. The parts of a query tree are

the command type

This is a simple value telling which command (`SELECT`, `INSERT`, `UPDATE`, `DELETE`) produced the query tree.

the range table

The range table is a list of relations that are used in the query. In a `SELECT` statement these are the relations given after the `FROM` key word.

Every range table entry identifies a table or view and tells by which name it is called in the other parts of the query. In the query tree, the range table entries are referenced by number rather than by name, so here it doesn't matter if there are duplicate names as it would in an SQL statement. This can happen after the range tables of rules have been merged in. The examples in this chapter will not have this situation.

the result relation

This is an index into the range table that identifies the relation where the results of the query go.

`SELECT` queries don't have a result relation. (The special case of `SELECT INTO` is mostly identical to `CREATE TABLE` followed by `INSERT ... SELECT`, and is not discussed separately here.)

For `INSERT`, `UPDATE`, and `DELETE` commands, the result relation is the table (or view!) where the changes are to take effect.

the target list

The target list is a list of expressions that define the result of the query. In the case of a `SELECT`, these expressions are the ones that build the final output of the query. They correspond to the expressions between the key words `SELECT` and `FROM`. (\* is just an abbreviation for all the column names of a relation. It is expanded by the parser into the individual columns, so the rule system never sees it.)

`DELETE` commands don't need a normal target list because they don't produce any result. Instead, the planner adds a special `CTID` entry to the empty target list, to allow the executor to find the row to be deleted. (`CTID` is added when the result relation is an ordinary table. If it is a view, a whole-row variable is added instead, by the rule system, as described in Section 39.2.4.)

For `INSERT` commands, the target list describes the new rows that should go into the result relation. It consists of the expressions in the `VALUES` clause or the ones from the `SELECT` clause in `INSERT . . . SELECT`. The first step of the rewrite process adds target list entries for any columns that were not assigned to by the original command but have defaults. Any remaining columns (with neither a given value nor a default) will be filled in by the planner with a constant null expression.

For `UPDATE` commands, the target list describes the new rows that should replace the old ones. In the rule system, it contains just the expressions from the `SET column = expression` part of the command. The planner will handle missing columns by inserting expressions that copy the values from the old row into the new one. Just as for `DELETE`, a `CTID` or whole-row variable is added so that the executor can identify the old row to be updated.

Every entry in the target list contains an expression that can be a constant value, a variable pointing to a column of one of the relations in the range table, a parameter, or an expression tree made of function calls, constants, variables, operators, etc.

the qualification

The query's qualification is an expression much like one of those contained in the target list entries. The result value of this expression is a Boolean that tells whether the operation (`INSERT`, `UPDATE`, `DELETE`, or `SELECT`) for the final result row should be executed or not. It corresponds to the `WHERE` clause of an SQL statement.

the join tree

The query's join tree shows the structure of the `FROM` clause. For a simple query like `SELECT . . . FROM a, b, c`, the join tree is just a list of the `FROM` items, because we are allowed to join them in any order. But when `JOIN` expressions, particularly outer joins, are used, we have to join in the order shown by the joins. In that case, the join tree shows the structure of the `JOIN` expressions. The restrictions associated with particular `JOIN` clauses (from `ON` or `USING` expressions) are stored as qualification expressions attached to those join-tree nodes. It turns out to be convenient to store the top-level `WHERE` expression as a qualification attached to the top-level join-tree item, too. So really the join tree represents both the `FROM` and `WHERE` clauses of a `SELECT`.

the others

The other parts of the query tree like the `ORDER BY` clause aren't of interest here. The rule system substitutes some entries there while applying rules, but that doesn't have much to do with the fundamentals of the rule system.

## 39.2. Views and the Rule System

Views in LightDB are implemented using the rule system. In fact, there is essentially no difference between:

```
CREATE VIEW myview AS SELECT * FROM mytab;
```

compared against the two commands:

```
CREATE TABLE myview (same column list as mytab);
CREATE RULE "_RETURN" AS ON SELECT TO myview DO INSTEAD
    SELECT * FROM mytab;
```

because this is exactly what the CREATE VIEW command does internally. This has some side effects. One of them is that the information about a view in the LightDB system catalogs is exactly the same as it is for a table. So for the parser, there is absolutely no difference between a table and a view. They are the same thing: relations.

## 39.2.1. How SELECT Rules Work

Rules ON SELECT are applied to all queries as the last step, even if the command given is an INSERT, UPDATE or DELETE. And they have different semantics from rules on the other command types in that they modify the query tree in place instead of creating a new one. So SELECT rules are described first.

Currently, there can be only one action in an ON SELECT rule, and it must be an unconditional SELECT action that is INSTEAD. This restriction was required to make rules safe enough to open them for ordinary users, and it restricts ON SELECT rules to act like views.

The examples for this chapter are two join views that do some calculations and some more views using them in turn. One of the two first views is customized later by adding rules for INSERT, UPDATE, and DELETE operations so that the final result will be a view that behaves like a real table with some magic functionality. This is not such a simple example to start from and this makes things harder to get into. But it's better to have one example that covers all the points discussed step by step rather than having many different ones that might mix up in mind.

The real tables we need in the first two rule system descriptions are these:

```
CREATE TABLE shoe_data (
    shoename    text,           -- primary key
    sh_avail    integer,       -- available number of pairs
    slcolor     text,           -- preferred shoelace color
    slminlen    real,          -- minimum shoelace length
    slmaxlen    real,          -- maximum shoelace length
    slunit      text           -- length unit
);

CREATE TABLE shoelace_data (
    sl_name     text,           -- primary key
    sl_avail    integer,       -- available number of pairs
    sl_color    text,          -- shoelace color
    sl_len      real,          -- shoelace length
    sl_unit     text           -- length unit
);

CREATE TABLE unit (
    un_name     text,           -- primary key
    un_fact     real           -- factor to transform to cm
);
```

);

As you can see, they represent shoe-store data.

The views are created as:

```
CREATE VIEW shoe AS
  SELECT sh.shoename,
         sh.sh_avail,
         sh.slcolor,
         sh.slminlen,
         sh.slminlen * un.un_fact AS slminlen_cm,
         sh.slmaxlen,
         sh.slmaxlen * un.un_fact AS slmaxlen_cm,
         sh.slunit
  FROM shoe_data sh, unit un
  WHERE sh.slunit = un.un_name;

CREATE VIEW shoelace AS
  SELECT s.sl_name,
         s.sl_avail,
         s.sl_color,
         s.sl_len,
         s.sl_unit,
         s.sl_len * u.un_fact AS sl_len_cm
  FROM shoelace_data s, unit u
  WHERE s.sl_unit = u.un_name;

CREATE VIEW shoe_ready AS
  SELECT rsh.shoename,
         rsh.sh_avail,
         rsl.sl_name,
         rsl.sl_avail,
         least(rsh.sh_avail, rsl.sl_avail) AS total_avail
  FROM shoe rsh, shoelace rsl
  WHERE rsl.sl_color = rsh.slcolor
         AND rsl.sl_len_cm >= rsh.slminlen_cm
         AND rsl.sl_len_cm <= rsh.slmaxlen_cm;
```

The CREATE VIEW command for the shoelace view (which is the simplest one we have) will create a relation shoelace and an entry in pg\_rewrite that tells that there is a rewrite rule that must be applied whenever the relation shoelace is referenced in a query's range table. The rule has no rule qualification (discussed later, with the non-SELECT rules, since SELECT rules currently cannot have them) and it is INSTEAD. Note that rule qualifications are not the same as query qualifications. The action of our rule has a query qualification. The action of the rule is one query tree that is a copy of the SELECT statement in the view creation command.

### Note

The two extra range table entries for NEW and OLD that you can see in the pg\_rewrite entry aren't of interest for SELECT rules.

Now we populate unit, shoe\_data and shoelace\_data and run a simple query on a view:

```
INSERT INTO unit VALUES ('cm', 1.0);
INSERT INTO unit VALUES ('m', 100.0);
```

```

INSERT INTO unit VALUES ('inch', 2.54);

INSERT INTO shoe_data VALUES ('sh1', 2, 'black', 70.0, 90.0, 'cm');
INSERT INTO shoe_data VALUES ('sh2', 0, 'black', 30.0, 40.0,
    'inch');
INSERT INTO shoe_data VALUES ('sh3', 4, 'brown', 50.0, 65.0, 'cm');
INSERT INTO shoe_data VALUES ('sh4', 3, 'brown', 40.0, 50.0,
    'inch');

INSERT INTO shoelace_data VALUES ('sl1', 5, 'black', 80.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl2', 6, 'black', 100.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl3', 0, 'black', 35.0 ,
    'inch');
INSERT INTO shoelace_data VALUES ('sl4', 8, 'black', 40.0 ,
    'inch');
INSERT INTO shoelace_data VALUES ('sl5', 4, 'brown', 1.0 , 'm');
INSERT INTO shoelace_data VALUES ('sl6', 0, 'brown', 0.9 , 'm');
INSERT INTO shoelace_data VALUES ('sl7', 7, 'brown', 60 , 'cm');
INSERT INTO shoelace_data VALUES ('sl8', 1, 'brown', 40 , 'inch');

SELECT * FROM shoelace;

```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	7	brown	60	cm	60
sl3	0	black	35	inch	88.9
sl4	8	black	40	inch	101.6
sl8	1	brown	40	inch	101.6
sl5	4	brown	1	m	100
sl6	0	brown	0.9	m	90

(8 rows)

This is the simplest SELECT you can do on our views, so we take this opportunity to explain the basics of view rules. The SELECT \* FROM shoelace was interpreted by the parser and produced the query tree:

```

SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
FROM shoelace shoelace;

```

and this is given to the rule system. The rule system walks through the range table and checks if there are rules for any relation. When processing the range table entry for shoelace (the only one up to now) it finds the `_RETURN` rule with the query tree:

```

SELECT s.sl_name, s.sl_avail,
       s.sl_color, s.sl_len, s.sl_unit,
       s.sl_len * u.un_fact AS sl_len_cm
FROM shoelace old, shoelace new,
     shoelace_data s, unit u
WHERE s.sl_unit = u.un_name;

```

To expand the view, the rewriter simply creates a subquery range-table entry containing the rule's action query tree, and substitutes this range table entry for the original one that referenced the view. The resulting rewritten query tree is almost the same as if you had typed:

```

SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
FROM (SELECT s.sl_name,
            s.sl_avail,
            s.sl_color,
            s.sl_len,
            s.sl_unit,
            s.sl_len * u.un_fact AS sl_len_cm
      FROM shoelace_data s, unit u
      WHERE s.sl_unit = u.un_name) shoelace;

```

There is one difference however: the subquery's range table has two extra entries `shoelace old` and `shoelace new`. These entries don't participate directly in the query, since they aren't referenced by the subquery's join tree or target list. The rewriter uses them to store the access privilege check information that was originally present in the range-table entry that referenced the view. In this way, the executor will still check that the user has proper privileges to access the view, even though there's no direct use of the view in the rewritten query.

That was the first rule applied. The rule system will continue checking the remaining range-table entries in the top query (in this example there are no more), and it will recursively check the range-table entries in the added subquery to see if any of them reference views. (But it won't expand `old` or `new` — otherwise we'd have infinite recursion!) In this example, there are no rewrite rules for `shoelace_data` or `unit`, so rewriting is complete and the above is the final result given to the planner.

Now we want to write a query that finds out for which shoes currently in the store we have the matching shoelaces (color and length) and where the total number of exactly matching pairs is greater than or equal to two.

```

SELECT * FROM shoe_ready WHERE total_avail >= 2;

```

shoename	sh_avail	sl_name	sl_avail	total_avail
sh1	2	sl1	5	2
sh3	4	sl7	7	4

(2 rows)

The output of the parser this time is the query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM shoe_ready shoe_ready
WHERE shoe_ready.total_avail >= 2;

```

The first rule applied will be the one for the `shoe_ready` view and it results in the query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM (SELECT rsh.shoename,
            rsh.sh_avail,
            rsl.sl_name,
            rsl.sl_avail,

```

```

        least(rsh.sh_avail, rsl.sl_avail) AS total_avail
    FROM shoe rsh, shoelace rsl
    WHERE rsl.sl_color = rsh.slcolor
        AND rsl.sl_len_cm >= rsh.slminlen_cm
        AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
WHERE shoe_ready.total_avail >= 2;

```

Similarly, the rules for shoe and shoelace are substituted into the range table of the subquery, leading to a three-level final query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM (SELECT rsh.shoename,
            rsh.sh_avail,
            rsl.sl_name,
            rsl.sl_avail,
            least(rsh.sh_avail, rsl.sl_avail) AS total_avail
     FROM (SELECT sh.shoename,
                 sh.sh_avail,
                 sh.slcolor,
                 sh.slminlen,
                 sh.slminlen * un.un_fact AS slminlen_cm,
                 sh.slmaxlen,
                 sh.slmaxlen * un.un_fact AS slmaxlen_cm,
                 sh.slunit
            FROM shoe_data sh, unit un
            WHERE sh.slunit = un.un_name) rsh,
         (SELECT s.sl_name,
                 s.sl_avail,
                 s.sl_color,
                 s.sl_len,
                 s.sl_unit,
                 s.sl_len * u.un_fact AS sl_len_cm
            FROM shoelace_data s, unit u
            WHERE s.sl_unit = u.un_name) rsl
     WHERE rsl.sl_color = rsh.slcolor
        AND rsl.sl_len_cm >= rsh.slminlen_cm
        AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
WHERE shoe_ready.total_avail > 2;

```

This might look inefficient, but the planner will collapse this into a single-level query tree by “pulling up” the subqueries, and then it will plan the joins just as if we'd written them out manually. So collapsing the query tree is an optimization that the rewrite system doesn't have to concern itself with.

## 39.2.2. View Rules in Non-SELECT Statements

Two details of the query tree aren't touched in the description of view rules above. These are the command type and the result relation. In fact, the command type is not needed by view rules, but the result relation may affect the way in which the query rewriter works, because special care needs to be taken if the result relation is a view.

There are only a few differences between a query tree for a SELECT and one for any other command. Obviously, they have a different command type and for a command other than a SELECT, the result relation points to the range-table entry where the result should go. Everything else is absolutely the same. So having two tables *t1* and *t2* with columns *a* and *b*, the query trees for the two statements:



```
SELECT t2.b FROM t1, t2 WHERE t1.a = t2.a;
```

```
UPDATE t1 SET b = t2.b FROM t2 WHERE t1.a = t2.a;
```

are nearly identical. In particular:

- The range tables contain entries for the tables `t1` and `t2`.
- The target lists contain one variable that points to column `b` of the range table entry for table `t2`.
- The qualification expressions compare the columns `a` of both range-table entries for equality.
- The join trees show a simple join between `t1` and `t2`.

The consequence is, that both query trees result in similar execution plans: They are both joins over the two tables. For the `UPDATE` the missing columns from `t1` are added to the target list by the planner and the final query tree will read as:

```
UPDATE t1 SET a = t1.a, b = t2.b FROM t2 WHERE t1.a = t2.a;
```

and thus the executor run over the join will produce exactly the same result set as:

```
SELECT t1.a, t2.b FROM t1, t2 WHERE t1.a = t2.a;
```

But there is a little problem in `UPDATE`: the part of the executor plan that does the join does not care what the results from the join are meant for. It just produces a result set of rows. The fact that one is a `SELECT` command and the other is an `UPDATE` is handled higher up in the executor, where it knows that this is an `UPDATE`, and it knows that this result should go into table `t1`. But which of the rows that are there has to be replaced by the new row?

To resolve this problem, another entry is added to the target list in `UPDATE` (and also in `DELETE`) statements: the current tuple ID (CTID). This is a system column containing the file block number and position in the block for the row. Knowing the table, the CTID can be used to retrieve the original row of `t1` to be updated. After adding the CTID to the target list, the query actually looks like:

```
SELECT t1.a, t2.b, t1.ctid FROM t1, t2 WHERE t1.a = t2.a;
```

Now another detail of LightDB enters the stage. Old table rows aren't overwritten, and this is why `ROLLBACK` is fast. In an `UPDATE`, the new result row is inserted into the table (after stripping the CTID) and in the row header of the old row, which the CTID pointed to, the `cmax` and `xmax` entries are set to the current command counter and current transaction ID. Thus the old row is hidden, and after the transaction commits the vacuum cleaner can eventually remove the dead row.

Knowing all that, we can simply apply view rules in absolutely the same way to any command. There is no difference.

### 39.2.3. The Power of Views in LightDB

The above demonstrates how the rule system incorporates view definitions into the original query tree. In the second example, a simple `SELECT` from one view created a final query tree that is a join of 4 tables (`unit` was used twice with different names).

The benefit of implementing views with the rule system is that the planner has all the information about which tables have to be scanned plus the relationships between these tables plus the restrictive qualifications from the views plus the qualifications from the original query in one single query tree. And this is still the situation when the original query is already a join over views. The planner has to decide which is the best path to execute the query, and the more information the planner has, the

better this decision can be. And the rule system as implemented in LightDB ensures that this is all information available about the query up to that point.

### 39.2.4. Updating a View

What happens if a view is named as the target relation for an INSERT, UPDATE, or DELETE? Doing the substitutions described above would give a query tree in which the result relation points at a subquery range-table entry, which will not work. There are several ways in which LightDB can support the appearance of updating a view, however.

If the subquery selects from a single base relation and is simple enough, the rewriter can automatically replace the subquery with the underlying base relation so that the INSERT, UPDATE, or DELETE is applied to the base relation in the appropriate way. Views that are “simple enough” for this are called *automatically updatable*. For detailed information on the kinds of view that can be automatically updated, see CREATE VIEW.

Alternatively, the operation may be handled by a user-provided INSTEAD OF trigger on the view. Rewriting works slightly differently in this case. For INSERT, the rewriter does nothing at all with the view, leaving it as the result relation for the query. For UPDATE and DELETE, it's still necessary to expand the view query to produce the “old” rows that the command will attempt to update or delete. So the view is expanded as normal, but another unexpanded range-table entry is added to the query to represent the view in its capacity as the result relation.

The problem that now arises is how to identify the rows to be updated in the view. Recall that when the result relation is a table, a special CTID entry is added to the target list to identify the physical locations of the rows to be updated. This does not work if the result relation is a view, because a view does not have any CTID, since its rows do not have actual physical locations. Instead, for an UPDATE or DELETE operation, a special wholerow entry is added to the target list, which expands to include all columns from the view. The executor uses this value to supply the “old” row to the INSTEAD OF trigger. It is up to the trigger to work out what to update based on the old and new row values.

Another possibility is for the user to define INSTEAD rules that specify substitute actions for INSERT, UPDATE, and DELETE commands on a view. These rules will rewrite the command, typically into a command that updates one or more tables, rather than views. That is the topic of Section 39.4.

Note that rules are evaluated first, rewriting the original query before it is planned and executed. Therefore, if a view has INSTEAD OF triggers as well as rules on INSERT, UPDATE, or DELETE, then the rules will be evaluated first, and depending on the result, the triggers may not be used at all.

Automatic rewriting of an INSERT, UPDATE, or DELETE query on a simple view is always tried last. Therefore, if a view has rules or triggers, they will override the default behavior of automatically updatable views.

If there are no INSTEAD rules or INSTEAD OF triggers for the view, and the rewriter cannot automatically rewrite the query as an update on the underlying base relation, an error will be thrown because the executor cannot update a view as such.

## 39.3. Materialized Views

Materialized views in LightDB use the rule system like views do, but persist the results in a table-like form. The main differences between:

```
CREATE MATERIALIZED VIEW mymatview AS SELECT * FROM mytab;
```

and:

```
CREATE TABLE mymatview AS SELECT * FROM mytab;
```

are that the materialized view cannot subsequently be directly updated and that the query used to create the materialized view is stored in exactly the same way that a view's query is stored, so that fresh data can be generated for the materialized view with:

```
REFRESH MATERIALIZED VIEW mymatview;
```

The information about a materialized view in the LightDB system catalogs is exactly the same as it is for a table or view. So for the parser, a materialized view is a relation, just like a table or a view. When a materialized view is referenced in a query, the data is returned directly from the materialized view, like from a table; the rule is only used for populating the materialized view.

While access to the data stored in a materialized view is often much faster than accessing the underlying tables directly or through a view, the data is not always current; yet sometimes current data is not needed. Consider a table which records sales:

```
CREATE TABLE invoice (  
    invoice_no    integer          PRIMARY KEY,  
    seller_no     integer,         -- ID of salesperson  
    invoice_date  date,           -- date of sale  
    invoice_amt   numeric(13,2)   -- amount of sale  
);
```

If people want to be able to quickly graph historical sales data, they might want to summarize, and they may not care about the incomplete data for the current date:

```
CREATE MATERIALIZED VIEW sales_summary AS  
SELECT  
    seller_no,  
    invoice_date,  
    sum(invoice_amt)::numeric(13,2) as sales_amt  
FROM invoice  
WHERE invoice_date < CURRENT_DATE  
GROUP BY  
    seller_no,  
    invoice_date;
```

```
CREATE UNIQUE INDEX sales_summary_seller  
ON sales_summary (seller_no, invoice_date);
```

This materialized view might be useful for displaying a graph in the dashboard created for salespeople. A job could be scheduled to update the statistics each night using this SQL statement:

```
REFRESH MATERIALIZED VIEW sales_summary;
```

Another use for a materialized view is to allow faster access to data brought across from a remote system through a foreign data wrapper. A simple example using `file_fdw` is below, with timings, but since this is using cache on the local system the performance difference compared to access to a remote system would usually be greater than shown here. Notice we are also exploiting the ability to put an index on the materialized view, whereas `file_fdw` does not support indexes; this advantage might not apply for other sorts of foreign data access.

Setup:

```
CREATE EXTENSION file_fdw;  
CREATE SERVER local_file FOREIGN DATA WRAPPER file_fdw;
```

```
CREATE FOREIGN TABLE words (word text NOT NULL)
  SERVER local_file
  OPTIONS (filename '/usr/share/dict/words');
CREATE MATERIALIZED VIEW wrd AS SELECT * FROM words;
CREATE UNIQUE INDEX wrd_word ON wrd (word);
CREATE EXTENSION lt_trgm;
CREATE INDEX wrd_trgm ON wrd USING gist (word gist_trgm_ops);
VACUUM ANALYZE wrd;
```

Now let's spell-check a word. Using file\_fdw directly:

```
SELECT count(*) FROM words WHERE word = 'caterpiler';
```

```
count
-----
      0
(1 row)
```

With EXPLAIN ANALYZE, we see:

```
Aggregate (cost=21763.99..21764.00 rows=1 width=0) (actual
time=188.180..188.181 rows=1 loops=1)
  -> Foreign Scan on words (cost=0.00..21761.41 rows=1032
width=0) (actual time=188.177..188.177 rows=0 loops=1)
    Filter: (word = 'caterpiler'::text)
    Rows Removed by Filter: 479829
    Foreign File: /usr/share/dict/words
    Foreign File Size: 4953699
Planning time: 0.118 ms
Execution time: 188.273 ms
```

If the materialized view is used instead, the query is much faster:

```
Aggregate (cost=4.44..4.45 rows=1 width=0) (actual
time=0.042..0.042 rows=1 loops=1)
  -> Index Only Scan using wrd_word on wrd (cost=0.42..4.44
rows=1 width=0) (actual time=0.039..0.039 rows=0 loops=1)
    Index Cond: (word = 'caterpiler'::text)
    Heap Fetches: 0
Planning time: 0.164 ms
Execution time: 0.117 ms
```

Either way, the word is spelled wrong, so let's look for what we might have wanted. Again using file\_fdw and lt\_trgm:

```
SELECT word FROM words ORDER BY word <-> 'caterpiler' LIMIT 10;
```

```
word
-----
cater
caterpillar
Caterpillar
caterpillars
caterpillar's
Caterpillar's
caterer
```

```
caterer's
caters
catered
(10 rows)
```

```
Limit (cost=11583.61..11583.64 rows=10 width=32) (actual
time=1431.591..1431.594 rows=10 loops=1)
  -> Sort (cost=11583.61..11804.76 rows=88459 width=32) (actual
time=1431.589..1431.591 rows=10 loops=1)
    Sort Key: ((word <-> 'caterpiler'::text))
    Sort Method: top-N heapsort  Memory: 25kB
  -> Foreign Scan on words (cost=0.00..9672.05 rows=88459
width=32) (actual time=0.057..1286.455 rows=479829 loops=1)
    Foreign File: /usr/share/dict/words
    Foreign File Size: 4953699
Planning time: 0.128 ms
Execution time: 1431.679 ms
```

Using the materialized view:

```
Limit (cost=0.29..1.06 rows=10 width=10) (actual
time=187.222..188.257 rows=10 loops=1)
  -> Index Scan using wrd_trgm on wrd (cost=0.29..37020.87
rows=479829 width=10) (actual time=187.219..188.252 rows=10
loops=1)
    Order By: (word <-> 'caterpiler'::text)
Planning time: 0.196 ms
Execution time: 198.640 ms
```

If you can tolerate periodic update of the remote data to the local database, the performance benefit can be substantial.

## 39.4. Rules on INSERT, UPDATE, and DELETE

Rules that are defined on INSERT, UPDATE, and DELETE are significantly different from the view rules described in the previous section. First, their CREATE RULE command allows more:

- They are allowed to have no action.
- They can have multiple actions.
- They can be INSTEAD or ALSO (the default).
- The pseudorelations NEW and OLD become useful.
- They can have rule qualifications.

Second, they don't modify the query tree in place. Instead they create zero or more new query trees and can throw away the original one.

### Caution

In many cases, tasks that could be performed by rules on INSERT/UPDATE/DELETE are better done with triggers. Triggers are notationally a bit more complicated, but their semantics are much simpler to understand. Rules tend to have surprising results when the original query contains volatile functions: volatile functions may get executed more times than expected in the process of carrying out the rules.

Also, there are some cases that are not supported by these types of rules at all, notably including `WITH` clauses in the original query and multiple-assignment sub-`SELECT`s in the `SET` list of `UPDATE` queries. This is because copying these constructs into a rule query would result in multiple evaluations of the sub-query, contrary to the express intent of the query's author.

## 39.4.1. How Update Rules Work

Keep the syntax:

```
CREATE [ OR REPLACE ] RULE name AS ON event
    TO table [ WHERE condition ]
    DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command
    ... ) }
```

in mind. In the following, *update rules* means rules that are defined on `INSERT`, `UPDATE`, or `DELETE`.

Update rules get applied by the rule system when the result relation and the command type of a query tree are equal to the object and event given in the `CREATE RULE` command. For update rules, the rule system creates a list of query trees. Initially the query-tree list is empty. There can be zero (`NOTHING` key word), one, or multiple actions. To simplify, we will look at a rule with one action. This rule can have a qualification or not and it can be `INSTEAD` or `ALSO` (the default).

What is a rule qualification? It is a restriction that tells when the actions of the rule should be done and when not. This qualification can only reference the pseudorelations `NEW` and/or `OLD`, which basically represent the relation that was given as object (but with a special meaning).

So we have three cases that produce the following query trees for a one-action rule.

No qualification, with either `ALSO` or `INSTEAD`

the query tree from the rule action with the original query tree's qualification added

Qualification given and `ALSO`

the query tree from the rule action with the rule qualification and the original query tree's qualification added

Qualification given and `INSTEAD`

the query tree from the rule action with the rule qualification and the original query tree's qualification; and the original query tree with the negated rule qualification added

Finally, if the rule is `ALSO`, the unchanged original query tree is added to the list. Since only qualified `INSTEAD` rules already add the original query tree, we end up with either one or two output query trees for a rule with one action.

For `ON INSERT` rules, the original query (if not suppressed by `INSTEAD`) is done before any actions added by rules. This allows the actions to see the inserted row(s). But for `ON UPDATE` and `ON DELETE` rules, the original query is done after the actions added by rules. This ensures that the actions can see the to-be-updated or to-be-deleted rows; otherwise, the actions might do nothing because they find no rows matching their qualifications.

The query trees generated from rule actions are thrown into the rewrite system again, and maybe more rules get applied resulting in additional or fewer query trees. So a rule's actions must have either a different command type or a different result relation than the rule itself is on, otherwise this recursive process will end up in an infinite loop. (Recursive expansion of a rule will be detected and reported as an error.)

The query trees found in the actions of the `pg_rewrite` system catalog are only templates. Since they can reference the range-table entries for `NEW` and `OLD`, some substitutions have to be made before they can be used. For any reference to `NEW`, the target list of the original query is searched for a corresponding entry. If found, that entry's expression replaces the reference. Otherwise, `NEW` means the same as `OLD` (for an `UPDATE`) or is replaced by a null value (for an `INSERT`). Any reference to `OLD` is replaced by a reference to the range-table entry that is the result relation.

After the system is done applying update rules, it applies view rules to the produced query tree(s). Views cannot insert new update actions so there is no need to apply update rules to the output of view rewriting.

### 39.4.1.1. A First Rule Step by Step

Say we want to trace changes to the `sl_avail` column in the `shoelace_data` relation. So we set up a log table and a rule that conditionally writes a log entry when an `UPDATE` is performed on `shoelace_data`.

```
CREATE TABLE shoelace_log (
    sl_name      text,          -- shoelace changed
    sl_avail     integer,      -- new available value
    log_who      text,          -- who did it
    log_when     timestamp     -- when
);

CREATE RULE log_shoelace AS ON UPDATE TO shoelace_data
WHERE NEW.sl_avail <> OLD.sl_avail
DO INSERT INTO shoelace_log VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    current_user,
    current_timestamp
);
```

Now someone does:

```
UPDATE shoelace_data SET sl_avail = 6 WHERE sl_name = 'sl7';
```

and we look at the log table:

```
SELECT * FROM shoelace_log;
```

```
sl_name | sl_avail | log_who | log_when
-----+-----+-----+-----
sl7     |        6 | Al      | Tue Oct 20 16:14:45 1998 MET DST
(1 row)
```

That's what we expected. What happened in the background is the following. The parser created the query tree:

```
UPDATE shoelace_data SET sl_avail = 6
FROM shoelace_data shoelace_data
WHERE shoelace_data.sl_name = 'sl7';
```

There is a rule `log_shoelace` that is `ON UPDATE` with the rule qualification expression:

```
NEW.sl_avail <> OLD.sl_avail
```

and the action:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old;
```

(This looks a little strange since you cannot normally write `INSERT ... VALUES ... FROM`. The `FROM` clause here is just to indicate that there are range-table entries in the query tree for `new` and `old`. These are needed so that they can be referenced by variables in the `INSERT` command's query tree.)

The rule is a qualified `ALSO` rule, so the rule system has to return two query trees: the modified rule action and the original query tree. In step 1, the range table of the original query is incorporated into the rule's action query tree. This results in:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data;
```

In step 2, the rule qualification is added to it, so the result set is restricted to rows where `sl_avail` changes:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data
WHERE new.sl_avail <> old.sl_avail;
```

(This looks even stranger, since `INSERT ... VALUES` doesn't have a `WHERE` clause either, but the planner and executor will have no difficulty with it. They need to support this same functionality anyway for `INSERT ... SELECT`.)

In step 3, the original query tree's qualification is added, restricting the result set further to only the rows that would have been touched by the original query:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data
WHERE new.sl_avail <> old.sl_avail
    AND shoelace_data.sl_name = 'sl7';
```

Step 4 replaces references to `NEW` by the target list entries from the original query tree or by the matching variable references from the result relation:

```
INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
```



```

        shoelace_data shoelace_data
WHERE 6 <> old.sl_avail
      AND shoelace_data.sl_name = 'sl7';

```

Step 5 changes OLD references into result relation references:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
     shoelace_data shoelace_data
WHERE 6 <> shoelace_data.sl_avail
      AND shoelace_data.sl_name = 'sl7';

```

That's it. Since the rule is ALSO, we also output the original query tree. In short, the output from the rule system is a list of two query trees that correspond to these statements:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
    current_user, current_timestamp )
FROM shoelace_data
WHERE 6 <> shoelace_data.sl_avail
      AND shoelace_data.sl_name = 'sl7';

```

```

UPDATE shoelace_data SET sl_avail = 6
WHERE sl_name = 'sl7';

```

These are executed in this order, and that is exactly what the rule was meant to do.

The substitutions and the added qualifications ensure that, if the original query would be, say:

```

UPDATE shoelace_data SET sl_color = 'green'
WHERE sl_name = 'sl7';

```

no log entry would get written. In that case, the original query tree does not contain a target list entry for `sl_avail`, so `NEW.sl_avail` will get replaced by `shoelace_data.sl_avail`. Thus, the extra command generated by the rule is:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, shoelace_data.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data
WHERE shoelace_data.sl_avail <> shoelace_data.sl_avail
      AND shoelace_data.sl_name = 'sl7';

```

and that qualification will never be true.

It will also work if the original query modifies multiple rows. So if someone issued the command:

```

UPDATE shoelace_data SET sl_avail = 0
WHERE sl_color = 'black';

```

four rows in fact get updated (`sl1`, `sl2`, `sl3`, and `sl4`). But `sl3` already has `sl_avail = 0`. In this case, the original query trees qualification is different and that results in the extra query tree:

```
INSERT INTO shoelace_log
SELECT shoelace_data.sl_name, 0,
       current_user, current_timestamp
FROM shoelace_data
WHERE 0 <> shoelace_data.sl_avail
AND shoelace_data.sl_color = 'black';
```

being generated by the rule. This query tree will surely insert three new log entries. And that's absolutely correct.

Here we can see why it is important that the original query tree is executed last. If the UPDATE had been executed first, all the rows would have already been set to zero, so the logging INSERT would not find any row where `0 <> shoelace_data.sl_avail`.

## 39.4.2. Cooperation with Views

A simple way to protect view relations from the mentioned possibility that someone can try to run INSERT, UPDATE, or DELETE on them is to let those query trees get thrown away. So we could create the rules:

```
CREATE RULE shoe_ins_protect AS ON INSERT TO shoe
DO INSTEAD NOTHING;
CREATE RULE shoe_upd_protect AS ON UPDATE TO shoe
DO INSTEAD NOTHING;
CREATE RULE shoe_del_protect AS ON DELETE TO shoe
DO INSTEAD NOTHING;
```

If someone now tries to do any of these operations on the view relation `shoe`, the rule system will apply these rules. Since the rules have no actions and are INSTEAD, the resulting list of query trees will be empty and the whole query will become nothing because there is nothing left to be optimized or executed after the rule system is done with it.

A more sophisticated way to use the rule system is to create rules that rewrite the query tree into one that does the right operation on the real tables. To do that on the shoelace view, we create the following rules:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
DO INSTEAD
INSERT INTO shoelace_data VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    NEW.sl_color,
    NEW.sl_len,
    NEW.sl_unit
);

CREATE RULE shoelace_upd AS ON UPDATE TO shoelace
DO INSTEAD
UPDATE shoelace_data
SET sl_name = NEW.sl_name,
    sl_avail = NEW.sl_avail,
    sl_color = NEW.sl_color,
    sl_len = NEW.sl_len,
    sl_unit = NEW.sl_unit
WHERE sl_name = OLD.sl_name;

CREATE RULE shoelace_del AS ON DELETE TO shoelace
```

```
DO INSTEAD
DELETE FROM shoelace_data
WHERE sl_name = OLD.sl_name;
```

If you want to support RETURNING queries on the view, you need to make the rules include RETURNING clauses that compute the view rows. This is usually pretty trivial for views on a single table, but it's a bit tedious for join views such as shoelace. An example for the insert case is:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
DO INSTEAD
INSERT INTO shoelace_data VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    NEW.sl_color,
    NEW.sl_len,
    NEW.sl_unit
)
RETURNING
shoelace_data.*,
(SELECT shoelace_data.sl_len * u.un_fact
FROM unit u WHERE shoelace_data.sl_unit = u.un_name);
```

Note that this one rule supports both INSERT and INSERT RETURNING queries on the view — the RETURNING clause is simply ignored for INSERT.

Now assume that once in a while, a pack of shoelaces arrives at the shop and a big parts list along with it. But you don't want to manually update the shoelace view every time. Instead we set up two little tables: one where you can insert the items from the part list, and one with a special trick. The creation commands for these are:

```
CREATE TABLE shoelace_arrive (
    arr_name    text,
    arr_quant   integer
);

CREATE TABLE shoelace_ok (
    ok_name     text,
    ok_quant    integer
);

CREATE RULE shoelace_ok_ins AS ON INSERT TO shoelace_ok
DO INSTEAD
UPDATE shoelace
SET sl_avail = sl_avail + NEW.ok_quant
WHERE sl_name = NEW.ok_name;
```

Now you can fill the table shoelace\_arrive with the data from the parts list:

```
SELECT * FROM shoelace_arrive;
```

```
arr_name | arr_quant
-----+-----
s13      |         10
s16      |         20
s18      |         20
(3 rows)
```

Take a quick look at the current data:

```
SELECT * FROM shoelace;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
s11	5	black	80	cm	80
s12	6	black	100	cm	100
s17	6	brown	60	cm	60
s13	0	black	35	inch	88.9
s14	8	black	40	inch	101.6
s18	1	brown	40	inch	101.6
s15	4	brown	1	m	100
s16	0	brown	0.9	m	90

(8 rows)

Now move the arrived shoelaces in:

```
INSERT INTO shoelace_ok SELECT * FROM shoelace_arrive;
```

and check the results:

```
SELECT * FROM shoelace ORDER BY sl_name;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
s11	5	black	80	cm	80
s12	6	black	100	cm	100
s17	6	brown	60	cm	60
s14	8	black	40	inch	101.6
s13	10	black	35	inch	88.9
s18	21	brown	40	inch	101.6
s15	4	brown	1	m	100
s16	20	brown	0.9	m	90

(8 rows)

```
SELECT * FROM shoelace_log;
```

sl_name	sl_avail	log_who	log_when
s17	6	Al	Tue Oct 20 19:14:45 1998 MET DST
s13	10	Al	Tue Oct 20 19:25:16 1998 MET DST
s16	20	Al	Tue Oct 20 19:25:16 1998 MET DST
s18	21	Al	Tue Oct 20 19:25:16 1998 MET DST

(4 rows)

It's a long way from the one `INSERT ... SELECT` to these results. And the description of the query-tree transformation will be the last in this chapter. First, there is the parser's output:

```
INSERT INTO shoelace_ok
SELECT shoelace_arrive.arr_name, shoelace_arrive.arr_quant
FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok;
```

Now the first rule `shoelace_ok_ins` is applied and turns this into:

```
UPDATE shoelace
  SET sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace
  WHERE shoelace.sl_name = shoelace_arrive.arr_name;
```

and throws away the original INSERT on shoelace\_ok. This rewritten query is passed to the rule system again, and the second applied rule shoelace\_upd produces:

```
UPDATE shoelace_data
  SET sl_name = shoelace.sl_name,
      sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant,
      sl_color = shoelace.sl_color,
      sl_len = shoelace.sl_len,
      sl_unit = shoelace.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data
  WHERE shoelace.sl_name = shoelace_arrive.arr_name
        AND shoelace_data.sl_name = shoelace.sl_name;
```

Again it's an INSTEAD rule and the previous query tree is trashed. Note that this query still uses the view shoelace. But the rule system isn't finished with this step, so it continues and applies the \_RETURN rule on it, and we get:

```
UPDATE shoelace_data
  SET sl_name = s.sl_name,
      sl_avail = s.sl_avail + shoelace_arrive.arr_quant,
      sl_color = s.sl_color,
      sl_len = s.sl_len,
      sl_unit = s.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data,
       shoelace old, shoelace new,
       shoelace_data s, unit u
  WHERE s.sl_name = shoelace_arrive.arr_name
        AND shoelace_data.sl_name = s.sl_name;
```

Finally, the rule log\_shoelace gets applied, producing the extra query tree:

```
INSERT INTO shoelace_log
SELECT s.sl_name,
      s.sl_avail + shoelace_arrive.arr_quant,
      current_user,
      current_timestamp
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data,
       shoelace old, shoelace new,
       shoelace_data s, unit u,
       shoelace_data old, shoelace_data new
```

```

        shoelace_log shoelace_log
WHERE s.sl_name = shoelace_arrive.arr_name
      AND shoelace_data.sl_name = s.sl_name
      AND (s.sl_avail + shoelace_arrive.arr_quant) <> s.sl_avail;

```

After that the rule system runs out of rules and returns the generated query trees.

So we end up with two final query trees that are equivalent to the SQL statements:

```

INSERT INTO shoelace_log
SELECT s.sl_name,
       s.sl_avail + shoelace_arrive.arr_quant,
       current_user,
       current_timestamp
FROM shoelace_arrive shoelace_arrive, shoelace_data
shoelace_data,
     shoelace_data s
WHERE s.sl_name = shoelace_arrive.arr_name
      AND shoelace_data.sl_name = s.sl_name
      AND s.sl_avail + shoelace_arrive.arr_quant <> s.sl_avail;

```

```

UPDATE shoelace_data
SET sl_avail = shoelace_data.sl_avail +
shoelace_arrive.arr_quant
FROM shoelace_arrive shoelace_arrive,
     shoelace_data shoelace_data,
     shoelace_data s
WHERE s.sl_name = shoelace_arrive.sl_name
      AND shoelace_data.sl_name = s.sl_name;

```

The result is that data coming from one relation inserted into another, changed into updates on a third, changed into updating a fourth plus logging that final update in a fifth gets reduced into two queries.

There is a little detail that's a bit ugly. Looking at the two queries, it turns out that the `shoelace_data` relation appears twice in the range table where it could definitely be reduced to one. The planner does not handle it and so the execution plan for the rule systems output of the INSERT will be

```

Nested Loop
-> Merge Join
    -> Seq Scan
        -> Sort
            -> Seq Scan on s
    -> Seq Scan
        -> Sort
            -> Seq Scan on shoelace_arrive
-> Seq Scan on shoelace_data

```

while omitting the extra range table entry would result in a

```

Merge Join
-> Seq Scan
    -> Sort
        -> Seq Scan on s
-> Seq Scan
    -> Sort
        -> Seq Scan on shoelace_arrive

```

which produces exactly the same entries in the log table. Thus, the rule system caused one extra scan on the table `shoelace_data` that is absolutely not necessary. And the same redundant scan is done once more in the `UPDATE`. But it was a really hard job to make that all possible at all.

Now we make a final demonstration of the LightDB rule system and its power. Say you add some shoelaces with extraordinary colors to your database:

```
INSERT INTO shoelace VALUES ('sl9', 0, 'pink', 35.0, 'inch', 0.0);
INSERT INTO shoelace VALUES ('sl10', 1000, 'magenta', 40.0, 'inch',
0.0);
```

We would like to make a view to check which shoelace entries do not fit any shoe in color. The view for this is:

```
CREATE VIEW shoelace_mismatch AS
SELECT * FROM shoelace WHERE NOT EXISTS
(SELECT shoename FROM shoe WHERE slcolor = sl_color);
```

Its output is:

```
SELECT * FROM shoelace_mismatch;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl9	0	pink	35	inch	88.9
sl10	1000	magenta	40	inch	101.6

Now we want to set it up so that mismatching shoelaces that are not in stock are deleted from the database. To make it a little harder for LightDB, we don't delete it directly. Instead we create one more view:

```
CREATE VIEW shoelace_can_delete AS
SELECT * FROM shoelace_mismatch WHERE sl_avail = 0;
```

and do it this way:

```
DELETE FROM shoelace WHERE EXISTS
(SELECT * FROM shoelace_can_delete
WHERE sl_name = shoelace.sl_name);
```

*Voilà:*

```
SELECT * FROM shoelace;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	6	brown	60	cm	60
sl4	8	black	40	inch	101.6
sl3	10	black	35	inch	88.9
sl8	21	brown	40	inch	101.6
sl10	1000	magenta	40	inch	101.6
sl5	4	brown	1	m	100

```
s16      |      20 | brown   |      0.9 | m      |      90
(9 rows)
```

A DELETE on a view, with a subquery qualification that in total uses 4 nesting/joined views, where one of them itself has a subquery qualification containing a view and where calculated view columns are used, gets rewritten into one single query tree that deletes the requested data from a real table.

There are probably only a few situations out in the real world where such a construct is necessary. But it makes you feel comfortable that it works.

## 39.5. Rules and Privileges

Due to rewriting of queries by the LightDB rule system, other tables/views than those used in the original query get accessed. When update rules are used, this can include write access to tables.

Rewrite rules don't have a separate owner. The owner of a relation (table or view) is automatically the owner of the rewrite rules that are defined for it. The LightDB rule system changes the behavior of the default access control system. Relations that are used due to rules get checked against the privileges of the rule owner, not the user invoking the rule. This means that users only need the required privileges for the tables/views that are explicitly named in their queries.

For example: A user has a list of phone numbers where some of them are private, the others are of interest for the assistant of the office. The user can construct the following:

```
CREATE TABLE phone_data (person text, phone text, private boolean);
CREATE VIEW phone_number AS
    SELECT person, CASE WHEN NOT private THEN phone END AS phone
    FROM phone_data;
GRANT SELECT ON phone_number TO assistant;
```

Nobody except that user (and the database superusers) can access the `phone_data` table. But because of the GRANT, the assistant can run a SELECT on the `phone_number` view. The rule system will rewrite the SELECT from `phone_number` into a SELECT from `phone_data`. Since the user is the owner of `phone_number` and therefore the owner of the rule, the read access to `phone_data` is now checked against the user's privileges and the query is permitted. The check for accessing `phone_number` is also performed, but this is done against the invoking user, so nobody but the user and the assistant can use it.

The privileges are checked rule by rule. So the assistant is for now the only one who can see the public phone numbers. But the assistant can set up another view and grant access to that to the public. Then, anyone can see the `phone_number` data through the assistant's view. What the assistant cannot do is to create a view that directly accesses `phone_data`. (Actually the assistant can, but it will not work since every access will be denied during the permission checks.) And as soon as the user notices that the assistant opened their `phone_number` view, the user can revoke the assistant's access. Immediately, any access to the assistant's view would fail.

One might think that this rule-by-rule checking is a security hole, but in fact it isn't. But if it did not work this way, the assistant could set up a table with the same columns as `phone_number` and copy the data to there once per day. Then it's the assistant's own data and the assistant can grant access to everyone they want. A GRANT command means, "I trust you". If someone you trust does the thing above, it's time to think it over and then use REVOKE.

Note that while views can be used to hide the contents of certain columns using the technique shown above, they cannot be used to reliably conceal the data in unseen rows unless the `security_barrier` flag has been set. For example, the following view is insecure:

```
CREATE VIEW phone_number AS
```



```
SELECT person, phone FROM phone_data WHERE phone NOT LIKE
'412%';
```

This view might seem secure, since the rule system will rewrite any `SELECT` from `phone_number` into a `SELECT` from `phone_data` and add the qualification that only entries where `phone` does not begin with 412 are wanted. But if the user can create their own functions, it is not difficult to convince the planner to execute the user-defined function prior to the `NOT LIKE` expression. For example:

```
CREATE FUNCTION tricky(text, text) RETURNS bool AS $$
BEGIN
    RAISE NOTICE '% => %', $1, $2;
    RETURN true;
END;
$$ LANGUAGE plpgsql COST 0.000000000000000000000001;

SELECT * FROM phone_number WHERE tricky(person, phone);
```

Every person and phone number in the `phone_data` table will be printed as a `NOTICE`, because the planner will choose to execute the inexpensive `tricky` function before the more expensive `NOT LIKE`. Even if the user is prevented from defining new functions, built-in functions can be used in similar attacks. (For example, most casting functions include their input values in the error messages they produce.)

Similar considerations apply to update rules. In the examples of the previous section, the owner of the tables in the example database could grant the privileges `SELECT`, `INSERT`, `UPDATE`, and `DELETE` on the `shoelace` view to someone else, but only `SELECT` on `shoelace_log`. The rule action to write log entries will still be executed successfully, and that other user could see the log entries. But they could not create fake entries, nor could they manipulate or remove existing ones. In this case, there is no possibility of subverting the rules by convincing the planner to alter the order of operations, because the only rule which references `shoelace_log` is an unqualified `INSERT`. This might not be true in more complex scenarios.

When it is necessary for a view to provide row level security, the `security_barrier` attribute should be applied to the view. This prevents maliciously-chosen functions and operators from being passed values from rows until after the view has done its work. For example, if the view shown above had been created like this, it would be secure:

```
CREATE VIEW phone_number WITH (security_barrier) AS
SELECT person, phone FROM phone_data WHERE phone NOT LIKE
'412%';
```

Views created with the `security_barrier` may perform far worse than views created without this option. In general, there is no way to avoid this: the fastest possible plan must be rejected if it may compromise security. For this reason, this option is not enabled by default.

The query planner has more flexibility when dealing with functions that have no side effects. Such functions are referred to as `LEAKPROOF`, and include many simple, commonly used operators, such as many equality operators. The query planner can safely allow such functions to be evaluated at any point in the query execution process, since invoking them on rows invisible to the user will not leak any information about the unseen rows. Further, functions which do not take arguments or which are not passed any arguments from the security barrier view do not have to be marked as `LEAKPROOF` to be pushed down, as they never receive data from the view. In contrast, a function that might throw an error depending on the values received as arguments (such as one that throws an error in the event of overflow or division by zero) is not leak-proof, and could provide significant information about the unseen rows if applied before the security view's row filters.

It is important to understand that even a view created with the `security_barrier` option is intended to be secure only in the limited sense that the contents of the invisible tuples will not be passed

to possibly-insecure functions. The user may well have other means of making inferences about the unseen data; for example, they can see the query plan using `EXPLAIN`, or measure the run time of queries against the view. A malicious attacker might be able to infer something about the amount of unseen data, or even gain some information about the data distribution or most common values (since these things may affect the run time of the plan; or even, since they are also reflected in the optimizer statistics, the choice of plan). If these types of "covert channel" attacks are of concern, it is probably unwise to grant any access to the data at all.

## 39.6. Rules and Command Status

The LightDB server returns a command status string, such as `INSERT 149592 1`, for each command it receives. This is simple enough when there are no rules involved, but what happens when the query is rewritten by rules?

Rules affect the command status as follows:

- If there is no unconditional `INSTEAD` rule for the query, then the originally given query will be executed, and its command status will be returned as usual. (But note that if there were any conditional `INSTEAD` rules, the negation of their qualifications will have been added to the original query. This might reduce the number of rows it processes, and if so the reported status will be affected.)
- If there is any unconditional `INSTEAD` rule for the query, then the original query will not be executed at all. In this case, the server will return the command status for the last query that was inserted by an `INSTEAD` rule (conditional or unconditional) and is of the same command type (`INSERT`, `UPDATE`, or `DELETE`) as the original query. If no query meeting those requirements is added by any rule, then the returned command status shows the original query type and zeroes for the row-count and OID fields.

The programmer can ensure that any desired `INSTEAD` rule is the one that sets the command status in the second case, by giving it the alphabetically last rule name among the active rules, so that it gets applied last.

## 39.7. Rules Versus Triggers

Many things that can be done using triggers can also be implemented using the LightDB rule system. One of the things that cannot be implemented by rules are some kinds of constraints, especially foreign keys. It is possible to place a qualified rule that rewrites a command to `NOTHING` if the value of a column does not appear in another table. But then the data is silently thrown away and that's not a good idea. If checks for valid values are required, and in the case of an invalid value an error message should be generated, it must be done by a trigger.

In this chapter, we focused on using rules to update views. All of the update rule examples in this chapter can also be implemented using `INSTEAD OF` triggers on the views. Writing such triggers is often easier than writing rules, particularly if complex logic is required to perform the update.

For the things that can be implemented by both, which is best depends on the usage of the database. A trigger is fired once for each affected row. A rule modifies the query or generates an additional query. So if many rows are affected in one statement, a rule issuing one extra command is likely to be faster than a trigger that is called for every single row and must re-determine what to do many times. However, the trigger approach is conceptually far simpler than the rule approach, and is easier for novices to get right.

Here we show an example of how the choice of rules versus triggers plays out in one situation. There are two tables:

```
CREATE TABLE computer (
```

```
    hostname      text,      -- indexed
    manufacturer  text       -- indexed
);
```

```
CREATE TABLE software (
    software      text,      -- indexed
    hostname     text       -- indexed
);
```

Both tables have many thousands of rows and the indexes on `hostname` are unique. The rule or trigger should implement a constraint that deletes rows from `software` that reference a deleted computer. The trigger would use this command:

```
DELETE FROM software WHERE hostname = $1;
```

Since the trigger is called for each individual row deleted from `computer`, it can prepare and save the plan for this command and pass the `hostname` value in the parameter. The rule would be written as:

```
CREATE RULE computer_del AS ON DELETE TO computer
DO DELETE FROM software WHERE hostname = OLD.hostname;
```

Now we look at different types of deletes. In the case of a:

```
DELETE FROM computer WHERE hostname = 'mypc.local.net';
```

the table `computer` is scanned by index (fast), and the command issued by the trigger would also use an index scan (also fast). The extra command from the rule would be:

```
DELETE FROM software WHERE computer.hostname = 'mypc.local.net'
AND software.hostname = computer.hostname;
```

Since there are appropriate indexes set up, the planner will create a plan of

Nestloop

```
-> Index Scan using comp_hostidx on computer
-> Index Scan using soft_hostidx on software
```

So there would be not that much difference in speed between the trigger and the rule implementation.

With the next delete we want to get rid of all the 2000 computers where the `hostname` starts with `old`. There are two possible commands to do that. One is:

```
DELETE FROM computer WHERE hostname >= 'old'
AND hostname < 'ole'
```

The command added by the rule will be:

```
DELETE FROM software WHERE computer.hostname >= 'old' AND
computer.hostname < 'ole'
AND software.hostname = computer.hostname;
```

with the plan

Hash Join

```
-> Seq Scan on software
-> Hash
    -> Index Scan using comp_hostidx on computer
```

The other possible command is:

```
DELETE FROM computer WHERE hostname ~ '^old';
```

which results in the following executing plan for the command added by the rule:

Nestloop

```
-> Index Scan using comp_hostidx on computer
-> Index Scan using soft_hostidx on software
```

This shows, that the planner does not realize that the qualification for `hostname` in `computer` could also be used for an index scan on `software` when there are multiple qualification expressions combined with `AND`, which is what it does in the regular-expression version of the command. The trigger will get invoked once for each of the 2000 old computers that have to be deleted, and that will result in one index scan over `computer` and 2000 index scans over `software`. The rule implementation will do it with two commands that use indexes. And it depends on the overall size of the table `software` whether the rule will still be faster in the sequential scan situation. 2000 command executions from the trigger over the SPI manager take some time, even if all the index blocks will soon be in the cache.

The last command we look at is:

```
DELETE FROM computer WHERE manufacturer = 'bim';
```

Again this could result in many rows to be deleted from `computer`. So the trigger will again run many commands through the executor. The command generated by the rule will be:

```
DELETE FROM software WHERE computer.manufacturer = 'bim'
                        AND software.hostname = computer.hostname;
```

The plan for that command will again be the nested loop over two index scans, only using a different index on `computer`:

Nestloop

```
-> Index Scan using comp_manufidx on computer
-> Index Scan using soft_hostidx on software
```

In any of these cases, the extra commands from the rule system will be more or less independent from the number of affected rows in a command.

The summary is, rules will only be significantly slower than triggers if their actions result in large and badly qualified joins, a situation where the planner fails.

---

# Chapter 40. Procedural Languages

LightDB allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). For a function written in a procedural language, the database server has no built-in knowledge about how to interpret the function's source text. Instead, the task is passed to a special handler that knows the details of the language. The handler could either do all the work of parsing, syntax analysis, execution, etc. itself, or it could serve as “glue” between LightDB and an existing implementation of a programming language. The handler itself is a C language function compiled into a shared object and loaded on demand, just like any other C function.

There are currently two procedural languages available in the standard LightDB distribution: PL/pgSQL (Chapter 41), PL/oraSQL (Chapter 42). There are additional procedural languages available that are not included in the core distribution. Appendix H has information about finding them. In addition other languages can be defined by users; the basics of developing a new procedural language are covered in Chapter 52.

## 40.1. Installing Procedural Languages

A procedural language must be “installed” into each database where it is to be used. But procedural languages installed in the database `template1` are automatically available in all subsequently created databases, since their entries in `template1` will be copied by `CREATE DATABASE`. So the database administrator can decide which languages are available in which databases and can make some languages available by default if desired.

For the languages supplied with the standard distribution, it is only necessary to execute `CREATE EXTENSION language_name` to install the language into the current database. The manual procedure described below is only recommended for installing languages that have not been packaged as extensions.

### Manual Procedural Language Installation

A procedural language is installed in a database in five steps, which must be carried out by a database superuser. In most cases the required SQL commands should be packaged as the installation script of an “extension”, so that `CREATE EXTENSION` can be used to execute them.

1. The shared object for the language handler must be compiled and installed into an appropriate library directory. This works in the same way as building and installing modules with regular user-defined C functions does; see Section 36.10.5. Often, the language handler will depend on an external library that provides the actual programming language engine; if so, that must be installed as well.
2. The handler must be declared with the command

```
CREATE FUNCTION handler_function_name( )
    RETURNS language_handler
    AS 'path-to-shared-object'
    LANGUAGE C;
```

The special return type of `language_handler` tells the database system that this function does not return one of the defined SQL data types and is not directly usable in SQL statements.

3. (Optional) Optionally, the language handler can provide an “inline” handler function that executes anonymous code blocks (DO commands) written in this language. If an inline handler function is provided by the language, declare it with a command like

```
CREATE FUNCTION inline_function_name(internal)
  RETURNS void
  AS 'path-to-shared-object'
  LANGUAGE C;
```

4. (Optional) Optionally, the language handler can provide a “validator” function that checks a function definition for correctness without actually executing it. The validator function is called by CREATE FUNCTION if it exists. If a validator function is provided by the language, declare it with a command like

```
CREATE FUNCTION validator_function_name(oid)
  RETURNS void
  AS 'path-to-shared-object'
  LANGUAGE C STRICT;
```

5. Finally, the PL must be declared with the command

```
CREATE [TRUSTED] LANGUAGE language_name
  HANDLER handler_function_name
  [INLINE inline_function_name]
  [VALIDATOR validator_function_name] ;
```

The optional key word TRUSTED specifies that the language does not grant access to data that the user would not otherwise have. Trusted languages are designed for ordinary database users (those without superuser privilege) and allows them to safely create functions and procedures. Since PL functions are executed inside the database server, the TRUSTED flag should only be given for languages that do not allow access to database server internals or the file system. The languages PL/pgSQL, PL/oraSQL are considered trusted.

In a default LightDB installation, the handlers for the PL/pgSQL and PL/oraSQL languages are built and installed into the “library” directory; furthermore, the PL/pgSQL and PL/oraSQL languages are installed in all databases.

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# Chapter 41. PL/pgSQL — SQL Procedural Language

## 41.1. Overview

PL/pgSQL is a loadable procedural language for the LightDB database system. The design goals of PL/pgSQL were to create a loadable procedural language that

- can be used to create functions, procedures, and triggers,
- adds control structures to the SQL language,
- can perform complex computations,
- inherits all user-defined types, functions, procedures, and operators,
- can be defined to be trusted by the server,
- is easy to use.

Functions created with PL/pgSQL can be used anywhere that built-in functions could be used. For example, it is possible to create complex conditional computation functions and later use them to define operators or use them in index expressions.

In LightDB 9.0 and later, PL/pgSQL is installed by default. However it is still a loadable module, so especially security-conscious administrators could choose to remove it.

### 41.1.1. Advantages of Using PL/pgSQL

SQL is the language LightDB and most other relational databases use as query language. It's portable and easy to learn. But every SQL statement must be executed individually by the database server.

That means that your client application must send each query to the database server, wait for it to be processed, receive and process the results, do some computation, then send further queries to the server. All this incurs interprocess communication and will also incur network overhead if your client is on a different machine than the database server.

With PL/pgSQL you can group a block of computation and a series of queries *inside* the database server, thus having the power of a procedural language and the ease of use of SQL, but with considerable savings of client/server communication overhead.

- Extra round trips between client and server are eliminated
- Intermediate results that the client does not need do not have to be marshaled or transferred between server and client
- Multiple rounds of query parsing can be avoided

This can result in a considerable performance increase as compared to an application that does not use stored functions.

Also, with PL/pgSQL you can use all the data types, operators and functions of SQL.

### 41.1.2. Supported Argument and Result Data Types

Functions written in PL/pgSQL can accept as arguments any scalar or array data type supported by the server, and they can return a result of any of these types. They can also accept or return any composite

type (row type) specified by name. It is also possible to declare a PL/pgSQL function as accepting `record`, which means that any composite type will do as input, or as returning `record`, which means that the result is a row type whose columns are determined by specification in the calling query, as discussed in Section 7.2.1.4.

PL/pgSQL functions can be declared to accept a variable number of arguments by using the `VARIADIC` marker. This works exactly the same way as for SQL functions, as discussed in Section 36.5.5.

PL/pgSQL functions can also be declared to accept and return the polymorphic types described in Section 36.2.5, thus allowing the actual data types handled by the function to vary from call to call. Examples appear in Section 41.3.1.

PL/pgSQL functions can also be declared to return a “set” (or table) of any data type that can be returned as a single instance. Such a function generates its output by executing `RETURN NEXT` for each desired element of the result set, or by using `RETURN QUERY` to output the result of evaluating a query.

Finally, a PL/pgSQL function can be declared to return `void` if it has no useful return value. (Alternatively, it could be written as a procedure in that case.)

PL/pgSQL functions can also be declared with output parameters in place of an explicit specification of the return type. This does not add any fundamental capability to the language, but it is often convenient, especially for returning multiple values. The `RETURNS TABLE` notation can also be used in place of `RETURNS SETOF`.

Specific examples appear in Section 41.3.1 and Section 41.6.1.

## 41.2. Structure of PL/pgSQL

Functions written in PL/pgSQL are defined to the server by executing `CREATE FUNCTION` commands. Such a command would normally look like, say,

```
CREATE FUNCTION somefunc(integer, text) RETURNS integer
AS 'function body text'
LANGUAGE plpgsql;
```

The function body is simply a string literal so far as `CREATE FUNCTION` is concerned. It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the function body, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function body must be escaped by doubling them. Almost all the examples in this chapter use dollar-quoted literals for their function bodies.

PL/pgSQL is a block-structured language. The complete text of a function body must be a *block*. A block is defined as:

```
[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
END [ label ];
```

Each declaration and each statement within a block is terminated by a semicolon. A block that appears within another block must have a semicolon after `END`, as shown above; however the final `END` that concludes a function body does not require a semicolon.



### Tip

A common mistake is to write a semicolon immediately after `BEGIN`. This is incorrect and will result in a syntax error.

A *label* is only needed if you want to identify the block for use in an `EXIT` statement, or to qualify the names of the variables declared in the block. If a label is given after `END`, it must match the label at the block's beginning.

All key words are case-insensitive. Identifiers are implicitly converted to lower case unless double-quoted, just as they are in ordinary SQL commands.

Comments work the same way in PL/pgSQL code as in ordinary SQL. A double dash (`--`) starts a comment that extends to the end of the line. A `/*` starts a block comment that extends to the matching occurrence of `*/`. Block comments nest.

Any statement in the statement section of a block can be a *subblock*. Subblocks can be used for logical grouping or to localize variables to a small group of statements. Variables declared in a subblock mask any similarly-named variables of outer blocks for the duration of the subblock; but you can access the outer variables anyway if you qualify their names with their block's label. For example:

```
CREATE FUNCTION somefunc() RETURNS integer AS $$
<< outerblock >>
DECLARE
    quantity integer := 30;
BEGIN
    RAISE NOTICE 'Quantity here is %', quantity; -- Prints 30
    quantity := 50;
    --
    -- Create a subblock
    --
    DECLARE
        quantity integer := 80;
    BEGIN
        RAISE NOTICE 'Quantity here is %', quantity; -- Prints 80
        RAISE NOTICE 'Outer quantity here is %',
outerblock.quantity; -- Prints 50
    END;

    RAISE NOTICE 'Quantity here is %', quantity; -- Prints 50

    RETURN quantity;
END;
$$ LANGUAGE plpgsql;
```

### Note

There is actually a hidden “outer block” surrounding the body of any PL/pgSQL function. This block provides the declarations of the function's parameters (if any), as well as some special variables such as `FOUND` (see Section 41.5.5). The outer block is labeled with the function's name, meaning that parameters and special variables can be qualified with the function's name.

It is important not to confuse the use of `BEGIN/END` for grouping statements in PL/pgSQL with the similarly-named SQL commands for transaction control. PL/pgSQL's `BEGIN/END` are only for

grouping; they do not start or end a transaction. See Section 41.8 for information on managing transactions in PL/pgSQL. Also, a block containing an `EXCEPTION` clause effectively forms a subtransaction that can be rolled back without affecting the outer transaction. For more about that see Section 41.6.8.

## 41.3. Declarations

All variables used in a block must be declared in the declarations section of the block. (The only exceptions are that the loop variable of a `FOR` loop iterating over a range of integer values is automatically declared as an integer variable, and likewise the loop variable of a `FOR` loop iterating over a cursor's result is automatically declared as a record variable.)

PL/pgSQL variables can have any SQL data type, such as `integer`, `varchar`, and `char`.

Here are some examples of variable declarations:

```
user_id integer;
quantity numeric(5);
url varchar;
myrow tablename%ROWTYPE;
myfield tablename.columnname%TYPE;
arow RECORD;
```

The general syntax of a variable declaration is:

```
name [ CONSTANT ] type [ COLLATE collation_name ] [ NOT NULL ]
[ { DEFAULT | := | = } expression ];
```

The `DEFAULT` clause, if given, specifies the initial value assigned to the variable when the block is entered. If the `DEFAULT` clause is not given then the variable is initialized to the SQL null value. The `CONSTANT` option prevents the variable from being assigned to after initialization, so that its value will remain constant for the duration of the block. The `COLLATE` option specifies a collation to use for the variable (see Section 41.3.6). If `NOT NULL` is specified, an assignment of a null value results in a run-time error. All variables declared as `NOT NULL` must have a nonnull default value specified. Equal (`=`) can be used instead of PL/SQL-compliant `:=`.

A variable's default value is evaluated and assigned to the variable each time the block is entered (not just once per function call). So, for example, assigning `now()` to a variable of type `timestamp` causes the variable to have the time of the current function call, not the time when the function was precompiled.

Examples:

```
quantity integer DEFAULT 32;
url varchar := 'http://mysite.com';
user_id CONSTANT integer := 10;
```

### 41.3.1. Declaring Function Parameters

Parameters passed to functions are named with the identifiers `$1`, `$2`, etc. Optionally, aliases can be declared for `$n` parameter names for increased readability. Either the alias or the numeric identifier can then be used to refer to the parameter value.

There are two ways to create an alias. The preferred way is to give a name to the parameter in the `CREATE FUNCTION` command, for example:

```
CREATE FUNCTION sales_tax(subtotal real) RETURNS real AS $$
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

The other way is to explicitly declare an alias, using the declaration syntax

```
name ALIAS FOR $n;
```

The same example in this style looks like:

```
CREATE FUNCTION sales_tax(real) RETURNS real AS $$
DECLARE
    subtotal ALIAS FOR $1;
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

### Note

These two examples are not perfectly equivalent. In the first case, `subtotal` could be referenced as `sales_tax.subtotal`, but in the second case it could not. (Had we attached a label to the inner block, `subtotal` could be qualified with that label, instead.)

Some more examples:

```
CREATE FUNCTION instr(vvarchar, integer) RETURNS integer AS $$
DECLARE
    v_string ALIAS FOR $1;
    index ALIAS FOR $2;
BEGIN
    -- some computations using v_string and index here
END;
$$ LANGUAGE plpgsql;
```

```
CREATE FUNCTION concat_selected_fields(in_t sometablename) RETURNS
text AS $$
BEGIN
    RETURN in_t.f1 || in_t.f3 || in_t.f5 || in_t.f7;
END;
$$ LANGUAGE plpgsql;
```

When a PL/pgSQL function is declared with output parameters, the output parameters are given `$n` names and optional aliases in just the same way as the normal input parameters. An output parameter is effectively a variable that starts out `NULL`; it should be assigned to during the execution of the function. The final value of the parameter is what is returned. For instance, the sales-tax example could also be done this way:

```
CREATE FUNCTION sales_tax(subtotal real, OUT tax real) AS $$
BEGIN
    tax := subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

Notice that we omitted `RETURNS real` — we could have included it, but it would be redundant.

Output parameters are most useful when returning multiple values. A trivial example is:

```
CREATE FUNCTION sum_n_product(x int, y int, OUT sum int, OUT prod
int) AS $$
BEGIN
    sum := x + y;
    prod := x * y;
END;
$$ LANGUAGE plpgsql;
```

As discussed in Section 36.5.4, this effectively creates an anonymous record type for the function's results. If a `RETURNS` clause is given, it must say `RETURNS record`.

Another way to declare a PL/pgSQL function is with `RETURNS TABLE`, for example:

```
CREATE FUNCTION extended_sales(p_itemno int)
RETURNS TABLE(quantity int, total numeric) AS $$
BEGIN
    RETURN QUERY SELECT s.quantity, s.quantity * s.price FROM sales
    AS s
        WHERE s.itemno = p_itemno;
END;
$$ LANGUAGE plpgsql;
```

This is exactly equivalent to declaring one or more `OUT` parameters and specifying `RETURNS SETOF some_type`.

When the return type of a PL/pgSQL function is declared as a polymorphic type (see Section 36.2.5), a special parameter `$0` is created. Its data type is the actual return type of the function, as deduced from the actual input types. This allows the function to access its actual return type as shown in Section 41.3.3. `$0` is initialized to null and can be modified by the function, so it can be used to hold the return value if desired, though that is not required. `$0` can also be given an alias. For example, this function works on any data type that has a `+` operator:

```
CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3
anyelement)
RETURNS anyelement AS $$
DECLARE
    result ALIAS FOR $0;
BEGIN
    result := v1 + v2 + v3;
    RETURN result;
END;
$$ LANGUAGE plpgsql;
```

The same effect can be obtained by declaring one or more output parameters as polymorphic types. In this case the special `$0` parameter is not used; the output parameters themselves serve the same purpose. For example:

```
CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3
    anyelement,
                                OUT sum anyelement)
AS $$
BEGIN
    sum := v1 + v2 + v3;
END;
$$ LANGUAGE plpgsql;
```

In practice it might be more useful to declare a polymorphic function using the `anycompatible` family of types, so that automatic promotion of the input arguments to a common type will occur. For example:

```
CREATE FUNCTION add_three_values(v1 anycompatible, v2
    anycompatible, v3 anycompatible)
RETURNS anycompatible AS $$
BEGIN
    RETURN v1 + v2 + v3;
END;
$$ LANGUAGE plpgsql;
```

With this example, a call such as

```
SELECT add_three_values(1, 2, 4.7);
```

will work, automatically promoting the integer inputs to numeric. The function using `anyelement` would require you to cast the three inputs to the same type manually.

## 41.3.2. ALIAS

```
newname ALIAS FOR oldname;
```

The `ALIAS` syntax is more general than is suggested in the previous section: you can declare an alias for any variable, not just function parameters. The main practical use for this is to assign a different name for variables with predetermined names, such as `NEW` or `OLD` within a trigger function.

Examples:

```
DECLARE
    prior ALIAS FOR old;
    updated ALIAS FOR new;
```

Since `ALIAS` creates two different ways to name the same object, unrestricted use can be confusing. It's best to use it only for the purpose of overriding predetermined names.

## 41.3.3. Copying Types

```
variable%TYPE
```

`%TYPE` provides the data type of a variable or table column. You can use this to declare variables that will hold database values. For example, let's say you have a column named `user_id` in your `users` table. To declare a variable with the same data type as `users.user_id` you write:

```
user_id users.user_id%TYPE;
```

By using `%TYPE` you don't need to know the data type of the structure you are referencing, and most importantly, if the data type of the referenced item changes in the future (for instance: you change the type of `user_id` from `integer` to `real`), you might not need to change your function definition.

`%TYPE` is particularly valuable in polymorphic functions, since the data types needed for internal variables can change from one call to the next. Appropriate variables can be created by applying `%TYPE` to the function's arguments or result placeholders.

## 41.3.4. Row Types

```
name table_name%ROWTYPE;
name composite_type_name;
```

A variable of a composite type is called a *row variable* (or *row-type variable*). Such a variable can hold a whole row of a `SELECT` or `FOR` query result, so long as that query's column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example `rowvar.field`.

A row variable can be declared to have the same type as the rows of an existing table or view, by using the `table_name%ROWTYPE` notation; or it can be declared by giving a composite type's name. (Since every table has an associated composite type of the same name, it actually does not matter in PostgreSQL whether you write `%ROWTYPE` or not. But the form with `%ROWTYPE` is more portable.)

Parameters to a function can be composite types (complete table rows). In that case, the corresponding identifier `$n` will be a row variable, and fields can be selected from it, for example `$1.user_id`.

Here is an example of using composite types. `table1` and `table2` are existing tables having at least the mentioned fields:

```
CREATE FUNCTION merge_fields(t_row table1) RETURNS text AS $$
DECLARE
    t2_row table2%ROWTYPE;
BEGIN
    SELECT * INTO t2_row FROM table2 WHERE ... ;
    RETURN t_row.f1 || t2_row.f3 || t_row.f5 || t2_row.f7;
END;
$$ LANGUAGE plpgsql;

SELECT merge_fields(t.*) FROM table1 t WHERE ... ;
```

## 41.3.5. Record Types

```
name RECORD;
```

Record variables are similar to row-type variables, but they have no predefined structure. They take on the actual row structure of the row they are assigned during a `SELECT` or `FOR` command. The substructure of a record variable can change each time it is assigned to. A consequence of this is that until a record variable is first assigned to, it has no substructure, and any attempt to access a field in it will draw a run-time error.

Note that `RECORD` is not a true data type, only a placeholder. One should also realize that when a PL/pgSQL function is declared to return type `record`, this is not quite the same concept as a record

variable, even though such a function might use a record variable to hold its result. In both cases the actual row structure is unknown when the function is written, but for a function returning `record` the actual structure is determined when the calling query is parsed, whereas a record variable can change its row structure on-the-fly.

## 41.3.6. Collation of PL/pgSQL Variables

When a PL/pgSQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 21.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly. This will affect the behavior of collation-sensitive operations within the function. For example, consider

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b;
END;
$$ LANGUAGE plpgsql;

SELECT less_than(text_field_1, text_field_2) FROM table1;
SELECT less_than(text_field_1, text_field_2 COLLATE "C") FROM
    table1;
```

The first use of `less_than` will use the common collation of `text_field_1` and `text_field_2` for the comparison, while the second use will use C collation.

Furthermore, the identified collation is also assumed as the collation of any local variables that are of collatable types. Thus this function would not work any differently if it were written as

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
DECLARE
    local_a text := a;
    local_b text := b;
BEGIN
    RETURN local_a < local_b;
END;
$$ LANGUAGE plpgsql;
```

If there are no parameters of collatable data types, or no common collation can be identified for them, then parameters and local variables use the default collation of their data type (which is usually the database's default collation, but could be different for variables of domain types).

A local variable of a collatable data type can have a different collation associated with it by including the `COLLATE` option in its declaration, for example

```
DECLARE
    local_a text COLLATE "en_US";
```

This option overrides the collation that would otherwise be given to the variable according to the rules above.

Also, of course explicit `COLLATE` clauses can be written inside a function if it is desired to force a particular collation to be used in a particular operation. For example,

```
CREATE FUNCTION less_than_c(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b COLLATE "C";
END;
$$ LANGUAGE plpgsql;
```

This overrides the collations associated with the table columns, parameters, or local variables used in the expression, just as would happen in a plain SQL command.

## 41.4. Expressions

All expressions used in PL/pgSQL statements are processed using the server's main SQL executor. For example, when you write a PL/pgSQL statement like

```
IF expression THEN ...
```

PL/pgSQL will evaluate the expression by feeding a query like

```
SELECT expression
```

to the main SQL engine. While forming the `SELECT` command, any occurrences of PL/pgSQL variable names are replaced by parameters, as discussed in detail in Section 41.11.1. This allows the query plan for the `SELECT` to be prepared just once and then reused for subsequent evaluations with different values of the variables. Thus, what really happens on first use of an expression is essentially a `PREPARE` command. For example, if we have declared two integer variables `x` and `y`, and we write

```
IF x < y THEN ...
```

what happens behind the scenes is equivalent to

```
PREPARE statement_name(integer, integer) AS SELECT $1 < $2;
```

and then this prepared statement is `EXECUTED` for each execution of the `IF` statement, with the current values of the PL/pgSQL variables supplied as parameter values. Normally these details are not important to a PL/pgSQL user, but they are useful to know when trying to diagnose a problem. More information appears in Section 41.11.2.

## 41.5. Basic Statements

In this section and the following ones, we describe all the statement types that are explicitly understood by PL/pgSQL. Anything not recognized as one of these statement types is presumed to be an SQL command and is sent to the main database engine to execute, as described in Section 41.5.2 and Section 41.5.3.

### 41.5.1. Assignment

An assignment of a value to a PL/pgSQL variable is written as:

```
variable { := | = } expression;
```

As explained previously, the expression in such a statement is evaluated by means of an SQL `SELECT` command sent to the main database engine. The expression must yield a single value (possibly a



row value, if the variable is a row or record variable). The target variable can be a simple variable (optionally qualified with a block name), a field of a row or record variable, or an element of an array that is a simple variable or field. Equal (=) can be used instead of PL/SQL-compliant :=.

If the expression's result data type doesn't match the variable's data type, the value will be coerced as though by an assignment cast (see Section 10.4). If no assignment cast is known for the pair of data types involved, the PL/pgSQL interpreter will attempt to convert the result value textually, that is by applying the result type's output function followed by the variable type's input function. Note that this could result in run-time errors generated by the input function, if the string form of the result value is not acceptable to the input function.

Examples:

```
tax := subtotal * 0.06;
my_record.user_id := 20;
```

## 41.5.2. Executing a Command with No Result

For any SQL command that does not return rows, for example INSERT without a RETURNING clause, you can execute the command within a PL/pgSQL function just by writing the command.

Any PL/pgSQL variable name appearing in the command text is treated as a parameter, and then the current value of the variable is provided as the parameter value at run time. This is exactly like the processing described earlier for expressions; for details see Section 41.11.1.

When executing a SQL command in this way, PL/pgSQL may cache and re-use the execution plan for the command, as discussed in Section 41.11.2.

Sometimes it is useful to evaluate an expression or SELECT query but discard the result, for example when calling a function that has side-effects but no useful result value. To do this in PL/pgSQL, use the PERFORM statement:

```
PERFORM query;
```

This executes *query* and discards the result. Write the *query* the same way you would write an SQL SELECT command, but replace the initial keyword SELECT with PERFORM. For WITH queries, use PERFORM and then place the query in parentheses. (In this case, the query can only return one row.) PL/pgSQL variables will be substituted into the query just as for commands that return no result, and the plan is cached in the same way. Also, the special variable FOUND is set to true if the query produced at least one row, or false if it produced no rows (see Section 41.5.5).

### Note

One might expect that writing SELECT directly would accomplish this result, but at present the only accepted way to do it is PERFORM. A SQL command that can return rows, such as SELECT, will be rejected as an error unless it has an INTO clause as discussed in the next section.

An example:

```
PERFORM create_mv('cs_session_page_requests_mv', my_query);
```

## 41.5.3. Executing a Query with a Single-Row Result

The result of a SQL command yielding a single row (possibly of multiple columns) can be assigned to a record variable, row-type variable, or list of scalar variables. This is done by writing the base SQL command and adding an INTO clause. For example,

```
SELECT select_expressions INTO [STRICT] target FROM ...;
INSERT ... RETURNING expressions INTO [STRICT] target;
UPDATE ... RETURNING expressions INTO [STRICT] target;
DELETE ... RETURNING expressions INTO [STRICT] target;
```

where *target* can be a record variable, a row variable, or a comma-separated list of simple variables and record/row fields. PL/pgSQL variables will be substituted into the rest of the query, and the plan is cached, just as described above for commands that do not return rows. This works for SELECT, INSERT/UPDATE/DELETE with RETURNING, and utility commands that return row-set results (such as EXPLAIN). Except for the INTO clause, the SQL command is the same as it would be written outside PL/pgSQL.

### Tip

Note that this interpretation of SELECT with INTO is quite different from LightDB's regular SELECT INTO command, wherein the INTO target is a newly created table. If you want to create a table from a SELECT result inside a PL/pgSQL function, use the syntax CREATE TABLE ... AS SELECT.

If a row or a variable list is used as target, the query's result columns must exactly match the structure of the target as to number and data types, or else a run-time error occurs. When a record variable is the target, it automatically configures itself to the row type of the query result columns.

The INTO clause can appear almost anywhere in the SQL command. Customarily it is written either just before or just after the list of *select\_expressions* in a SELECT command, or at the end of the command for other command types. It is recommended that you follow this convention in case the PL/pgSQL parser becomes stricter in future versions.

If STRICT is not specified in the INTO clause, then *target* will be set to the first row returned by the query, or to nulls if the query returned no rows. (Note that “the first row” is not well-defined unless you've used ORDER BY.) Any result rows after the first row are discarded. You can check the special FOUND variable (see Section 41.5.5) to determine whether a row was returned:

```
SELECT * INTO myrec FROM emp WHERE empname = myname;
IF NOT FOUND THEN
    RAISE EXCEPTION 'employee % not found', myname;
END IF;
```

If the STRICT option is specified, the query must return exactly one row or a run-time error will be reported, either NO\_DATA\_FOUND (no rows) or TOO\_MANY\_ROWS (more than one row). You can use an exception block if you wish to catch the error, for example:

```
BEGIN
    SELECT * INTO STRICT myrec FROM emp WHERE empname = myname;
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        RAISE EXCEPTION 'employee % not found', myname;
    WHEN TOO_MANY_ROWS THEN
        RAISE EXCEPTION 'employee % not unique', myname;
```

END;

Successful execution of a command with `STRICT` always sets `FOUND` to true.

For `INSERT/UPDATE/DELETE` with `RETURNING`, PL/pgSQL reports an error for more than one returned row, even when `STRICT` is not specified. This is because there is no option such as `ORDER BY` with which to determine which affected row should be returned.

If `print_strict_params` is enabled for the function, then when an error is thrown because the requirements of `STRICT` are not met, the `DETAIL` part of the error message will include information about the parameters passed to the query. You can change the `print_strict_params` setting for all functions by setting `plpgsql.print_strict_params`, though only subsequent function compilations will be affected. You can also enable it on a per-function basis by using a compiler option, for example:

```
CREATE FUNCTION get_userid(username text) RETURNS int
AS $$
#print_strict_params on
DECLARE
userid int;
BEGIN
    SELECT users.userid INTO STRICT userid
        FROM users WHERE users.username = get_userid.username;
    RETURN userid;
END;
$$ LANGUAGE plpgsql;
```

On failure, this function might produce an error message such as

```
ERROR: query returned no rows
DETAIL: parameters: $1 = 'nosuchuser'
CONTEXT: PL/pgSQL function get_userid(text) line 6 at SQL
statement
```

### Note

The `STRICT` option matches the behavior of Oracle PL/SQL's `SELECT INTO` and related statements.

To handle cases where you need to process multiple result rows from a SQL query, see Section 41.6.6.

## 41.5.4. Executing Dynamic Commands

Oftentimes you will want to generate dynamic commands inside your PL/pgSQL functions, that is, commands that will involve different tables or different data types each time they are executed. PL/pgSQL's normal attempts to cache plans for commands (as discussed in Section 41.11.2) will not work in such scenarios. To handle this sort of problem, the `EXECUTE` statement is provided:

```
EXECUTE [IMMEDIATE] command-string [ INTO [STRICT] target ]
[ USING expression [, ... ] ];
```

where *command-string* is an expression yielding a string (of type `text`) containing the command to be executed. The optional *target* is a record variable, a row variable, or a comma-separated list of simple variables and record/row fields, into which the results of the command will be stored. The optional `USING` expressions supply values to be inserted into the command.

No substitution of PL/pgSQL variables is done on the computed command string. Any required variable values must be inserted in the command string as it is constructed; or you can use parameters as described below.

Also, there is no plan caching for commands executed via EXECUTE. Instead, the command is always planned each time the statement is run. Thus the command string can be dynamically created within the function to perform actions on different tables and columns.

The INTO clause specifies where the results of a SQL command returning rows should be assigned. If a row or variable list is provided, it must exactly match the structure of the query's results (when a record variable is used, it will configure itself to match the result structure automatically). If multiple rows are returned, only the first will be assigned to the INTO variable. If no rows are returned, NULL is assigned to the INTO variable(s). If no INTO clause is specified, the query results are discarded.

If the STRICT option is given, an error is reported unless the query produces exactly one row.

The command string can use parameter values, which are referenced in the command as \$1, \$2, etc. These symbols refer to values supplied in the USING clause. This method is often preferable to inserting data values into the command string as text: it avoids run-time overhead of converting the values to text and back, and it is much less prone to SQL-injection attacks since there is no need for quoting or escaping. An example is:

```
EXECUTE 'SELECT count(*) FROM mytable WHERE inserted_by = $1 AND
        inserted <= $2'
        INTO c
        USING checked_user, checked_date;
```

Note that parameter symbols can only be used for data values — if you want to use dynamically determined table or column names, you must insert them into the command string textually. For example, if the preceding query needed to be done against a dynamically selected table, you could do this:

```
EXECUTE 'SELECT count(*) FROM '
        || quote_ident(tabname)
        || ' WHERE inserted_by = $1 AND inserted <= $2'
        INTO c
        USING checked_user, checked_date;
```

A cleaner approach is to use format()'s %I specification for table or column names (strings separated by a newline are concatenated):

```
EXECUTE format('SELECT count(*) FROM %I '
               'WHERE inserted_by = $1 AND inserted <= $2', tabname)
        INTO c
        USING checked_user, checked_date;
```

Another restriction on parameter symbols is that they only work in SELECT, INSERT, UPDATE, and DELETE commands. In other statement types (generically called utility statements), you must insert values textually even if they are just data values.

An EXECUTE with a simple constant command string and some USING parameters, as in the first example above, is functionally equivalent to just writing the command directly in PL/pgSQL and allowing replacement of PL/pgSQL variables to happen automatically. The important difference is that EXECUTE will re-plan the command on each execution, generating a plan that is specific to the current parameter values; whereas PL/pgSQL may otherwise create a generic plan and cache it for reuse. In situations where the best plan depends strongly on the parameter values, it can be helpful to use EXECUTE to positively ensure that a generic plan is not selected.

`SELECT INTO` is not currently supported within `EXECUTE`; instead, execute a plain `SELECT` command and specify `INTO` as part of the `EXECUTE` itself.

In order to be compatible with Oracle databases, LightDB supports `EXECUTE IMMEDIATE` syntax, which is currently only syntactic sugar.

### Note

The PL/pgSQL `EXECUTE` statement is not related to the `EXECUTE SQL` statement supported by the LightDB server. The server's `EXECUTE` statement cannot be used directly within PL/pgSQL functions (and is not needed).

## Example 41.1. Quoting Values in Dynamic Queries

When working with dynamic commands you will often have to handle escaping of single quotes. The recommended method for quoting fixed text in your function body is dollar quoting. (If you have legacy code that does not use dollar quoting, please refer to the overview in Section 41.12.1, which can save you some effort when translating said code to a more reasonable scheme.)

Dynamic values require careful handling since they might contain quote characters. An example using `format()` (this assumes that you are dollar quoting the function body so quote marks need not be doubled):

```
EXECUTE format('UPDATE tbl SET %I = $1 '
              'WHERE key = $2', colname) USING newvalue, keyvalue;
```

It is also possible to call the quoting functions directly:

```
EXECUTE 'UPDATE tbl SET '
        || quote_ident(colname)
        || ' = '
        || quote_literal(newvalue)
        || ' WHERE key = '
        || quote_literal(keyvalue);
```

This example demonstrates the use of the `quote_ident` and `quote_literal` functions (see Section 9.4). For safety, expressions containing column or table identifiers should be passed through `quote_ident` before insertion in a dynamic query. Expressions containing values that should be literal strings in the constructed command should be passed through `quote_literal`. These functions take the appropriate steps to return the input text enclosed in double or single quotes respectively, with any embedded special characters properly escaped.

Because `quote_literal` is labeled `STRICT`, it will always return null when called with a null argument. In the above example, if `newvalue` or `keyvalue` were null, the entire dynamic query string would become null, leading to an error from `EXECUTE`. You can avoid this problem by using the `quote_nullable` function, which works the same as `quote_literal` except that when called with a null argument it returns the string `NULL`. For example,

```
EXECUTE 'UPDATE tbl SET '
        || quote_ident(colname)
        || ' = '
        || quote_nullable(newvalue)
        || ' WHERE key = ';
```

```
|| quote_nullable(keyvalue);
```

If you are dealing with values that might be null, you should usually use `quote_nullable` in place of `quote_literal`.

As always, care must be taken to ensure that null values in a query do not deliver unintended results. For example the `WHERE` clause

```
'WHERE key = ' || quote_nullable(keyvalue)
```

will never succeed if `keyvalue` is null, because the result of using the equality operator `=` with a null operand is always null. If you wish null to work like an ordinary key value, you would need to rewrite the above as

```
'WHERE key IS NOT DISTINCT FROM ' || quote_nullable(keyvalue)
```

(At present, `IS NOT DISTINCT FROM` is handled much less efficiently than `=`, so don't do this unless you must. See Section 9.2 for more information on nulls and `IS DISTINCT`.)

Note that dollar quoting is only useful for quoting fixed text. It would be a very bad idea to try to write this example as:

```
EXECUTE 'UPDATE tbl SET '
      || quote_ident(colname)
      || ' = $$'
      || newvalue
      || '$$ WHERE key = '
      || quote_literal(keyvalue);
```

because it would break if the contents of `newvalue` happened to contain `$$`. The same objection would apply to any other dollar-quoting delimiter you might pick. So, to safely quote text that is not known in advance, you *must* use `quote_literal`, `quote_nullable`, or `quote_ident`, as appropriate.

Dynamic SQL statements can also be safely constructed using the `format` function (see Section 9.4.1). For example:

```
EXECUTE format('UPDATE tbl SET %I = %L '
      'WHERE key = %L', colname, newvalue, keyvalue);
```

`%I` is equivalent to `quote_ident`, and `%L` is equivalent to `quote_nullable`. The `format` function can be used in conjunction with the `USING` clause:

```
EXECUTE format('UPDATE tbl SET %I = $1 WHERE key = $2', colname)
      USING newvalue, keyvalue;
```

This form is better because the variables are handled in their native data type format, rather than unconditionally converting them to text and quoting them via `%L`. It is also more efficient.

A much larger example of a dynamic command and `EXECUTE` can be seen in Example 41.10, which builds and executes a `CREATE FUNCTION` command to define a new function.

Example of the use of `EXECUTE IMMEDIATE`.

```
-- create table
CREATE TABLE test_employees (
    employee_id SERIAL PRIMARY KEY,
    first_name VARCHAR(50)
);
INSERT INTO test_employees (first_name) VALUES ('John'), ('Jane'),
('Alice'), ('Bob'), ('David');

-- create function
CREATE OR REPLACE FUNCTION get_employee_name_func(p_employee_id
INTEGER)
RETURNS VARCHAR AS $$
DECLARE
    sql_query TEXT;
    emp_name VARCHAR;
BEGIN
    sql_query := 'SELECT first_name FROM test_employees WHERE
employee_id = $1';
    EXECUTE IMMEDIATE sql_query INTO emp_name USING p_employee_id;

    RAISE NOTICE 'Employee name is: %', emp_name;
    RETURN emp_name;
END;
$$ LANGUAGE plpgsql;
```

## 41.5.5. Obtaining the Result Status

There are several ways to determine the effect of a command. The first method is to use the GET DIAGNOSTICS command, which has the form:

```
GET [ CURRENT ] DIAGNOSTICS variable { = | := } item [ , ... ];
```

This command allows retrieval of system status indicators. CURRENT is a noise word (but see also GET STACKED DIAGNOSTICS in Section 41.6.8.1). Each *item* is a key word identifying a status value to be assigned to the specified *variable* (which should be of the right data type to receive it). The currently available status items are shown in Table 41.1. Colon-equal (:=) can be used instead of the SQL-standard = token. An example:

```
GET DIAGNOSTICS integer_var = ROW_COUNT;
```

**Table 41.1. Available Diagnostics Items**

Name	Type	Description
ROW_COUNT	bigint	the number of rows processed by the most recent SQL command
PG_CONTEXT	text	line(s) of text describing the current call stack (see Section 41.6.9)

The second method to determine the effects of a command is to check the special variable named FOUND, which is of type boolean. FOUND starts out false within each PL/pgSQL function call. It is set by each of the following types of statements:

- A SELECT INTO statement sets FOUND true if a row is assigned, false if no row is returned.
- A PERFORM statement sets FOUND true if it produces (and discards) one or more rows, false if no row is produced.

- UPDATE, INSERT, and DELETE statements set FOUND true if at least one row is affected, false if no row is affected.
- A FETCH statement sets FOUND true if it returns a row, false if no row is returned.
- A MOVE statement sets FOUND true if it successfully repositions the cursor, false otherwise.
- A FOR or FOREACH statement sets FOUND true if it iterates one or more times, else false. FOUND is set this way when the loop exits; inside the execution of the loop, FOUND is not modified by the loop statement, although it might be changed by the execution of other statements within the loop body.
- RETURN QUERY and RETURN QUERY EXECUTE statements set FOUND true if the query returns at least one row, false if no row is returned.

Other PL/pgSQL statements do not change the state of FOUND. Note in particular that EXECUTE changes the output of GET DIAGNOSTICS, but does not change FOUND.

FOUND is a local variable within each PL/pgSQL function; any changes to it affect only the current function.

## 41.5.6. Doing Nothing At All

Sometimes a placeholder statement that does nothing is useful. For example, it can indicate that one arm of an if/then/else chain is deliberately empty. For this purpose, use the NULL statement:

```
NULL;
```

For example, the following two fragments of code are equivalent:

```
BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN
        NULL; -- ignore the error
END;
```

```
BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN -- ignore the error
END;
```

Which is preferable is a matter of taste.

### Note

In Oracle's PL/SQL, empty statement lists are not allowed, and so NULL statements are *required* for situations such as this. PL/pgSQL allows you to just write nothing, instead.

## 41.6. Control Structures

Control structures are probably the most useful (and important) part of PL/pgSQL. With PL/pgSQL's control structures, you can manipulate LightDB data in a very flexible and powerful way.



## 41.6.1. Returning from a Function

There are two commands available that allow you to return data from a function: `RETURN` and `RETURN NEXT`.

### 41.6.1.1. RETURN

```
RETURN expression;
```

`RETURN` with an expression terminates the function and returns the value of *expression* to the caller. This form is used for PL/pgSQL functions that do not return a set.

In a function that returns a scalar type, the expression's result will automatically be cast into the function's return type as described for assignments. But to return a composite (row) value, you must write an expression delivering exactly the requested column set. This may require use of explicit casting.

If you declared the function with output parameters, write just `RETURN` with no expression. The current values of the output parameter variables will be returned.

If you declared the function to return `void`, a `RETURN` statement can be used to exit the function early; but do not write an expression following `RETURN`.

The return value of a function cannot be left undefined. If control reaches the end of the top-level block of the function without hitting a `RETURN` statement, a run-time error will occur. This restriction does not apply to functions with output parameters and functions returning `void`, however. In those cases a `RETURN` statement is automatically executed if the top-level block finishes.

Some examples:

```
-- functions returning a scalar type
RETURN 1 + 2;
RETURN scalar_var;

-- functions returning a composite type
RETURN composite_type_var;
RETURN (1, 2, 'three'::text); -- must cast columns to correct
types
```

### 41.6.1.2. RETURN NEXT and RETURN QUERY

```
RETURN NEXT expression;
RETURN QUERY query;
RETURN QUERY EXECUTE command-string [ USING expression [, ... ] ];
```

When a PL/pgSQL function is declared to return `SETOF sometype`, the procedure to follow is slightly different. In that case, the individual items to return are specified by a sequence of `RETURN NEXT` or `RETURN QUERY` commands, and then a final `RETURN` command with no argument is used to indicate that the function has finished executing. `RETURN NEXT` can be used with both scalar and composite data types; with a composite result type, an entire “table” of results will be returned. `RETURN QUERY` appends the results of executing a query to the function's result set. `RETURN NEXT` and `RETURN QUERY` can be freely intermixed in a single set-returning function, in which case their results will be concatenated.

`RETURN NEXT` and `RETURN QUERY` do not actually return from the function — they simply append zero or more rows to the function's result set. Execution then continues with the next statement in the

PL/pgSQL function. As successive `RETURN NEXT` or `RETURN QUERY` commands are executed, the result set is built up. A final `RETURN`, which should have no argument, causes control to exit the function (or you can just let control reach the end of the function).

`RETURN QUERY` has a variant `RETURN QUERY EXECUTE`, which specifies the query to be executed dynamically. Parameter expressions can be inserted into the computed query string via `USING`, in just the same way as in the `EXECUTE` command.

If you declared the function with output parameters, write just `RETURN NEXT` with no expression. On each execution, the current values of the output parameter variable(s) will be saved for eventual return as a row of the result. Note that you must declare the function as returning `SETOF record` when there are multiple output parameters, or `SETOF sometype` when there is just one output parameter of type *sometype*, in order to create a set-returning function with output parameters.

Here is an example of a function using `RETURN NEXT`:

```
CREATE TABLE foo (fooid INT, foosubid INT, fooname TEXT);
INSERT INTO foo VALUES (1, 2, 'three');
INSERT INTO foo VALUES (4, 5, 'six');

CREATE OR REPLACE FUNCTION get_all_foo() RETURNS SETOF foo AS
$BODY$
DECLARE
    r foo%rowtype;
BEGIN
    FOR r IN
        SELECT * FROM foo WHERE fooid > 0
    LOOP
        -- can do some processing here
        RETURN NEXT r; -- return current row of SELECT
    END LOOP;
    RETURN;
END;
$BODY$
LANGUAGE plpgsql;

SELECT * FROM get_all_foo();
```

Here is an example of a function using `RETURN QUERY`:

```
CREATE FUNCTION get_available_flightid(date) RETURNS SETOF integer
AS
$BODY$
BEGIN
    RETURN QUERY SELECT flightid
                  FROM flight
                  WHERE flightdate >= $1
                     AND flightdate < ($1 + 1);

    -- Since execution is not finished, we can check whether rows
    were returned
    -- and raise exception if not.
    IF NOT FOUND THEN
        RAISE EXCEPTION 'No flight at %.', $1;
    END IF;

    RETURN;
```

```

END;
$BODY$
LANGUAGE plpgsql;

-- Returns available flights or raises exception if there are no
-- available flights.
SELECT * FROM get_available_flightid(CURRENT_DATE);

```

### Note

The current implementation of `RETURN NEXT` and `RETURN QUERY` stores the entire result set before returning from the function, as discussed above. That means that if a PL/pgSQL function produces a very large result set, performance might be poor: data will be written to disk to avoid memory exhaustion, but the function itself will not return until the entire result set has been generated. A future version of PL/pgSQL might allow users to define set-returning functions that do not have this limitation. Currently, the point at which data begins being written to disk is controlled by the `work_mem` configuration variable. Administrators who have sufficient memory to store larger result sets in memory should consider increasing this parameter.

## 41.6.2. Returning from a Procedure

A procedure does not have a return value. A procedure can therefore end without a `RETURN` statement. If you wish to use a `RETURN` statement to exit the code early, write just `RETURN` with no expression.

If the procedure has output parameters, the final values of the output parameter variables will be returned to the caller.

## 41.6.3. Calling a Procedure

A PL/pgSQL function, procedure, or `DO` block can call a procedure using `CALL`. Output parameters are handled differently from the way that `CALL` works in plain SQL. Each `INOUT` parameter of the procedure must correspond to a variable in the `CALL` statement, and whatever the procedure returns is assigned back to that variable after it returns. For example:

```

CREATE PROCEDURE triple(INOUT x int)
LANGUAGE plpgsql
AS $$
BEGIN
    x := x * 3;
END;
$$;

DO $$
DECLARE myvar int := 5;
BEGIN
    CALL triple(myvar);
    RAISE NOTICE 'myvar = %', myvar; -- prints 15
END;
$$;

```

## 41.6.4. Conditionals

`IF` and `CASE` statements let you execute alternative commands based on certain conditions. PL/pgSQL has three forms of `IF`:

- IF ... THEN ... END IF
- IF ... THEN ... ELSE ... END IF
- IF ... THEN ... ELSIF ... THEN ... ELSE ... END IF

and two forms of CASE:

- CASE ... WHEN ... THEN ... ELSE ... END CASE
- CASE WHEN ... THEN ... ELSE ... END CASE

#### 41.6.4.1. IF-THEN

```
IF boolean-expression THEN
    statements
END IF;
```

IF-THEN statements are the simplest form of IF. The statements between THEN and END IF will be executed if the condition is true. Otherwise, they are skipped.

Example:

```
IF v_user_id <> 0 THEN
    UPDATE users SET email = v_email WHERE user_id = v_user_id;
END IF;
```

#### 41.6.4.2. IF-THEN-ELSE

```
IF boolean-expression THEN
    statements
ELSE
    statements
END IF;
```

IF-THEN-ELSE statements add to IF-THEN by letting you specify an alternative set of statements that should be executed if the condition is not true. (Note this includes the case where the condition evaluates to NULL.)

Examples:

```
IF parentid IS NULL OR parentid = ''
THEN
    RETURN fullname;
ELSE
    RETURN hp_true_filename(parentid) || '/' || fullname;
END IF;
```

```
IF v_count > 0 THEN
    INSERT INTO users_count (count) VALUES (v_count);
    RETURN 't';
ELSE
    RETURN 'f';
END IF;
```

### 41.6.4.3. IF-THEN-ELSIF

```

IF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
    ...
]
]
[ ELSE
    statements ]
END IF;

```

Sometimes there are more than just two alternatives. IF-THEN-ELSIF provides a convenient method of checking several alternatives in turn. The IF conditions are tested successively until the first one that is true is found. Then the associated statement(s) are executed, after which control passes to the next statement after END IF. (Any subsequent IF conditions are *not* tested.) If none of the IF conditions is true, then the ELSE block (if any) is executed.

Here is an example:

```

IF number = 0 THEN
    result := 'zero';
ELSIF number > 0 THEN
    result := 'positive';
ELSIF number < 0 THEN
    result := 'negative';
ELSE
    -- hmm, the only other possibility is that number is null
    result := 'NULL';
END IF;

```

The key word ELSIF can also be spelled ELSEIF.

An alternative way of accomplishing the same task is to nest IF-THEN-ELSE statements, as in the following example:

```

IF demo_row.sex = 'm' THEN
    pretty_sex := 'man';
ELSE
    IF demo_row.sex = 'f' THEN
        pretty_sex := 'woman';
    END IF;
END IF;

```

However, this method requires writing a matching END IF for each IF, so it is much more cumbersome than using ELSIF when there are many alternatives.

### 41.6.4.4. Simple CASE

```

CASE search-expression
    WHEN expression [, expression [ ... ]] THEN
        statements
    [ WHEN expression [, expression [ ... ]] THEN

```

```

        statements
    ... ]
[ ELSE
    statements ]
END CASE;
```

The simple form of CASE provides conditional execution based on equality of operands. The *search-expression* is evaluated (once) and successively compared to each *expression* in the WHEN clauses. If a match is found, then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no match is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE\_NOT\_FOUND exception is raised.

Here is a simple example:

```

CASE x
  WHEN 1, 2 THEN
    msg := 'one or two';
  ELSE
    msg := 'other value than one or two';
END CASE;
```

#### 41.6.4.5. Searched CASE

```

CASE
  WHEN boolean-expression THEN
    statements
  [ WHEN boolean-expression THEN
    statements
    ... ]
  [ ELSE
    statements ]
END CASE;
```

The searched form of CASE provides conditional execution based on truth of Boolean expressions. Each WHEN clause's *boolean-expression* is evaluated in turn, until one is found that yields true. Then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no true result is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE\_NOT\_FOUND exception is raised.

Here is an example:

```

CASE
  WHEN x BETWEEN 0 AND 10 THEN
    msg := 'value is between zero and ten';
  WHEN x BETWEEN 11 AND 20 THEN
    msg := 'value is between eleven and twenty';
END CASE;
```

This form of CASE is entirely equivalent to IF-THEN-ELSIF, except for the rule that reaching an omitted ELSE clause results in an error rather than doing nothing.

#### 41.6.5. Simple Loops

With the LOOP, EXIT, CONTINUE, WHILE, FOR, and FOREACH statements, you can arrange for your PL/pgSQL function to repeat a series of commands.

### 41.6.5.1. LOOP

```
[ <<label>> ]
LOOP
    statements
END LOOP [ label ];
```

LOOP defines an unconditional loop that is repeated indefinitely until terminated by an EXIT or RETURN statement. The optional *label* can be used by EXIT and CONTINUE statements within nested loops to specify which loop those statements refer to.

### 41.6.5.2. EXIT

```
EXIT [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the innermost loop is terminated and the statement following END LOOP is executed next. If *label* is given, it must be the label of the current or some outer level of nested loop or block. Then the named loop or block is terminated and control continues with the statement after the loop's/block's corresponding END.

If WHEN is specified, the loop exit occurs only if *boolean-expression* is true. Otherwise, control passes to the statement after EXIT.

EXIT can be used with all types of loops; it is not limited to use with unconditional loops.

When used with a BEGIN block, EXIT passes control to the next statement after the end of the block. Note that a label must be used for this purpose; an unlabeled EXIT is never considered to match a BEGIN block.

Examples:

```
LOOP
    -- some computations
    IF count > 0 THEN
        EXIT; -- exit loop
    END IF;
END LOOP;
```

```
LOOP
    -- some computations
    EXIT WHEN count > 0; -- same result as previous example
END LOOP;
```

```
<<ablock>>
BEGIN
    -- some computations
    IF stocks > 100000 THEN
        EXIT ablock; -- causes exit from the BEGIN block
    END IF;
    -- computations here will be skipped when stocks > 100000
END;
```

### 41.6.5.3. CONTINUE

```
CONTINUE [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the next iteration of the innermost loop is begun. That is, all statements remaining in the loop body are skipped, and control returns to the loop control expression (if any) to determine whether another loop iteration is needed. If *label* is present, it specifies the label of the loop whose execution will be continued.

If **WHEN** is specified, the next iteration of the loop is begun only if *boolean-expression* is true. Otherwise, control passes to the statement after **CONTINUE**.

**CONTINUE** can be used with all types of loops; it is not limited to use with unconditional loops.

Examples:

```
LOOP
  -- some computations
  EXIT WHEN count > 100;
  CONTINUE WHEN count < 50;
  -- some computations for count IN [50 .. 100]
END LOOP;
```

#### 41.6.5.4. WHILE

```
[ <<label>> ]
WHILE boolean-expression LOOP
  statements
END LOOP [ label ];
```

The **WHILE** statement repeats a sequence of statements so long as the *boolean-expression* evaluates to true. The expression is checked just before each entry to the loop body.

For example:

```
WHILE amount_owed > 0 AND gift_certificate_balance > 0 LOOP
  -- some computations here
END LOOP;

WHILE NOT done LOOP
  -- some computations here
END LOOP;
```

#### 41.6.5.5. FOR (Integer Variant)

```
[ <<label>> ]
FOR name IN [ REVERSE ] expression .. expression [ BY expression ]
LOOP
  statements
END LOOP [ label ];
```

This form of **FOR** creates a loop that iterates over a range of integer values. The variable *name* is automatically defined as type `integer` and exists only inside the loop (any existing definition of the variable name is ignored within the loop). The two expressions giving the lower and upper bound of the range are evaluated once when entering the loop. If the **BY** clause isn't specified the iteration step is 1, otherwise it's the value specified in the **BY** clause, which again is evaluated once on loop entry. If **REVERSE** is specified then the step value is subtracted, rather than added, after each iteration.

Some examples of integer **FOR** loops:



```
FOR i IN 1..10 LOOP
    -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the
    loop
END LOOP;
```

```
FOR i IN REVERSE 10..1 LOOP
    -- i will take on the values 10,9,8,7,6,5,4,3,2,1 within the
    loop
END LOOP;
```

```
FOR i IN REVERSE 10..1 BY 2 LOOP
    -- i will take on the values 10,8,6,4,2 within the loop
END LOOP;
```

If the lower bound is greater than the upper bound (or less than, in the REVERSE case), the loop body is not executed at all. No error is raised.

If a *label* is attached to the FOR loop then the integer loop variable can be referenced with a qualified name, using that *label*.

## 41.6.6. Looping through Query Results

Using a different type of FOR loop, you can iterate through the results of a query and manipulate that data accordingly. The syntax is:

```
[ <<label>> ]
FOR target IN query LOOP
    statements
END LOOP [ label ];
```

The *target* is a record variable, row variable, or comma-separated list of scalar variables. The *target* is successively assigned each row resulting from the *query* and the loop body is executed for each row. Here is an example:

```
CREATE FUNCTION refresh_mvviews() RETURNS integer AS $$
DECLARE
    mvviews RECORD;
BEGIN
    RAISE NOTICE 'Refreshing all materialized views...';

    FOR mvviews IN
        SELECT n.nspname AS mv_schema,
               c.relname AS mv_name,
               pg_catalog.pg_get_userbyid(c.relowner) AS owner
        FROM pg_catalog.pg_class c
        LEFT JOIN pg_catalog.pg_namespace n ON (n.oid = c.relnamespace)
        WHERE c.relkind = 'm'
        ORDER BY 1
    LOOP

        -- Now "mvviews" has one record with information about the
        materialized view

        RAISE NOTICE 'Refreshing materialized view %.% (owner:
        %)...',
                       quote_ident(mvviews.mv_schema),
                       quote_ident(mvviews.mv_name),
```

```

        quote_ident(mviews.owner);
        EXECUTE format('REFRESH MATERIALIZED VIEW %I.%I',
mviews.mv_schema, mviews.mv_name);
    END LOOP;

    RAISE NOTICE 'Done refreshing materialized views.';
    RETURN 1;
END;
$$ LANGUAGE plpgsql;

```

If the loop is terminated by an EXIT statement, the last assigned row value is still accessible after the loop.

The *query* used in this type of FOR statement can be any SQL command that returns rows to the caller: SELECT is the most common case, but you can also use INSERT, UPDATE, or DELETE with a RETURNING clause. Some utility commands such as EXPLAIN will work too.

PL/pgSQL variables are substituted into the query text, and the query plan is cached for possible reuse, as discussed in detail in Section 41.11.1 and Section 41.11.2.

The FOR-IN-EXECUTE statement is another way to iterate over rows:

```

[ <<label>> ]
FOR target IN EXECUTE text_expression [ USING expression [, ... ] ]
LOOP
    statements
END LOOP [ label ];

```

This is like the previous form, except that the source query is specified as a string expression, which is evaluated and replanned on each entry to the FOR loop. This allows the programmer to choose the speed of a preplanned query or the flexibility of a dynamic query, just as with a plain EXECUTE statement. As with EXECUTE, parameter values can be inserted into the dynamic command via USING.

Another way to specify the query whose results should be iterated through is to declare it as a cursor. This is described in Section 41.7.4.

## 41.6.7. Looping through Arrays

The FOREACH loop is much like a FOR loop, but instead of iterating through the rows returned by a SQL query, it iterates through the elements of an array value. (In general, FOREACH is meant for looping through components of a composite-valued expression; variants for looping through composites besides arrays may be added in future.) The FOREACH statement to loop over an array is:

```

[ <<label>> ]
FOREACH target [ SLICE number ] IN ARRAY expression LOOP
    statements
END LOOP [ label ];

```

Without SLICE, or if SLICE 0 is specified, the loop iterates through individual elements of the array produced by evaluating the *expression*. The *target* variable is assigned each element value in sequence, and the loop body is executed for each element. Here is an example of looping through the elements of an integer array:

```

CREATE FUNCTION sum(int[]) RETURNS int8 AS $$
DECLARE
    s int8 := 0;

```

```

    x int;
BEGIN
    FOREACH x IN ARRAY $1
    LOOP
        s := s + x;
    END LOOP;
    RETURN s;
END;
$$ LANGUAGE plpgsql;

```

The elements are visited in storage order, regardless of the number of array dimensions. Although the *target* is usually just a single variable, it can be a list of variables when looping through an array of composite values (records). In that case, for each array element, the variables are assigned from successive columns of the composite value.

With a positive *SLICE* value, *FOREACH* iterates through slices of the array rather than single elements. The *SLICE* value must be an integer constant not larger than the number of dimensions of the array. The *target* variable must be an array, and it receives successive slices of the array value, where each slice is of the number of dimensions specified by *SLICE*. Here is an example of iterating through one-dimensional slices:

```

CREATE FUNCTION scan_rows(int[]) RETURNS void AS $$
DECLARE
    x int[];
BEGIN
    FOREACH x SLICE 1 IN ARRAY $1
    LOOP
        RAISE NOTICE 'row = %', x;
    END LOOP;
END;
$$ LANGUAGE plpgsql;

SELECT scan_rows(ARRAY[[1,2,3],[4,5,6],[7,8,9],[10,11,12]]);

NOTICE:  row = {1,2,3}
NOTICE:  row = {4,5,6}
NOTICE:  row = {7,8,9}
NOTICE:  row = {10,11,12}

```

## 41.6.8. Trapping Errors

By default, any error occurring in a PL/pgSQL function aborts execution of the function and the surrounding transaction. You can trap errors and recover from them by using a *BEGIN* block with an *EXCEPTION* clause. The syntax is an extension of the normal syntax for a *BEGIN* block:

```

[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
EXCEPTION
    WHEN condition [ OR condition ... ] THEN
        handler_statements
    [ WHEN condition [ OR condition ... ] THEN
        handler_statements
    ... ]
END;

```

If no error occurs, this form of block simply executes all the *statements*, and then control passes to the next statement after `END`. But if an error occurs within the *statements*, further processing of the *statements* is abandoned, and control passes to the `EXCEPTION` list. The list is searched for the first *condition* matching the error that occurred. If a match is found, the corresponding *handler\_statements* are executed, and then control passes to the next statement after `END`. If no match is found, the error propagates out as though the `EXCEPTION` clause were not there at all: the error can be caught by an enclosing block with `EXCEPTION`, or if there is none it aborts processing of the function.

The *condition* names can be any of those shown in Appendix A. A category name matches any error within its category. The special condition name `OTHERS` matches every error type except `QUERY_CANCELED` and `ASSERT_FAILURE`. (It is possible, but often unwise, to trap those two error types by name.) Condition names are not case-sensitive. Also, an error condition can be specified by `SQLSTATE` code; for example these are equivalent:

```
WHEN division_by_zero THEN ...
WHEN SQLSTATE '22012' THEN ...
```

If a new error occurs within the selected *handler\_statements*, it cannot be caught by this `EXCEPTION` clause, but is propagated out. A surrounding `EXCEPTION` clause could catch it.

When an error is caught by an `EXCEPTION` clause, the local variables of the PL/pgSQL function remain as they were when the error occurred, but all changes to persistent database state within the block are rolled back. As an example, consider this fragment:

```
INSERT INTO mytab(firstname, lastname) VALUES('Tom', 'Jones');
BEGIN
    UPDATE mytab SET firstname = 'Joe' WHERE lastname = 'Jones';
    x := x + 1;
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN
        RAISE NOTICE 'caught division_by_zero';
        RETURN x;
END;
```

When control reaches the assignment to `y`, it will fail with a `division_by_zero` error. This will be caught by the `EXCEPTION` clause. The value returned in the `RETURN` statement will be the incremented value of `x`, but the effects of the `UPDATE` command will have been rolled back. The `INSERT` command preceding the block is not rolled back, however, so the end result is that the database contains Tom Jones not Joe Jones.

### Tip

A block containing an `EXCEPTION` clause is significantly more expensive to enter and exit than a block without one. Therefore, don't use `EXCEPTION` without need.

### Example 41.2. Exceptions with `UPDATE/INSERT`

This example uses exception handling to perform either `UPDATE` or `INSERT`, as appropriate. It is recommended that applications use `INSERT` with `ON CONFLICT DO UPDATE` rather than actually using this pattern. This example serves primarily to illustrate use of PL/pgSQL control flow structures:

```
CREATE TABLE db (a INT PRIMARY KEY, b TEXT);
```

```

CREATE FUNCTION merge_db(key INT, data TEXT) RETURNS VOID AS
$$
BEGIN
    LOOP
        -- first try to update the key
        UPDATE db SET b = data WHERE a = key;
        IF found THEN
            RETURN;
        END IF;
        -- not there, so try to insert the key
        -- if someone else inserts the same key concurrently,
        -- we could get a unique-key failure
        BEGIN
            INSERT INTO db(a,b) VALUES (key, data);
            RETURN;
        EXCEPTION WHEN unique_violation THEN
            -- Do nothing, and loop to try the UPDATE again.
        END;
    END LOOP;
END;
$$
LANGUAGE plpgsql;

SELECT merge_db(1, 'david');
SELECT merge_db(1, 'dennis');

```

This coding assumes the `unique_violation` error is caused by the `INSERT`, and not by, say, an `INSERT` in a trigger function on the table. It might also misbehave if there is more than one unique index on the table, since it will retry the operation regardless of which index caused the error. More safety could be had by using the features discussed next to check that the trapped error was the one expected.

### 41.6.8.1. Obtaining Information about an Error

Exception handlers frequently need to identify the specific error that occurred. There are two ways to get information about the current exception in PL/pgSQL: special variables and the `GET STACKED DIAGNOSTICS` command.

Within an exception handler, the special variable `SQLSTATE` contains the error code that corresponds to the exception that was raised (refer to Table A.1 for a list of possible error codes). The special variable `SQLERRM` contains the error message associated with the exception. These variables are undefined outside exception handlers.

Within an exception handler, one may also retrieve information about the current exception by using the `GET STACKED DIAGNOSTICS` command, which has the form:

```
GET STACKED DIAGNOSTICS variable { = | := } item [ , ... ];
```

Each *item* is a key word identifying a status value to be assigned to the specified *variable* (which should be of the right data type to receive it). The currently available status items are shown in Table 41.2.

**Table 41.2. Error Diagnostics Items**

Name	Type	Description
RETURNED_SQLSTATE	text	the SQLSTATE error code of the exception

Name	Type	Description
COLUMN_NAME	text	the name of the column related to exception
CONSTRAINT_NAME	text	the name of the constraint related to exception
PG_DATATYPE_NAME	text	the name of the data type related to exception
MESSAGE_TEXT	text	the text of the exception's primary message
TABLE_NAME	text	the name of the table related to exception
SCHEMA_NAME	text	the name of the schema related to exception
PG_EXCEPTION_DETAIL	text	the text of the exception's detail message, if any
PG_EXCEPTION_HINT	text	the text of the exception's hint message, if any
PG_EXCEPTION_CONTEXT	text	line(s) of text describing the call stack at the time of the exception (see Section 41.6.9)

If the exception did not set a value for an item, an empty string will be returned.

Here is an example:

```

DECLARE
    text_var1 text;
    text_var2 text;
    text_var3 text;
BEGIN
    -- some processing which might cause an exception
    ...
EXCEPTION WHEN OTHERS THEN
    GET STACKED DIAGNOSTICS text_var1 = MESSAGE_TEXT,
                           text_var2 = PG_EXCEPTION_DETAIL,
                           text_var3 = PG_EXCEPTION_HINT;
END;
```

## 41.6.9. Obtaining Execution Location Information

The `GET DIAGNOSTICS` command, previously described in Section 41.5.5, retrieves information about current execution state (whereas the `GET STACKED DIAGNOSTICS` command discussed above reports information about the execution state as of a previous error). Its `PG_CONTEXT` status item is useful for identifying the current execution location. `PG_CONTEXT` returns a text string with line(s) of text describing the call stack. The first line refers to the current function and currently executing `GET DIAGNOSTICS` command. The second and any subsequent lines refer to calling functions further up the call stack. For example:

```

CREATE OR REPLACE FUNCTION outer_func() RETURNS integer AS $$
BEGIN
    RETURN inner_func();
END;
$$ LANGUAGE plpgsql;
```

```
CREATE OR REPLACE FUNCTION inner_func() RETURNS integer AS $$
DECLARE
    stack text;
BEGIN
    GET DIAGNOSTICS stack = PG_CONTEXT;
    RAISE NOTICE E'--- Call Stack ---\n%', stack;
    RETURN 1;
END;
$$ LANGUAGE plpgsql;
```

```
SELECT outer_func();
```

```
NOTICE: --- Call Stack ---
PL/pgSQL function inner_func() line 5 at GET DIAGNOSTICS
PL/pgSQL function outer_func() line 3 at RETURN
CONTEXT: PL/pgSQL function outer_func() line 3 at RETURN
outer_func
-----
          1
(1 row)
```

GET STACKED DIAGNOSTICS ... PG\_EXCEPTION\_CONTEXT returns the same sort of stack trace, but describing the location at which an error was detected, rather than the current location.

## 41.7. Cursors

Rather than executing a whole query at once, it is possible to set up a *cursor* that encapsulates the query, and then read the query result a few rows at a time. One reason for doing this is to avoid memory overrun when the result contains a large number of rows. (However, PL/pgSQL users do not normally need to worry about that, since FOR loops automatically use a cursor internally to avoid memory problems.) A more interesting usage is to return a reference to a cursor that a function has created, allowing the caller to read the rows. This provides an efficient way to return large row sets from functions.

### 41.7.1. Declaring Cursor Variables

All access to cursors in PL/pgSQL goes through cursor variables, which are always of the special data type `refcursor`. One way to create a cursor variable is just to declare it as a variable of type `refcursor`. Another way is to use the cursor declaration syntax, which in general is:

```
name [ [ NO ] SCROLL ] CURSOR [ ( arguments ) ] FOR query;
```

(FOR can be replaced by IS for Oracle compatibility.) If SCROLL is specified, the cursor will be capable of scrolling backward; if NO SCROLL is specified, backward fetches will be rejected; if neither specification appears, it is query-dependent whether backward fetches will be allowed. *arguments*, if specified, is a comma-separated list of pairs *name datatype* that define names to be replaced by parameter values in the given query. The actual values to substitute for these names will be specified later, when the cursor is opened.

Some examples:

```
DECLARE
    curs1 refcursor;
    curs2 CURSOR FOR SELECT * FROM tenk1;
```

```
curs3 CURSOR (key integer) FOR SELECT * FROM tenk1 WHERE
unique1 = key;
```

All three of these variables have the data type `refcursor`, but the first can be used with any query, while the second has a fully specified query already *bound* to it, and the last has a parameterized query bound to it. (`key` will be replaced by an integer parameter value when the cursor is opened.) The variable `curs1` is said to be *unbound* since it is not bound to any particular query.

The `SCROLL` option cannot be used when the cursor's query uses `FOR UPDATE/SHARE`. Also, it is best to use `NO SCROLL` with a query that involves volatile functions. The implementation of `SCROLL` assumes that re-reading the query's output will give consistent results, which a volatile function might not do.

## 41.7.2. Opening Cursors

Before a cursor can be used to retrieve rows, it must be *opened*. (This is the equivalent action to the SQL command `DECLARE CURSOR`.) PL/pgSQL has three forms of the `OPEN` statement, two of which use unbound cursor variables while the third uses a bound cursor variable.

### Note

Bound cursor variables can also be used without explicitly opening the cursor, via the `FOR` statement described in Section 41.7.4.

### 41.7.2.1. OPEN FOR query

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR query;
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query must be a `SELECT`, or something else that returns rows (such as `EXPLAIN`). The query is treated in the same way as other SQL commands in PL/pgSQL: PL/pgSQL variable names are substituted, and the query plan is cached for possible reuse. When a PL/pgSQL variable is substituted into the cursor query, the value that is substituted is the one it has at the time of the `OPEN`; subsequent changes to the variable will not affect the cursor's behavior. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:

```
OPEN curs1 FOR SELECT * FROM foo WHERE key = mykey;
```

### 41.7.2.2. OPEN FOR EXECUTE

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR EXECUTE query_string
    [ USING expression [, ... ] ];
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query is specified as a string expression, in the same way as in the `EXECUTE` command. As usual, this gives flexibility so the query plan can vary from one run to the next (see Section 41.11.2), and it also means that variable substitution is not done on the command string. As with `EXECUTE`, parameter values can be inserted into the dynamic command via `format()` and `USING`. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:



```
OPEN curs1 FOR EXECUTE format('SELECT * FROM %I WHERE coll =
    $1',tablename) USING keyvalue;
```

In this example, the table name is inserted into the query via `format()`. The comparison value for `coll` is inserted via a `USING` parameter, so it needs no quoting.

### 41.7.2.3. Opening a Bound Cursor

```
OPEN bound_cursorvar [ ( [ argument_name := ] argument_value
    [, ...] ) ];
```

This form of `OPEN` is used to open a cursor variable whose query was bound to it when it was declared. The cursor cannot be open already. A list of actual argument value expressions must appear if and only if the cursor was declared to take arguments. These values will be substituted in the query.

The query plan for a bound cursor is always considered cacheable; there is no equivalent of `EXECUTE` in this case. Notice that `SCROLL` and `NO SCROLL` cannot be specified in `OPEN`, as the cursor's scrolling behavior was already determined.

Argument values can be passed using either *positional* or *named* notation. In positional notation, all arguments are specified in order. In named notation, each argument's name is specified using `:=` to separate it from the argument expression. Similar to calling functions, described in Section 4.3, it is also allowed to mix positional and named notation.

Examples (these use the cursor declaration examples above):

```
OPEN curs2;
OPEN curs3(42);
OPEN curs3(key := 42);
```

Because variable substitution is done on a bound cursor's query, there are really two ways to pass values into the cursor: either with an explicit argument to `OPEN`, or implicitly by referencing a PL/pgSQL variable in the query. However, only variables declared before the bound cursor was declared will be substituted into it. In either case the value to be passed is determined at the time of the `OPEN`. For example, another way to get the same effect as the `curs3` example above is

```
DECLARE
    key integer;
    curs4 CURSOR FOR SELECT * FROM tenk1 WHERE unique1 = key;
BEGIN
    key := 42;
    OPEN curs4;
```

### 41.7.3. Using Cursors

Once a cursor has been opened, it can be manipulated with the statements described here.

These manipulations need not occur in the same function that opened the cursor to begin with. You can return a `refcursor` value out of a function and let the caller operate on the cursor. (Internally, a `refcursor` value is simply the string name of a so-called portal containing the active query for the cursor. This name can be passed around, assigned to other `refcursor` variables, and so on, without disturbing the portal.)

All portals are implicitly closed at transaction end. Therefore a `refcursor` value is usable to reference an open cursor only until the end of the transaction.

### 41.7.3.1. FETCH

```
FETCH [ direction { FROM | IN } ] cursor INTO target;
```

FETCH retrieves the next row from the cursor into a target, which might be a row variable, a record variable, or a comma-separated list of simple variables, just like SELECT INTO. If there is no next row, the target is set to NULL(s). As with SELECT INTO, the special variable FOUND can be checked to see whether a row was obtained or not.

The *direction* clause can be any of the variants allowed in the SQL FETCH command except the ones that can fetch more than one row; namely, it can be NEXT, PRIOR, FIRST, LAST, ABSOLUTE *count*, RELATIVE *count*, FORWARD, or BACKWARD. Omitting *direction* is the same as specifying NEXT. In the forms using a *count*, the *count* can be any integer-valued expression (unlike the SQL FETCH command, which only allows an integer constant). *direction* values that require moving backward are likely to fail unless the cursor was declared or opened with the SCROLL option.

*cursor* must be the name of a refcursor variable that references an open cursor portal.

Examples:

```
FETCH curs1 INTO rowvar;
FETCH curs2 INTO foo, bar, baz;
FETCH LAST FROM curs3 INTO x, y;
FETCH RELATIVE -2 FROM curs4 INTO x;
```

### 41.7.3.2. MOVE

```
MOVE [ direction { FROM | IN } ] cursor;
```

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only repositions the cursor and does not return the row moved to. As with SELECT INTO, the special variable FOUND can be checked to see whether there was a next row to move to.

Examples:

```
MOVE curs1;
MOVE LAST FROM curs3;
MOVE RELATIVE -2 FROM curs4;
MOVE FORWARD 2 FROM curs4;
```

### 41.7.3.3. UPDATE/DELETE WHERE CURRENT OF

```
UPDATE table SET ... WHERE CURRENT OF cursor;
DELETE FROM table WHERE CURRENT OF cursor;
```

When a cursor is positioned on a table row, that row can be updated or deleted using the cursor to identify the row. There are restrictions on what the cursor's query can be (in particular, no grouping) and it's best to use FOR UPDATE in the cursor. For more information see the DECLARE reference page.

An example:

```
UPDATE foo SET dataval = myval WHERE CURRENT OF curs1;
```

#### 41.7.3.4. CLOSE

```
CLOSE cursor;
```

CLOSE closes the portal underlying an open cursor. This can be used to release resources earlier than end of transaction, or to free up the cursor variable to be opened again.

An example:

```
CLOSE curs1;
```

#### 41.7.3.5. Returning Cursors

PL/pgSQL functions can return cursors to the caller. This is useful to return multiple rows or columns, especially with very large result sets. To do this, the function opens the cursor and returns the cursor name to the caller (or simply opens the cursor using a portal name specified by or otherwise known to the caller). The caller can then fetch rows from the cursor. The cursor can be closed by the caller, or it will be closed automatically when the transaction closes.

The portal name used for a cursor can be specified by the programmer or automatically generated. To specify a portal name, simply assign a string to the `refcursor` variable before opening it. The string value of the `refcursor` variable will be used by `OPEN` as the name of the underlying portal. However, if the `refcursor` variable is null, `OPEN` automatically generates a name that does not conflict with any existing portal, and assigns it to the `refcursor` variable.

#### Note

A bound cursor variable is initialized to the string value representing its name, so that the portal name is the same as the cursor variable name, unless the programmer overrides it by assignment before opening the cursor. But an unbound cursor variable defaults to the null value initially, so it will receive an automatically-generated unique name, unless overridden.

The following example shows one way a cursor name can be supplied by the caller:

```
CREATE TABLE test (col text);
INSERT INTO test VALUES ('123');

CREATE FUNCTION reffunc(refcursor) RETURNS refcursor AS '
BEGIN
    OPEN $1 FOR SELECT col FROM test;
    RETURN $1;
END;
' LANGUAGE plpgsql;

BEGIN;
SELECT reffunc('funcursor');
FETCH ALL IN funcursor;
COMMIT;
```

The following example uses automatic cursor name generation:

```

CREATE FUNCTION reffunc2() RETURNS refcursor AS '
DECLARE
    ref refcursor;
BEGIN
    OPEN ref FOR SELECT col FROM test;
    RETURN ref;
END;
' LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;
SELECT reffunc2();

           reffunc2
-----
<unnamed cursor 1>
(1 row)

FETCH ALL IN "<unnamed cursor 1>";
COMMIT;

```

The following example shows one way to return multiple cursors from a single function:

```

CREATE FUNCTION myfunc(refcursor, refcursor) RETURNS SETOF
refcursor AS $$
BEGIN
    OPEN $1 FOR SELECT * FROM table_1;
    RETURN NEXT $1;
    OPEN $2 FOR SELECT * FROM table_2;
    RETURN NEXT $2;
END;
$$ LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;

SELECT * FROM myfunc('a', 'b');

FETCH ALL FROM a;
FETCH ALL FROM b;
COMMIT;

```

## 41.7.4. Looping through a Cursor's Result

There is a variant of the FOR statement that allows iterating through the rows returned by a cursor. The syntax is:

```

[ <<label>> ]
FOR recordvar IN bound_cursorvar [ ( [ argument_name
:= ] argument_value [, ...] ) ] LOOP
    statements
END LOOP [ label ];

```

The cursor variable must have been bound to some query when it was declared, and it *cannot* be open already. The FOR statement automatically opens the cursor, and it closes the cursor again when the loop exits. A list of actual argument value expressions must appear if and only if the cursor was

declared to take arguments. These values will be substituted in the query, in just the same way as during an OPEN (see Section 41.7.2.3).

The variable *recordvar* is automatically defined as type *record* and exists only inside the loop (any existing definition of the variable name is ignored within the loop). Each row returned by the cursor is successively assigned to this record variable and the loop body is executed.

## 41.8. Transaction Management

In procedures invoked by the CALL command as well as in anonymous code blocks (DO command), it is possible to end transactions using the commands COMMIT and ROLLBACK. A new transaction is started automatically after a transaction is ended using these commands, so there is no separate START TRANSACTION command. (Note that BEGIN and END have different meanings in PL/pgSQL.)

Here is a simple example:

```
CREATE PROCEDURE transaction_test1()
LANGUAGE plpgsql
AS $$
BEGIN
    FOR i IN 0..9 LOOP
        INSERT INTO test1 (a) VALUES (i);
        IF i % 2 = 0 THEN
            COMMIT;
        ELSE
            ROLLBACK;
        END IF;
    END LOOP;
END;
$$;

CALL transaction_test1();
```

A new transaction starts out with default transaction characteristics such as transaction isolation level. In cases where transactions are committed in a loop, it might be desirable to start new transactions automatically with the same characteristics as the previous one. The commands COMMIT AND CHAIN and ROLLBACK AND CHAIN accomplish this.

Transaction control is only possible in CALL or DO invocations from the top level or nested CALL or DO invocations without any other intervening command. For example, if the call stack is CALL proc1() → CALL proc2() → CALL proc3(), then the second and third procedures can perform transaction control actions. But if the call stack is CALL proc1() → SELECT func2() → CALL proc3(), then the last procedure cannot do transaction control, because of the SELECT in between.

Special considerations apply to cursor loops. Consider this example:

```
CREATE PROCEDURE transaction_test2()
LANGUAGE plpgsql
AS $$
DECLARE
    r RECORD;
BEGIN
    FOR r IN SELECT * FROM test2 ORDER BY x LOOP
        INSERT INTO test1 (a) VALUES (r.x);
        COMMIT;
    END LOOP;
END;
```

```

        END LOOP;
    END;
    $$;

CALL transaction_test2();

```

Normally, cursors are automatically closed at transaction commit. However, a cursor created as part of a loop like this is automatically converted to a holdable cursor by the first COMMIT or ROLLBACK. That means that the cursor is fully evaluated at the first COMMIT or ROLLBACK rather than row by row. The cursor is still removed automatically after the loop, so this is mostly invisible to the user.

Transaction commands are not allowed in cursor loops driven by commands that are not read-only (for example UPDATE ... RETURNING).

A transaction cannot be ended inside a block with exception handlers.

## 41.9. Errors and Messages

### 41.9.1. Reporting Errors and Messages

Use the RAISE statement to report messages and raise errors.

```

RAISE [ level ] 'format' [, expression [, ... ] ] [ USING option
    = expression [, ... ] ];
RAISE [ level ] condition_name [ USING option = expression
    [, ... ] ];
RAISE [ level ] SQLSTATE 'sqlstate' [ USING option = expression
    [, ... ] ];
RAISE [ level ] USING option = expression [, ... ] ;
RAISE ;

```

The *level* option specifies the error severity. Allowed levels are DEBUG, LOG, INFO, NOTICE, WARNING, and EXCEPTION, with EXCEPTION being the default. EXCEPTION raises an error (which normally aborts the current transaction); the other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log\_min\_messages and client\_min\_messages configuration variables. See Chapter 17 for more information.

After *level* if any, you can specify a *format* string (which must be a simple string literal, not an expression). The format string specifies the error message text to be reported. The format string can be followed by optional argument expressions to be inserted into the message. Inside the format string, % is replaced by the string representation of the next optional argument's value. Write %% to emit a literal %. The number of arguments must match the number of % placeholders in the format string, or an error is raised during the compilation of the function.

In this example, the value of v\_job\_id will replace the % in the string:

```
RAISE NOTICE 'Calling cs_create_job(%)', v_job_id;
```

You can attach additional information to the error report by writing USING followed by *option = expression* items. Each *expression* can be any string-valued expression. The allowed *option* key words are:

MESSAGE

Sets the error message text. This option can't be used in the form of RAISE that includes a format string before USING.

DETAIL

Supplies an error detail message.

HINT

Supplies a hint message.

ERRCODE

Specifies the error code (SQLSTATE) to report, either by condition name, as shown in Appendix A, or directly as a five-character SQLSTATE code.

COLUMN

CONSTRAINT

DATATYPE

TABLE

SCHEMA

Supplies the name of a related object.

This example will abort the transaction with the given error message and hint:

```
RAISE EXCEPTION 'Nonexistent ID --> %', user_id
      USING HINT = 'Please check your user ID';
```

These two examples show equivalent ways of setting the SQLSTATE:

```
RAISE 'Duplicate user ID: %', user_id USING ERRCODE =
      'unique_violation';
RAISE 'Duplicate user ID: %', user_id USING ERRCODE = '23505';
```

There is a second RAISE syntax in which the main argument is the condition name or SQLSTATE to be reported, for example:

```
RAISE division_by_zero;
RAISE SQLSTATE '22012';
```

In this syntax, USING can be used to supply a custom error message, detail, or hint. Another way to do the earlier example is

```
RAISE unique_violation USING MESSAGE = 'Duplicate user ID: ' ||
      user_id;
```

Still another variant is to write RAISE USING or RAISE *level* USING and put everything else into the USING list.

The last variant of RAISE has no parameters at all. This form can only be used inside a BEGIN block's EXCEPTION clause; it causes the error currently being handled to be re-thrown.

**Note**

Before LightDB 9.1, RAISE without parameters was interpreted as re-throwing the error from the block containing the active exception handler. Thus an EXCEPTION clause nested within that handler could not catch it, even if the RAISE was within

the nested `EXCEPTION` clause's block. This was deemed surprising as well as being incompatible with Oracle's PL/SQL.

If no condition name nor `SQLSTATE` is specified in a `RAISE EXCEPTION` command, the default is to use `ERRCODE_RAISE_EXCEPTION` (P0001). If no message text is specified, the default is to use the condition name or `SQLSTATE` as message text.

### Note

When specifying an error code by `SQLSTATE` code, you are not limited to the predefined error codes, but can select any error code consisting of five digits and/or upper-case ASCII letters, other than 00000. It is recommended that you avoid throwing error codes that end in three zeroes, because these are category codes and can only be trapped by trapping the whole category.

## 41.9.2. Checking Assertions

The `ASSERT` statement is a convenient shorthand for inserting debugging checks into PL/pgSQL functions.

```
ASSERT condition [ , message ];
```

The *condition* is a Boolean expression that is expected to always evaluate to true; if it does, the `ASSERT` statement does nothing further. If the result is false or null, then an `ASSERT_FAILURE` exception is raised. (If an error occurs while evaluating the *condition*, it is reported as a normal error.)

If the optional *message* is provided, it is an expression whose result (if not null) replaces the default error message text “assertion failed”, should the *condition* fail. The *message* expression is not evaluated in the normal case where the assertion succeeds.

Testing of assertions can be enabled or disabled via the configuration parameter `plpgsql.check_asserts`, which takes a Boolean value; the default is `on`. If this parameter is `off` then `ASSERT` statements do nothing.

Note that `ASSERT` is meant for detecting program bugs, not for reporting ordinary error conditions. Use the `RAISE` statement, described above, for that.

## 41.10. Trigger Functions

PL/pgSQL can be used to define trigger functions on data changes or database events. A trigger function is created with the `CREATE FUNCTION` command, declaring it as a function with no arguments and a return type of `trigger` (for data change triggers) or `event_trigger` (for database event triggers). Special local variables named `TG_something` are automatically defined to describe the condition that triggered the call.

### 41.10.1. Triggers on Data Changes

A data change trigger is declared as a function with no arguments and a return type of `trigger`. Note that the function must be declared with no arguments even if it expects to receive some arguments specified in `CREATE TRIGGER` — such arguments are passed via `TG_ARGV`, as described below.

When a PL/pgSQL function is called as a trigger, several special variables are created automatically in the top-level block. They are:



NEW

Data type `RECORD`; variable holding the new database row for `INSERT/UPDATE` operations in row-level triggers. This variable is null in statement-level triggers and for `DELETE` operations.

OLD

Data type `RECORD`; variable holding the old database row for `UPDATE/DELETE` operations in row-level triggers. This variable is null in statement-level triggers and for `INSERT` operations.

TG\_NAME

Data type name; variable that contains the name of the trigger actually fired.

TG\_WHEN

Data type `text`; a string of `BEFORE`, `AFTER`, or `INSTEAD OF`, depending on the trigger's definition.

TG\_LEVEL

Data type `text`; a string of either `ROW` or `STATEMENT` depending on the trigger's definition.

TG\_OP

Data type `text`; a string of `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` telling for which operation the trigger was fired.

TG\_RELID

Data type `oid`; the object ID of the table that caused the trigger invocation.

TG\_RELNAME

Data type name; the name of the table that caused the trigger invocation. This is now deprecated, and could disappear in a future release. Use `TG_TABLE_NAME` instead.

TG\_TABLE\_NAME

Data type name; the name of the table that caused the trigger invocation.

TG\_TABLE\_SCHEMA

Data type name; the name of the schema of the table that caused the trigger invocation.

TG\_NARGS

Data type `integer`; the number of arguments given to the trigger function in the `CREATE TRIGGER` statement.

TG\_ARGV[ ]

Data type array of `text`; the arguments from the `CREATE TRIGGER` statement. The index counts from 0. Invalid indexes (less than 0 or greater than or equal to `tg_nargs`) result in a null value.

A trigger function must return either `NULL` or a record/row value having exactly the structure of the table the trigger was fired for.

Row-level triggers fired `BEFORE` can return null to signal the trigger manager to skip the rest of the operation for this row (i.e., subsequent triggers are not fired, and the `INSERT/UPDATE/DELETE` does not occur for this row). If a nonnull value is returned then the operation proceeds with that row value. Returning a row value different from the original value of `NEW` alters the row that will be inserted or

updated. Thus, if the trigger function wants the triggering action to succeed normally without altering the row value, `NEW` (or a value equal thereto) has to be returned. To alter the row to be stored, it is possible to replace single values directly in `NEW` and return the modified `NEW`, or to build a complete new record/row to return. In the case of a before-trigger on `DELETE`, the returned value has no direct effect, but it has to be nonnull to allow the trigger action to proceed. Note that `NEW` is null in `DELETE` triggers, so returning that is usually not sensible. The usual idiom in `DELETE` triggers is to return `OLD`.

`INSTEAD OF` triggers (which are always row-level triggers, and may only be used on views) can return null to signal that they did not perform any updates, and that the rest of the operation for this row should be skipped (i.e., subsequent triggers are not fired, and the row is not counted in the rows-affected status for the surrounding `INSERT/UPDATE/DELETE`). Otherwise a nonnull value should be returned, to signal that the trigger performed the requested operation. For `INSERT` and `UPDATE` operations, the return value should be `NEW`, which the trigger function may modify to support `INSERT RETURNING` and `UPDATE RETURNING` (this will also affect the row value passed to any subsequent triggers, or passed to a special `EXCLUDED` alias reference within an `INSERT` statement with an `ON CONFLICT DO UPDATE` clause). For `DELETE` operations, the return value should be `OLD`.

The return value of a row-level trigger fired `AFTER` or a statement-level trigger fired `BEFORE` or `AFTER` is always ignored; it might as well be null. However, any of these types of triggers might still abort the entire operation by raising an error.

Example 41.3 shows an example of a trigger function in PL/pgSQL.

### Example 41.3. A PL/pgSQL Trigger Function

This example trigger ensures that any time a row is inserted or updated in the table, the current user name and time are stamped into the row. And it checks that an employee's name is given and that the salary is a positive value.

```
CREATE TABLE emp (
    empname text,
    salary integer,
    last_date timestamp,
    last_user text
);

CREATE FUNCTION emp_stamp() RETURNS trigger AS $emp_stamp$
BEGIN
    -- Check that empname and salary are given
    IF NEW.empname IS NULL THEN
        RAISE EXCEPTION 'empname cannot be null';
    END IF;
    IF NEW.salary IS NULL THEN
        RAISE EXCEPTION '% cannot have null salary',
NEW.empname;
    END IF;

    -- Who works for us when they must pay for it?
    IF NEW.salary < 0 THEN
        RAISE EXCEPTION '% cannot have a negative salary',
NEW.empname;
    END IF;

    -- Remember who changed the payroll when
    NEW.last_date := current_timestamp;
    NEW.last_user := current_user;
    RETURN NEW;
END;
```

```
$emp_stamp$ LANGUAGE plpgsql;
```

```
CREATE TRIGGER emp_stamp BEFORE INSERT OR UPDATE ON emp
    FOR EACH ROW EXECUTE FUNCTION emp_stamp();
```

Another way to log changes to a table involves creating a new table that holds a row for each insert, update, or delete that occurs. This approach can be thought of as auditing changes to a table. Example 41.4 shows an example of an audit trigger function in PL/pgSQL.

#### Example 41.4. A PL/pgSQL Trigger Function for Auditing

This example trigger ensures that any insert, update or delete of a row in the `emp` table is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are stamped into the row, together with the type of operation performed on it.

```
CREATE TABLE emp (
    empname      text NOT NULL,
    salary       integer
);
```

```
CREATE TABLE emp_audit(
    operation     char(1)  NOT NULL,
    stamp         timestamp NOT NULL,
    userid        text     NOT NULL,
    empname       text     NOT NULL,
    salary        integer
);
```

```
CREATE OR REPLACE FUNCTION process_emp_audit() RETURNS TRIGGER AS
    $emp_audit$
    BEGIN
        --
        -- Create a row in emp_audit to reflect the operation
        performed on emp,
        -- making use of the special variable TG_OP to work out the
        operation.
        --
        IF (TG_OP = 'DELETE') THEN
            INSERT INTO emp_audit SELECT 'D', now(), user, OLD.*;
        ELSIF (TG_OP = 'UPDATE') THEN
            INSERT INTO emp_audit SELECT 'U', now(), user, NEW.*;
        ELSIF (TG_OP = 'INSERT') THEN
            INSERT INTO emp_audit SELECT 'I', now(), user, NEW.*;
        END IF;
        RETURN NULL; -- result is ignored since this is an AFTER
        trigger
    END;
$emp_audit$ LANGUAGE plpgsql;
```

```
CREATE TRIGGER emp_audit
AFTER INSERT OR UPDATE OR DELETE ON emp
    FOR EACH ROW EXECUTE FUNCTION process_emp_audit();
```

A variation of the previous example uses a view joining the main table to the audit table, to show when each entry was last modified. This approach still records the full audit trail of changes to the table, but also presents a simplified view of the audit trail, showing just the last modified timestamp derived from the audit trail for each entry. Example 41.5 shows an example of an audit trigger on a view in PL/pgSQL.

### Example 41.5. A PL/pgSQL View Trigger Function for Auditing

This example uses a trigger on the view to make it updatable, and ensure that any insert, update or delete of a row in the view is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are recorded, together with the type of operation performed, and the view displays the last modified time of each row.

```

CREATE TABLE emp (
    empname      text PRIMARY KEY,
    salary       integer
);

CREATE TABLE emp_audit(
    operation     char(1) NOT NULL,
    userid        text NOT NULL,
    empname       text NOT NULL,
    salary        integer,
    stamp         timestamp NOT NULL
);

CREATE VIEW emp_view AS
    SELECT e.empname,
           e.salary,
           max(ea.stamp) AS last_updated
    FROM emp e
    LEFT JOIN emp_audit ea ON ea.empname = e.empname
    GROUP BY 1, 2;

CREATE OR REPLACE FUNCTION update_emp_view() RETURNS TRIGGER AS $$
BEGIN
    --
    -- Perform the required operation on emp, and create a row
in emp_audit
    -- to reflect the change made to emp.
    --
    IF (TG_OP = 'DELETE') THEN
        DELETE FROM emp WHERE empname = OLD.empname;
        IF NOT FOUND THEN RETURN NULL; END IF;

        OLD.last_updated = now();
        INSERT INTO emp_audit VALUES('D', user, OLD.*);
        RETURN OLD;
    ELSIF (TG_OP = 'UPDATE') THEN
        UPDATE emp SET salary = NEW.salary WHERE empname =
OLD.empname;
        IF NOT FOUND THEN RETURN NULL; END IF;

        NEW.last_updated = now();
        INSERT INTO emp_audit VALUES('U', user, NEW.*);
        RETURN NEW;
    ELSIF (TG_OP = 'INSERT') THEN
        INSERT INTO emp VALUES(NEW.empname, NEW.salary);

        NEW.last_updated = now();
        INSERT INTO emp_audit VALUES('I', user, NEW.*);
        RETURN NEW;
    END IF;
END IF;

```

```

END;
$$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit
INSTEAD OF INSERT OR UPDATE OR DELETE ON emp_view
FOR EACH ROW EXECUTE FUNCTION update_emp_view();

```

One use of triggers is to maintain a summary table of another table. The resulting summary can be used in place of the original table for certain queries — often with vastly reduced run times. This technique is commonly used in Data Warehousing, where the tables of measured or observed data (called fact tables) might be extremely large. Example 41.6 shows an example of a trigger function in PL/pgSQL that maintains a summary table for a fact table in a data warehouse.

### Example 41.6. A PL/pgSQL Trigger Function for Maintaining a Summary Table

The schema detailed here is partly based on the *Grocery Store* example from *The Data Warehouse Toolkit* by Ralph Kimball.

```

--
-- Main tables - time dimension and sales fact.
--
CREATE TABLE time_dimension (
    time_key          integer NOT NULL,
    day_of_week       integer NOT NULL,
    day_of_month      integer NOT NULL,
    month             integer NOT NULL,
    quarter           integer NOT NULL,
    year              integer NOT NULL
);
CREATE UNIQUE INDEX time_dimension_key ON time_dimension(time_key);

CREATE TABLE sales_fact (
    time_key          integer NOT NULL,
    product_key       integer NOT NULL,
    store_key         integer NOT NULL,
    amount_sold       numeric(12,2) NOT NULL,
    units_sold        integer NOT NULL,
    amount_cost       numeric(12,2) NOT NULL
);
CREATE INDEX sales_fact_time ON sales_fact(time_key);

--
-- Summary table - sales by time.
--
CREATE TABLE sales_summary_bytime (
    time_key          integer NOT NULL,
    amount_sold       numeric(15,2) NOT NULL,
    units_sold        numeric(12) NOT NULL,
    amount_cost       numeric(15,2) NOT NULL
);
CREATE UNIQUE INDEX sales_summary_bytime_key ON
    sales_summary_bytime(time_key);

--
-- Function and trigger to amend summarized column(s) on UPDATE,
-- INSERT, DELETE.

```

```
--
CREATE OR REPLACE FUNCTION maint_sales_summary_bytime() RETURNS
TRIGGER
AS $maint_sales_summary_bytime$
    DECLARE
        delta_time_key          integer;
        delta_amount_sold       numeric(15,2);
        delta_units_sold        numeric(12);
        delta_amount_cost       numeric(15,2);
    BEGIN

        -- Work out the increment/decrement amount(s).
        IF (TG_OP = 'DELETE') THEN

            delta_time_key = OLD.time_key;
            delta_amount_sold = -1 * OLD.amount_sold;
            delta_units_sold = -1 * OLD.units_sold;
            delta_amount_cost = -1 * OLD.amount_cost;

        ELSIF (TG_OP = 'UPDATE') THEN

            -- forbid updates that change the time_key -
            -- (probably not too onerous, as DELETE + INSERT is how
most
            -- changes will be made).
            IF ( OLD.time_key != NEW.time_key) THEN
                RAISE EXCEPTION 'Update of time_key : % -> % not
allowed',
                                                                OLD.time_key,
NEW.time_key;
            END IF;

            delta_time_key = OLD.time_key;
            delta_amount_sold = NEW.amount_sold - OLD.amount_sold;
            delta_units_sold = NEW.units_sold - OLD.units_sold;
            delta_amount_cost = NEW.amount_cost - OLD.amount_cost;

        ELSIF (TG_OP = 'INSERT') THEN

            delta_time_key = NEW.time_key;
            delta_amount_sold = NEW.amount_sold;
            delta_units_sold = NEW.units_sold;
            delta_amount_cost = NEW.amount_cost;

        END IF;

        -- Insert or update the summary row with the new values.
        <<insert_update>>
        LOOP
            UPDATE sales_summary_bytime
                SET amount_sold = amount_sold + delta_amount_sold,
                    units_sold = units_sold + delta_units_sold,
                    amount_cost = amount_cost + delta_amount_cost
                WHERE time_key = delta_time_key;

            EXIT insert_update WHEN found;
        END LOOP;
    END;
$maint_sales_summary_bytime$
```

```

BEGIN
    INSERT INTO sales_summary_bytime (
        time_key,
        amount_sold,
        units_sold,
        amount_cost)
        VALUES (
            delta_time_key,
            delta_amount_sold,
            delta_units_sold,
            delta_amount_cost
        );

    EXIT insert_update;

EXCEPTION
    WHEN UNIQUE_VIOLATION THEN
        -- do nothing
    END;
END LOOP insert_update;

RETURN NULL;

END;
$maint_sales_summary_bytime$ LANGUAGE plpgsql;

CREATE TRIGGER maint_sales_summary_bytime
AFTER INSERT OR UPDATE OR DELETE ON sales_fact
    FOR EACH ROW EXECUTE FUNCTION maint_sales_summary_bytime();

INSERT INTO sales_fact VALUES(1,1,1,10,3,15);
INSERT INTO sales_fact VALUES(1,2,1,20,5,35);
INSERT INTO sales_fact VALUES(2,2,1,40,15,135);
INSERT INTO sales_fact VALUES(2,3,1,10,1,13);
SELECT * FROM sales_summary_bytime;
DELETE FROM sales_fact WHERE product_key = 1;
SELECT * FROM sales_summary_bytime;
UPDATE sales_fact SET units_sold = units_sold * 2;
SELECT * FROM sales_summary_bytime;

```

AFTER triggers can also make use of *transition tables* to inspect the entire set of rows changed by the triggering statement. The CREATE TRIGGER command assigns names to one or both transition tables, and then the function can refer to those names as though they were read-only temporary tables. Example 41.7 shows an example.

### Example 41.7. Auditing with Transition Tables

This example produces the same results as Example 41.4, but instead of using a trigger that fires for every row, it uses a trigger that fires once per statement, after collecting the relevant information in a transition table. This can be significantly faster than the row-trigger approach when the invoking statement has modified many rows. Notice that we must make a separate trigger declaration for each kind of event, since the REFERENCING clauses must be different for each case. But this does not stop us from using a single trigger function if we choose. (In practice, it might be better to use three separate functions and avoid the run-time tests on TG\_OP.)

```

CREATE TABLE emp (
    empname      text NOT NULL,
    salary       integer

```

```

);

CREATE TABLE emp_audit(
    operation      char(1)    NOT NULL,
    stamp          timestamp NOT NULL,
    userid         text       NOT NULL,
    empname        text       NOT NULL,
    salary integer
);

CREATE OR REPLACE FUNCTION process_emp_audit() RETURNS TRIGGER AS
$emp_audit$
    BEGIN
        --
        -- Create rows in emp_audit to reflect the operations
        performed on emp,
        -- making use of the special variable TG_OP to work out the
        operation.
        --
        IF (TG_OP = 'DELETE') THEN
            INSERT INTO emp_audit
                SELECT 'D', now(), user, o.* FROM old_table o;
        ELSIF (TG_OP = 'UPDATE') THEN
            INSERT INTO emp_audit
                SELECT 'U', now(), user, n.* FROM new_table n;
        ELSIF (TG_OP = 'INSERT') THEN
            INSERT INTO emp_audit
                SELECT 'I', now(), user, n.* FROM new_table n;
        END IF;
        RETURN NULL; -- result is ignored since this is an AFTER
        trigger
    END;
$emp_audit$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit_ins
    AFTER INSERT ON emp
    REFERENCING NEW TABLE AS new_table
    FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();
CREATE TRIGGER emp_audit_upd
    AFTER UPDATE ON emp
    REFERENCING OLD TABLE AS old_table NEW TABLE AS new_table
    FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();
CREATE TRIGGER emp_audit_del
    AFTER DELETE ON emp
    REFERENCING OLD TABLE AS old_table
    FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();

```

## 41.10.2. Triggers on Events

PL/pgSQL can be used to define event triggers. LightDB requires that a function that is to be called as an event trigger must be declared as a function with no arguments and a return type of `event_trigger`.

When a PL/pgSQL function is called as an event trigger, several special variables are created automatically in the top-level block. They are:

`TG_EVENT`

Data type `text`; a string representing the event the trigger is fired for.



TG\_TAG

Data type text; variable that contains the command tag for which the trigger is fired.

Example 41.8 shows an example of an event trigger function in PL/pgSQL.

### Example 41.8. A PL/pgSQL Event Trigger Function

This example trigger simply raises a NOTICE message each time a supported command is executed.

```
CREATE OR REPLACE FUNCTION snitch() RETURNS event_trigger AS $$
BEGIN
    RAISE NOTICE 'snitch: % %', tg_event, tg_tag;
END;
$$ LANGUAGE plpgsql;

CREATE EVENT TRIGGER snitch ON ddl_command_start EXECUTE FUNCTION
snitch();
```

## 41.11. PL/pgSQL under the Hood

This section discusses some implementation details that are frequently important for PL/pgSQL users to know.

### 41.11.1. Variable Substitution

SQL statements and expressions within a PL/pgSQL function can refer to variables and parameters of the function. Behind the scenes, PL/pgSQL substitutes query parameters for such references. Parameters will only be substituted in places where a parameter or column reference is syntactically allowed. As an extreme case, consider this example of poor programming style:

```
INSERT INTO foo (foo) VALUES (foo);
```

The first occurrence of `foo` must syntactically be a table name, so it will not be substituted, even if the function has a variable named `foo`. The second occurrence must be the name of a column of the table, so it will not be substituted either. Only the third occurrence is a candidate to be a reference to the function's variable.

#### Note

LightDB versions before 9.0 would try to substitute the variable in all three cases, leading to syntax errors.

Since the names of variables are syntactically no different from the names of table columns, there can be ambiguity in statements that also refer to tables: is a given name meant to refer to a table column, or a variable? Let's change the previous example to

```
INSERT INTO dest (col) SELECT foo + bar FROM src;
```

Here, `dest` and `src` must be table names, and `col` must be a column of `dest`, but `foo` and `bar` might reasonably be either variables of the function or columns of `src`.

By default, PL/pgSQL will report an error if a name in a SQL statement could refer to either a variable or a table column. You can fix such a problem by renaming the variable or column, or by qualifying the ambiguous reference, or by telling PL/pgSQL which interpretation to prefer.

The simplest solution is to rename the variable or column. A common coding rule is to use a different naming convention for PL/pgSQL variables than you use for column names. For example, if you consistently name function variables *v\_something* while none of your column names start with *v\_*, no conflicts will occur.

Alternatively you can qualify ambiguous references to make them clear. In the above example, `src.foo` would be an unambiguous reference to the table column. To create an unambiguous reference to a variable, declare it in a labeled block and use the block's label (see Section 41.2). For example,

```
<<block>>
DECLARE
    foo int;
BEGIN
    foo := ...;
    INSERT INTO dest (col) SELECT block.foo + bar FROM src;
```

Here `block.foo` means the variable even if there is a column `foo` in `src`. Function parameters, as well as special variables such as `FOUND`, can be qualified by the function's name, because they are implicitly declared in an outer block labeled with the function's name.

Sometimes it is impractical to fix all the ambiguous references in a large body of PL/pgSQL code. In such cases you can specify that PL/pgSQL should resolve ambiguous references as the variable (which is compatible with PL/pgSQL's behavior before LightDB 9.0), or as the table column (which is compatible with some other systems such as Oracle).

To change this behavior on a system-wide basis, set the configuration parameter `plpgsql.variable_conflict` to one of `error`, `use_variable`, or `use_column` (where `error` is the factory default). This parameter affects subsequent compilations of statements in PL/pgSQL functions, but not statements already compiled in the current session. Because changing this setting can cause unexpected changes in the behavior of PL/pgSQL functions, it can only be changed by a superuser.

You can also set the behavior on a function-by-function basis, by inserting one of these special commands at the start of the function text:

```
#variable_conflict error
#variable_conflict use_variable
#variable_conflict use_column
```

These commands affect only the function they are written in, and override the setting of `plpgsql.variable_conflict`. An example is

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    #variable_conflict use_variable
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = curtime, comment = comment
            WHERE users.id = id;
    END;
$$ LANGUAGE plpgsql;
```

In the UPDATE command, `curtime`, `comment`, and `id` will refer to the function's variable and parameters whether or not `users` has columns of those names. Notice that we had to qualify the reference to `users.id` in the WHERE clause to make it refer to the table column. But we did not have to qualify the reference to `comment` as a target in the UPDATE list, because syntactically that must be a column of `users`. We could write the same function without depending on the `variable_conflict` setting in this way:

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    <<fn>>
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = fn.curtime, comment =
stamp_user.comment
        WHERE users.id = stamp_user.id;
    END;
$$ LANGUAGE plpgsql;
```

Variable substitution does not happen in the command string given to EXECUTE or one of its variants. If you need to insert a varying value into such a command, do so as part of constructing the string value, or use USING, as illustrated in Section 41.5.4.

Variable substitution currently works only in SELECT, INSERT, UPDATE, and DELETE commands, because the main SQL engine allows query parameters only in these commands. To use a non-constant name or value in other statement types (generically called utility statements), you must construct the utility statement as a string and EXECUTE it.

## 41.11.2. Plan Caching

The PL/pgSQL interpreter parses the function's source text and produces an internal binary instruction tree the first time the function is called (within each session). The instruction tree fully translates the PL/pgSQL statement structure, but individual SQL expressions and SQL commands used in the function are not translated immediately.

As each expression and SQL command is first executed in the function, the PL/pgSQL interpreter parses and analyzes the command to create a prepared statement, using the SPI manager's SPI\_prepare function. Subsequent visits to that expression or command reuse the prepared statement. Thus, a function with conditional code paths that are seldom visited will never incur the overhead of analyzing those commands that are never executed within the current session. A disadvantage is that errors in a specific expression or command cannot be detected until that part of the function is reached in execution. (Trivial syntax errors will be detected during the initial parsing pass, but anything deeper will not be detected until execution.)

PL/pgSQL (or more precisely, the SPI manager) can furthermore attempt to cache the execution plan associated with any particular prepared statement. If a cached plan is not used, then a fresh execution plan is generated on each visit to the statement, and the current parameter values (that is, PL/pgSQL variable values) can be used to optimize the selected plan. If the statement has no parameters, or is executed many times, the SPI manager will consider creating a *generic* plan that is not dependent on specific parameter values, and caching that for re-use. Typically this will happen only if the execution plan is not very sensitive to the values of the PL/pgSQL variables referenced in it. If it is, generating a plan each time is a net win. See PREPARE for more information about the behavior of prepared statements.

Because PL/pgSQL saves prepared statements and sometimes execution plans in this way, SQL commands that appear directly in a PL/pgSQL function must refer to the same tables and columns on every execution; that is, you cannot use a parameter as the name of a table or column in an SQL command. To get around this restriction, you can construct dynamic commands using the PL/pgSQL

EXECUTE statement — at the price of performing new parse analysis and constructing a new execution plan on every execution.

The mutable nature of record variables presents another problem in this connection. When fields of a record variable are used in expressions or statements, the data types of the fields must not change from one call of the function to the next, since each expression will be analyzed using the data type that is present when the expression is first reached. EXECUTE can be used to get around this problem when necessary.

If the same function is used as a trigger for more than one table, PL/pgSQL prepares and caches statements independently for each such table — that is, there is a cache for each trigger function and table combination, not just for each function. This alleviates some of the problems with varying data types; for instance, a trigger function will be able to work successfully with a column named `key` even if it happens to have different types in different tables.

Likewise, functions having polymorphic argument types have a separate statement cache for each combination of actual argument types they have been invoked for, so that data type differences do not cause unexpected failures.

Statement caching can sometimes have surprising effects on the interpretation of time-sensitive values. For example there is a difference between what these two functions do:

```
CREATE FUNCTION logfunc1(logtxt text) RETURNS void AS $$
BEGIN
    INSERT INTO logtable VALUES (logtxt, 'now');
END;
$$ LANGUAGE plpgsql;
```

and:

```
CREATE FUNCTION logfunc2(logtxt text) RETURNS void AS $$
DECLARE
    curtime timestamp;
BEGIN
    curtime := 'now';
    INSERT INTO logtable VALUES (logtxt, curtime);
END;
$$ LANGUAGE plpgsql;
```

In the case of `logfunc1`, the LightDB main parser knows when analyzing the `INSERT` that the string `'now'` should be interpreted as `timestamp`, because the target column of `logtable` is of that type. Thus, `'now'` will be converted to a `timestamp` constant when the `INSERT` is analyzed, and then used in all invocations of `logfunc1` during the lifetime of the session. Needless to say, this isn't what the programmer wanted. A better idea is to use the `now()` or `current_timestamp` function.

In the case of `logfunc2`, the LightDB main parser does not know what type `'now'` should become and therefore it returns a data value of type `text` containing the string `now`. During the ensuing assignment to the local variable `curtime`, the PL/pgSQL interpreter casts this string to the `timestamp` type by calling the `textout` and `timestamp_in` functions for the conversion. So, the computed time stamp is updated on each execution as the programmer expects. Even though this happens to work as expected, it's not terribly efficient, so use of the `now()` function would still be a better idea.

## 41.12. Tips for Developing in PL/pgSQL

One good way to develop in PL/pgSQL is to use the text editor of your choice to create your functions, and in another window, use `ltsql` to load and test those functions. If you are doing it this way, it is a

good idea to write the function using `CREATE OR REPLACE FUNCTION`. That way you can just reload the file to update the function definition. For example:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS $$  
    . . . .  
$$ LANGUAGE plpgsql;
```

While running `ltsql`, you can load or reload such a function definition file with:

```
\i filename.sql
```

and then immediately issue SQL commands to test the function.

Another good way to develop in PL/pgSQL is with a GUI database access tool that facilitates development in a procedural language. One example of such a tool is pgAdmin, although others exist. These tools often provide convenient features such as escaping single quotes and making it easier to recreate and debug functions.

## 41.12.1. Handling of Quotation Marks

The code of a PL/pgSQL function is specified in `CREATE FUNCTION` as a string literal. If you write the string literal in the ordinary way with surrounding single quotes, then any single quotes inside the function body must be doubled; likewise any backslashes must be doubled (assuming escape string syntax is used). Doubling quotes is at best tedious, and in more complicated cases the code can become downright incomprehensible, because you can easily find yourself needing half a dozen or more adjacent quote marks. It's recommended that you instead write the function body as a “dollar-quoted” string literal (see Section 4.1.2.4). In the dollar-quoting approach, you never double any quote marks, but instead take care to choose a different dollar-quoting delimiter for each level of nesting you need. For example, you might write the `CREATE FUNCTION` command as:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS  
    $PROC$  
    . . . .  
$PROC$ LANGUAGE plpgsql;
```

Within this, you might use quote marks for simple literal strings in SQL commands and `$$` to delimit fragments of SQL commands that you are assembling as strings. If you need to quote text that includes `$$`, you could use `$Q$`, and so on.

The following chart shows what you have to do when writing quote marks without dollar quoting. It might be useful when translating pre-dollar quoting code into something more comprehensible.

### 1 quotation mark

To begin and end the function body, for example:

```
CREATE FUNCTION foo() RETURNS integer AS '  
    . . . .  
' LANGUAGE plpgsql;
```

Anywhere within a single-quoted function body, quote marks *must* appear in pairs.

### 2 quotation marks

For string literals inside the function body, for example:

```
a_output := 'Blah';  
SELECT * FROM users WHERE f_name='foobar';
```

In the dollar-quoting approach, you'd just write:

```
a_output := 'Blah';  
SELECT * FROM users WHERE f_name='foobar';
```

which is exactly what the PL/pgSQL parser would see in either case.

#### 4 quotation marks

When you need a single quotation mark in a string constant inside the function body, for example:

```
a_output := a_output || ' AND name LIKE '''foobar''' AND  
xyz'
```

The value actually appended to `a_output` would be: `AND name LIKE 'foobar' AND xyz`.

In the dollar-quoting approach, you'd write:

```
a_output := a_output || $$ AND name LIKE 'foobar' AND xyz$$
```

being careful that any dollar-quote delimiters around this are not just `$$`.

#### 6 quotation marks

When a single quotation mark in a string inside the function body is adjacent to the end of that string constant, for example:

```
a_output := a_output || ' AND name LIKE '''foobar''''
```

The value appended to `a_output` would then be: `AND name LIKE 'foobar'`.

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ AND name LIKE 'foobar'$$
```

#### 10 quotation marks

When you want two single quotation marks in a string constant (which accounts for 8 quotation marks) and this is adjacent to the end of that string constant (2 more). You will probably only need that if you are writing a function that generates other functions, as in Example 41.10. For example:

```
a_output := a_output || ' if v_' ||  
referrer_keys.kind || ' like ''' ||  
|| referrer_keys.key_string || ''' ||  
then return ''' || referrer_keys.referrer_type  
|| '''; end if;''';
```

The value of `a_output` would then be:

```
if v_... like '...' then return '...'; end if;
```

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ if v_$$ || referrer_keys.kind || $$  
like '$$  
|| referrer_keys.key_string || $$'  
then return '$$ || referrer_keys.referrer_type  
|| $$'; end if;$$;
```

where we assume we only need to put single quote marks into `a_output`, because it will be re-quoted before use.

## 41.12.2. Additional Compile-Time and Run-Time Checks

To aid the user in finding instances of simple but common problems before they cause harm, PL/pgSQL provides additional *checks*. When enabled, depending on the configuration, they can be used to emit either a `WARNING` or an `ERROR` during the compilation of a function. A function which has received a `WARNING` can be executed without producing further messages, so you are advised to test in a separate development environment.

Setting `plpgsql.extra_warnings`, or `plpgsql.extra_errors`, as appropriate, to `"all"` is encouraged in development and/or testing environments.

These additional checks are enabled through the configuration variables `plpgsql.extra_warnings` for warnings and `plpgsql.extra_errors` for errors. Both can be set either to a comma-separated list of checks, `"none"` or `"all"`. The default is `"none"`. Currently the list of available checks includes:

`shadowed_variables`

Checks if a declaration shadows a previously defined variable.

`strict_multi_assignment`

Some PL/PgSQL commands allow assigning values to more than one variable at a time, such as `SELECT INTO`. Typically, the number of target variables and the number of source variables should match, though PL/PgSQL will use `NULL` for missing values and extra variables are ignored. Enabling this check will cause PL/PgSQL to throw a `WARNING` or `ERROR` whenever the number of target variables and the number of source variables are different.

`too_many_rows`

Enabling this check will cause PL/PgSQL to check if a given query returns more than one row when an `INTO` clause is used. As an `INTO` statement will only ever use one row, having a query return multiple rows is generally either inefficient and/or nondeterministic and therefore is likely an error.

The following example shows the effect of `plpgsql.extra_warnings` set to `shadowed_variables`:

```
SET plpgsql.extra_warnings TO 'shadowed_variables';
```

```
CREATE FUNCTION foo(f1 int) RETURNS int AS $$  
DECLARE
```

```
f1 int;
BEGIN
RETURN f1;
END;
$$ LANGUAGE plpgsql;
WARNING: variable "f1" shadows a previously defined variable
LINE 3: f1 int;
      ^
CREATE FUNCTION
```

The below example shows the effects of setting `plpgsql.extra_warnings` to `strict_multi_assignment`:

```
SET plpgsql.extra_warnings TO 'strict_multi_assignment';

CREATE OR REPLACE FUNCTION public.foo()
  RETURNS void
  LANGUAGE plpgsql
AS $$
DECLARE
  x int;
  y int;
BEGIN
  SELECT 1 INTO x, y;
  SELECT 1, 2 INTO x, y;
  SELECT 1, 2, 3 INTO x, y;
END;
$$;

SELECT foo();
WARNING: number of source and target fields in assignment does not
match
DETAIL: strict_multi_assignment check of extra_warnings is active.
HINT: Make sure the query returns the exact list of columns.
WARNING: number of source and target fields in assignment does not
match
DETAIL: strict_multi_assignment check of extra_warnings is active.
HINT: Make sure the query returns the exact list of columns.

foo
----

(1 row)
```

## 41.13. Porting from Oracle PL/SQL

This section explains differences between LightDB's PL/pgSQL language and Oracle's PL/SQL language, to help developers who port applications from Oracle® to LightDB.

PL/pgSQL is similar to PL/SQL in many aspects. It is a block-structured, imperative language, and all variables have to be declared. Assignments, loops, and conditionals are similar. The main differences you should keep in mind when porting from PL/SQL to PL/pgSQL are:

- If a name used in a SQL command could be either a column name of a table or a reference to a variable of the function, PL/SQL treats it as a column name. This corresponds to PL/pgSQL's `plpgsql.variable_conflict = use_column` behavior, which is not the default, as explained in Section 41.11.1. It's often best to avoid such ambiguities in the first place, but if you



have to port a large amount of code that depends on this behavior, setting `variable_conflict` may be the best solution.

- In LightDB the function body must be written as a string literal. Therefore you need to use dollar quoting or escape single quotes in the function body. (See Section 41.12.1.)
- Data type names often need translation. For example, in Oracle string values are commonly declared as being of type `varchar2`, which is a non-SQL-standard type. In LightDB, use type `varchar` or `text` instead. Similarly, replace type `number` with `numeric`, or use some other numeric data type if there's a more appropriate one.
- Instead of packages, use schemas to organize your functions into groups.
- Since there are no packages, there are no package-level variables either. This is somewhat annoying. You can keep per-session state in temporary tables instead.
- Integer FOR loops with REVERSE work differently: PL/SQL counts down from the second number to the first, while PL/pgSQL counts down from the first number to the second, requiring the loop bounds to be swapped when porting. This incompatibility is unfortunate but is unlikely to be changed. (See Section 41.6.5.5.)
- FOR loops over queries (other than cursors) also work differently: the target variable(s) must have been declared, whereas PL/SQL always declares them implicitly. An advantage of this is that the variable values are still accessible after the loop exits.
- There are various notational differences for the use of cursor variables.

Since LightDB 22.2, LightDB is support Oracle PL/SQL procedure, user can directly export PL/SQL code from Oracle database, then reexecute in LightDB database. See Chapter 42.

## 41.13.1. Porting Examples

Example 41.9 shows how to port a simple function from PL/SQL to PL/pgSQL.

### Example 41.9. Porting a Simple Function from PL/SQL to PL/pgSQL

Here is an Oracle PL/SQL function:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar2,
                                                v_version
                                                varchar2)
RETURN varchar2 IS
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
/
show errors;
```

Let's go through this function and see the differences compared to PL/pgSQL:

- The type name `varchar2` has to be changed to `varchar` or `text`. In the examples in this section, we'll use `varchar`, but `text` is often a better choice if you do not need specific string length limits.
- The RETURN key word in the function prototype (not the function body) becomes RETURNS in LightDB. Also, IS becomes AS, and you need to add a LANGUAGE clause because PL/pgSQL is not the only possible function language.

- In LightDB, the function body is considered to be a string literal, so you need to use quote marks or dollar quotes around it. This substitutes for the terminating / in the Oracle approach.
- The show errors command does not exist in LightDB, and is not needed since errors are reported automatically.

This is how this function would look when ported to LightDB:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar,
                                                v_version
                                                varchar)
RETURNS varchar AS $$
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
$$ LANGUAGE plpgsql;
```

Example 41.10 shows how to port a function that creates another function and how to handle the ensuing quoting problems.

### Example 41.10. Porting a Function that Creates Another Function from PL/SQL to PL/pgSQL

The following procedure grabs rows from a SELECT statement and builds a large function with the results in IF statements, for the sake of efficiency.

This is the Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_update_referrer_type_proc IS
    CURSOR referrer_keys IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_cmd VARCHAR(4000);
BEGIN
    func_cmd := 'CREATE OR REPLACE FUNCTION
cs_find_referrer_type(v_host IN VARCHAR2,
                    v_domain IN VARCHAR2, v_url IN VARCHAR2) RETURN
VARCHAR2 IS BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_cmd := func_cmd ||
            ' IF v_' || referrer_key.kind
            || ' LIKE ''' || referrer_key.key_string
            || ''' THEN RETURN ''' || referrer_key.referrer_type
            || '''; END IF;';
    END LOOP;

    func_cmd := func_cmd || ' RETURN NULL; END;';

    EXECUTE IMMEDIATE func_cmd;
END;
/
show errors;
```

Here is how this function would end up in LightDB:

```
CREATE OR REPLACE PROCEDURE cs_update_referrer_type_proc() AS $func
$
DECLARE
    referrer_keys CURSOR IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_body text;
    func_cmd text;
BEGIN
    func_body := 'BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_body := func_body ||
            ' IF v_' || referrer_key.kind
            || ' LIKE ' || quote_literal(referrer_key.key_string)
            || ' THEN RETURN ' ||
quote_literal(referrer_key.referrer_type)
            || '; END IF;' ;
    END LOOP;

    func_body := func_body || ' RETURN NULL; END;';

    func_cmd :=
        'CREATE OR REPLACE FUNCTION cs_find_referrer_type(v_host
varchar,
                                                    v_domain
varchar,
                                                    v_url
varchar)
        RETURNS varchar AS '
        || quote_literal(func_body)
        || ' LANGUAGE plpgsql;' ;

    EXECUTE func_cmd;
END;
$func$ LANGUAGE plpgsql;
```

Notice how the body of the function is built separately and passed through `quote_literal` to double any quote marks in it. This technique is needed because we cannot safely use dollar quoting for defining the new function: we do not know for sure what strings will be interpolated from the `referrer_key.key_string` field. (We are assuming here that `referrer_key.kind` can be trusted to always be `host`, `domain`, or `url`, but `referrer_key.key_string` might be anything, in particular it might contain dollar signs.) This function is actually an improvement on the Oracle original, because it will not generate broken code when `referrer_key.key_string` or `referrer_key.referrer_type` contain quote marks.

Example 41.11 shows how to port a function with OUT parameters and string manipulation. LightDB does not have a built-in `instr` function, but you can create one using a combination of other functions. In Section 41.13.3 there is a PL/pgSQL implementation of `instr` that you can use to make your porting easier.

### **Example 41.11. Porting a Procedure With String Manipulation and OUT Parameters from PL/SQL to PL/pgSQL**

The following Oracle PL/SQL procedure is used to parse a URL and return several elements (host, path, and query).

This is the Oracle version:

```

CREATE OR REPLACE PROCEDURE cs_parse_url(
    v_url IN VARCHAR2,
    v_host OUT VARCHAR2, -- This will be passed back
    v_path OUT VARCHAR2, -- This one too
    v_query OUT VARCHAR2) -- And this one
IS
    a_pos1 INTEGER;
    a_pos2 INTEGER;
BEGIN
    v_host := NULL;
    v_path := NULL;
    v_query := NULL;
    a_pos1 := instr(v_url, '//');

    IF a_pos1 = 0 THEN
        RETURN;
    END IF;
    a_pos2 := instr(v_url, '/', a_pos1 + 2);
    IF a_pos2 = 0 THEN
        v_host := substr(v_url, a_pos1 + 2);
        v_path := '/';
        RETURN;
    END IF;

    v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);
    a_pos1 := instr(v_url, '?', a_pos2 + 1);

    IF a_pos1 = 0 THEN
        v_path := substr(v_url, a_pos2);
        RETURN;
    END IF;

    v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);
    v_query := substr(v_url, a_pos1 + 1);
END;
/
show errors;

```

Here is a possible translation into PL/pgSQL:

```

CREATE OR REPLACE FUNCTION cs_parse_url(
    v_url IN VARCHAR,
    v_host OUT VARCHAR, -- This will be passed back
    v_path OUT VARCHAR, -- This one too
    v_query OUT VARCHAR) -- And this one
AS $$
DECLARE
    a_pos1 INTEGER;
    a_pos2 INTEGER;
BEGIN
    v_host := NULL;
    v_path := NULL;
    v_query := NULL;
    a_pos1 := instr(v_url, '//');

```

```

IF a_pos1 = 0 THEN
    RETURN;
END IF;
a_pos2 := instr(v_url, '/', a_pos1 + 2);
IF a_pos2 = 0 THEN
    v_host := substr(v_url, a_pos1 + 2);
    v_path := '/';
    RETURN;
END IF;

v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);
a_pos1 := instr(v_url, '?', a_pos2 + 1);

IF a_pos1 = 0 THEN
    v_path := substr(v_url, a_pos2);
    RETURN;
END IF;

v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);
v_query := substr(v_url, a_pos1 + 1);
END;
$$ LANGUAGE plpgsql;

```

This function could be used like this:

```
SELECT * FROM cs_parse_url('http://foobar.com/query.cgi?baz');
```

Example 41.12 shows how to port a procedure that uses numerous features that are specific to Oracle.

### Example 41.12. Porting a Procedure from PL/SQL to PL/pgSQL

The Oracle version:

```

CREATE OR REPLACE PROCEDURE cs_create_job(v_job_id IN INTEGER) IS
    a_running_job_count INTEGER;
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE
end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        COMMIT; -- free lock
        raise_application_error(-20000,
            'Unable to create a new job: a job is currently
running.');
```

```

    END IF;

    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id,
now());
    EXCEPTION
        WHEN dup_val_on_index THEN NULL; -- don't worry if it
already exists

```

```

        END;
    COMMIT;
END;
/
show errors

```

This is how we could port this procedure to PL/pgSQL:

```

CREATE OR REPLACE PROCEDURE cs_create_job(v_job_id integer) AS $$
DECLARE
    a_running_job_count integer;
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE
end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        COMMIT; -- free lock
        RAISE EXCEPTION 'Unable to create a new job: a job is
currently running'; -- ❶
    END IF;

    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id,
now());
    EXCEPTION
        WHEN unique_violation THEN -- ❷
            -- don't worry if it already exists
    END;
    COMMIT;
END;
$$ LANGUAGE plpgsql;

```

- ❶ The syntax of RAISE is considerably different from Oracle's statement, although the basic case RAISE *exception\_name* works similarly.
- ❷ The exception names supported by PL/pgSQL are different from Oracle's. The set of built-in exception names is much larger (see Appendix A). There is not currently a way to declare user-defined exception names, although you can throw user-chosen SQLSTATE values instead.

## 41.13.2. Other Things to Watch For

This section explains a few other things to watch for when porting Oracle PL/SQL functions to LightDB.

### 41.13.2.1. Implicit Rollback after Exceptions

In PL/pgSQL, when an exception is caught by an EXCEPTION clause, all database changes since the block's BEGIN are automatically rolled back. That is, the behavior is equivalent to what you'd get in Oracle with:

```

BEGIN
    SAVEPOINT s1;
    ... code here ...

```

```
EXCEPTION
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
END;
```

If you are translating an Oracle procedure that uses `SAVEPOINT` and `ROLLBACK TO` in this style, your task is easy: just omit the `SAVEPOINT` and `ROLLBACK TO`. If you have a procedure that uses `SAVEPOINT` and `ROLLBACK TO` in a different way then some actual thought will be required.

### 41.13.2.2. EXECUTE

The PL/pgSQL version of `EXECUTE` works similarly to the PL/SQL version, but you have to remember to use `quote_literal` and `quote_ident` as described in Section 41.5.4. Constructs of the type `EXECUTE 'SELECT * FROM $1'` will not work reliably unless you use these functions.

### 41.13.2.3. Optimizing PL/pgSQL Functions

LightDB gives you two function creation modifiers to optimize execution: “volatility” (whether the function always returns the same result when given the same arguments) and “strictness” (whether the function returns null if any argument is null). Consult the `CREATE FUNCTION` reference page for details.

When making use of these optimization attributes, your `CREATE FUNCTION` statement might look something like this:

```
CREATE FUNCTION foo(...) RETURNS integer AS $$
...
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

## 41.13.3. Appendix

This section contains the code for a set of Oracle-compatible `instr` functions that you can use to simplify your porting efforts.

```
--
-- instr functions that mimic Oracle's counterpart
-- Syntax: instr(string1, string2 [, n [, m]])
-- where [] denotes optional parameters.
--
-- Search string1, beginning at the nth character, for the mth
-- occurrence
-- of string2. If n is negative, search backwards, starting at the
-- abs(n)'th
-- character from the end of string1.
-- If n is not passed, assume 1 (search starts at first character).
-- If m is not passed, assume 1 (find first occurrence).
-- Returns starting index of string2 in string1, or 0 if string2 is
-- not found.
--
CREATE FUNCTION instr(vvarchar, vvarchar) RETURNS integer AS $$
BEGIN
    RETURN instr($1, $2, 1);
```

```
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE FUNCTION instr(string varchar, string_to_search_for varchar,
                    beg_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    length integer;
    ss_length integer;
BEGIN
    IF beg_index > 0 THEN
        temp_str := substring(string FROM beg_index);
        pos := position(string_to_search_for IN temp_str);

        IF pos = 0 THEN
            RETURN 0;
        ELSE
            RETURN pos + beg_index - 1;
        END IF;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search_for);
        length := char_length(string);
        beg := length + 1 + beg_index;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            IF string_to_search_for = temp_str THEN
                RETURN beg;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

```
CREATE FUNCTION instr(string varchar, string_to_search_for varchar,
                    beg_index integer, occur_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    occur_number integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    i integer;
    length integer;
    ss_length integer;
BEGIN
    IF occur_index <= 0 THEN
```



```
        RAISE 'argument '%' is out of range', occur_index
        USING ERRCODE = '22003';
    END IF;

    IF beg_index > 0 THEN
        beg := beg_index - 1;
        FOR i IN 1..occur_index LOOP
            temp_str := substring(string FROM beg + 1);
            pos := position(string_to_search_for IN temp_str);
            IF pos = 0 THEN
                RETURN 0;
            END IF;
            beg := beg + pos;
        END LOOP;

        RETURN beg;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search_for);
        length := char_length(string);
        beg := length + 1 + beg_index;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            IF string_to_search_for = temp_str THEN
                occur_number := occur_number + 1;
                IF occur_number = occur_index THEN
                    RETURN beg;
                END IF;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

---

# Chapter 42. PL/oraSQL — SQL Procedural Language

## 42.1. Overview

PL/oraSQL is a loadable procedural language for the LightDB database system. It is used to be compatible with Oracle PL/SQL applications. The design goals of PL/oraSQL were to create a loadable procedural language that

- can be used to create functions, procedures, and triggers,
- adds control structures to the SQL language,
- can perform complex computations,
- inherits all user-defined types, functions, procedures, and operators,
- can be defined to be trusted by the server,
- is easy to use.

Functions created with PL/oraSQL can be used anywhere that built-in functions could be used. For example, it is possible to create complex conditional computation functions and later use them to define operators or use them in index expressions.

In LightDB 22.2 and later, PL/oraSQL is installed by default. However it is still a loadable module, so especially security-conscious administrators could choose to remove it.

Although most feature is enabled by default, some feature such as call Oracle-specific function or Oracle-builtin package also need LightDB run under Oracle mode.

### 42.1.1. Advantages of Using PL/oraSQL

SQL is the language LightDB and most other relational databases use as query language. It's portable and easy to learn. But every SQL statement must be executed individually by the database server.

That means that your client application must send each query to the database server, wait for it to be processed, receive and process the results, do some computation, then send further queries to the server. All this incurs interprocess communication and will also incur network overhead if your client is on a different machine than the database server.

With PL/oraSQL you can group a block of computation and a series of queries *inside* the database server, thus having the power of a procedural language and the ease of use of SQL, but with considerable savings of client/server communication overhead.

- Compatible with Oracle PL/SQL stored procedure language
- Extra round trips between client and server are eliminated
- Intermediate results that the client does not need do not have to be marshaled or transferred between server and client
- Multiple rounds of query parsing can be avoided

This can result in a considerable performance increase as compared to an application that does not use stored functions.

Also, with PL/oraSQL you can use all the data types, operators and functions of SQL.

## 42.1.2. Supported Argument and Result Data Types

Functions written in PL/oraSQL can accept as arguments any scalar or array data type supported by the server, and they can return a result of any of these types. They can also accept or return any composite type (row type) specified by name. It is also possible to declare a PL/oraSQL function as accepting `record`, which means that any composite type will do as input, or as returning `record`, which means that the result is a row type whose columns are determined by specification in the calling query.

## 42.2. Structure of PL/oraSQL

PL/oraSQL is a block-structured language. A function, procedure, package, trigger or anonymous block contains a block structure, and we call all the parts contained in the *anonymous block* a *block structure*.

### 42.2.1. Anonymous Block

An anonymous block is defined as:

```
[ DECLARE
    declarations ]
BEGIN
    statements
[ EXCEPTION
    Exception-handling part ]
END;
/
```

Each declaration and each statement within a block is terminated by a semicolon. A block that appears within another block must have a semicolon after `END`, as shown above; however the final `END` that concludes a function body does too require a semicolon. where `/` is the end character of `plorasql` lower block structure.

#### Tip

A common mistake is to write a semicolon immediately after `BEGIN`. This is incorrect and will result in a syntax error. Anonymous blocks currently do not support the use of `<<label>>`.

For example, use an anonymous block to output a value of 'quantity':

```
DECLARE
    quantity integer := 80;
BEGIN
    DBMS_OUTPUT.PUT_LINE('Quantity here is '||quantity); -- Prints
    80
END;
/
```

Before using the `DBMS_OUTPUT.PUT_LINE` function, you need to turn on the print permission.

```
select dbms_output.serveroutput(true);
```

Of course, this function can only be used in Oracle compatibility mode.

Starting with LightDB version 23.4, anonymous blocks support binding variables when used with libpq. It should be noted that the parameter types needs to be passed to server from client. The number of binding variables is limited to 65535.

For example, use an anonymous block in libpq with variables:

```
/*
 * src/test/examples/lt_testlibpq.c
 *
 *
 * lt_testlibpq.c
 * this test program shows to use LIBPQ to exec dostmt with bind
 * param
 *
 */
#include <stdio.h>
#include <stdlib.h>
#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    const char *paramValues[10];
    Oid paramTypes[10];
    int  nFields;
    int  i,
        j;

    if (argc > 1)
        conninfo = argv[1];
    else
        conninfo = "dbname = postgres";

    conn = PQconnectdb(conninfo);

    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
                PQerrorMessage(conn));
        exit_nicely(conn);
    }
}
```

```

    res = PQexec(conn, "create table test_dostmt(key1 int, key2
text);");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    PQclear(res);

    res = PQexec(conn, "insert into test_dostmt values(1,'a');");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    PQclear(res);

    paramTypes[0] = 23;
    paramValues[0] = "1";

    printf("update test_dostmt key2 to 'test_dostmt'\n");
    res = PQexecParams(conn, "begin\
        begin\
            update test_dostmt set key2 =
'test_dostmt' where key1 = $1 ;\
        end;\
        end;", 1, paramTypes, paramValues, NULL, NULL, 0);

    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    PQclear(res);

    printf("get test_dostmt key2 \n");
    res = PQexec(conn, "select key2 from test_dostmt where
key1=1;");
    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    nFields = PQnfields(res);

    /* print out the instances */
    for (i = 0; i < PQntuples(res); i++)
    {
        for (j = 0; j < nFields; j++)
            printf("%s: %s", PQfname(res, j), PQgetvalue(res, i, j));
    }

```

```

printf("\n");
}

PQclear(res);

printf("update test_dostmt key2 to 'test_dostmt_new'\n");
paramTypes[0] = 23;
paramValues[0] = "1";
paramTypes[1] = 25;
paramValues[1] = "test_dostmt1";
res = PQexecParams(conn, " \
    declare\
        id int := $1; \
        val text := $2; \
    begin\
        begin\
            val = val || '_new'; \
            update test_dostmt set key2 = val where
key1 = id ;\
        end;\
    end;", 2, paramTypes, paramValues, NULL, NULL, 0);

if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

PQclear(res);

printf("get test_dostmt key2 \n");
res = PQexec(conn, "select key2 from test_dostmt where
key1=1;");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

nFields = PQnfields(res);
/* print out the instances */
for (i = 0; i < PQntuples(res); i++)
{
    for (j = 0; j < nFields; j++)
        printf("%s: %s", PQfname(res, j), PQgetvalue(res, i, j));
    printf("\n");
}

PQclear(res);

res = PQexec(conn, "drop table test_dostmt;");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{

```

```

        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    PQclear(res);

    PQfinish(conn);

    return 0;
}

```

## 42.2.2. Comments

The PL/oraSQL compiler ignores comments. Their purpose is to help other application developers understand your source text. Typically, you use comments to describe the purpose and use of each code segment. You can also disable obsolete or unfinished pieces of code by turning them into comments.

### 42.2.2.1. Single-Line Comments

A single-line comment begins with `--` and extends to the end of the line. This example has three single-line comments.

```

DECLARE
    howmany      NUMBER;
    num_tables   NUMBER;
BEGIN
    -- Begin processing
    SELECT COUNT(*) INTO howmany
    FROM USER_OBJECTS
    WHERE OBJECT_TYPE = 'TABLE'; -- Check number of tables
    num_tables := howmany;      -- Compute another value
END;
/

```

### 42.2.2.2. Multiline Comments

A multiline comment begins with `/*`, ends with `*/`, and can span multiple lines.

```

BEGIN
    /*
    IF 2 + 2 = 4 THEN
        some_condition := TRUE;
    END IF;
    */
    NULL;
END;
/

```

## 42.3. Declarations

All variables used in a block must be declared in the declarations section of the block. (The only exceptions are that the loop variable of a FOR loop iterating over a range of integer values is automatically declared as an integer variable, and likewise the loop variable of a FOR loop iterating over a cursor's result is automatically declared as a record variable.)

PL/oraSQL variables can have any SQL data type, such as integer, varchar, and char.

Here are some examples of variable declarations:

```
user_id integer;
quantity numeric(5);
url varchar(64);
myrow tablename%ROWTYPE;
myfield tablename.columnname%TYPE;
arow RECORD;
```

The general syntax of a variable declaration is:

```
name [ CONSTANT ] type [ NOT NULL ] { DEFAULT | := } expression;
```

The DEFAULT clause, if given, specifies the initial value assigned to the variable when the block is entered. If the DEFAULT clause is not given then the variable is initialized to the SQL null value. The CONSTANT option prevents the variable from being assigned to after initialization, so that its value will remain constant for the duration of the block. If NOT NULL is specified, an assignment of a null value results in a run-time error. All variables declared as NOT NULL must have a nonnull default value specified.

Examples:

```
quantity integer DEFAULT 32;
url varchar(64) := 'http://mysite.com';
user_id CONSTANT integer := 10;
```

## 42.3.1. Declaring Function Parameters

The data type of the declared function parameter name can be either the SQL parameter type or the PL/SQL parameter type. And you can use in and out to modify the parameters. For example:

```
CREATE FUNCTION sales_tax(subtotal in real) RETURN real IS
BEGIN
    RETURN subtotal * 0.06;
END;
/
```

If the anonymous block requires a function return value, use the inout decorating parameter, and the return value must have a specific return value, otherwise it is a record. For example#

```
create table nested_tab(id int, name varchar2(100), job
    varchar2(100), age int);
insert into nested_tab values (2, 'sdfsd', 'cvxvx', 14);

create or replace function nested_func(id1 inout int, name1 inout
    varchar2(100), job1 inout varchar2(100), age1 inout int)
return int as
    id2 int;
    name2 varchar2(100);
    job2 varchar2(100);
    age2 int;
begin
    select * into id2, name2, job1, age1 from nested_tab where age =
14;
```



```

    id1 := id2;
    name1 := name2;
    job1 := job2;
    age1 := age2;
    begin
    id1 := 45;
        name1 := 'name';
        job1 := 'job';
        age1 := 45;
    end;
    return 0;
end;
/

create or replace function nested_func12(id1 inout int, name1 inout
    varchar2(100), job1 inout varchar2(100), age1 inout int)
return int as
    retcode int;
begin
    begin
    retcode := nested_func(id1, name1, job1, age1);
    end;
    return 1;
end;
/
declare
    id2 int;
    name2 varchar2(100);
    job2 varchar2(100);
    age2 int;
    retcode int;
begin
    begin
    retcode := nested_func12(id2, name2, job2, age2);
    end;
    dbms_output.put_line(id2 || name2 || job2 || age2);
end;
/

```

## 42.3.2. Copying Types

*variable*%TYPE

%TYPE provides the data type of a variable or table column. You can use this to declare variables that will hold database values. For example, let's say you have a column named `user_id` in your `users` table. To declare a variable with the same data type as `users.user_id` you write:

```
user_id users.user_id%TYPE;
```

By using %TYPE you don't need to know the data type of the structure you are referencing, and most importantly, if the data type of the referenced item changes in the future (for instance: you change the type of `user_id` from `integer` to `real`), you might not need to change your function definition.

%TYPE is particularly valuable in polymorphic functions, since the data types needed for internal variables can change from one call to the next. Appropriate variables can be created by applying %TYPE to the function's arguments or result placeholders.

`%TYPE` can also use to declare variables reference package variable. To declare a variable with the same data type as `package.variable` you write:

```
var package.variable%TYPE;
```

### 42.3.3. Row Types

```
name table_name%ROWTYPE;
```

A variable of a composite type is called a *row* variable (or *row-type* variable). Such a variable can hold a whole row of a `SELECT` or `FOR` query result, so long as that query's column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example `rowvar.field`.

A row variable can be declared to have the same type as the rows of an existing table or view, by using the `table_name%ROWTYPE` notation; or it can be declared by giving a composite type's name. (Since every table has an associated composite type of the same name, it actually does not matter in LightDB whether you write `%ROWTYPE` or not. But the form with `%ROWTYPE` is more portable.)

### 42.3.4. Record Types

```
name RECORD;
```

Record variables are similar to row-type variables, but they have no predefined structure. They take on the actual row structure of the row they are assigned during a `SELECT` or `FOR` command. The substructure of a record variable can change each time it is assigned to. A consequence of this is that until a record variable is first assigned to, it has no substructure, and any attempt to access a field in it will draw a run-time error.

Note that `RECORD` is not a true data type, only a placeholder. One should also realize that when a PL/oraSQL function is declared to return type `record`, this is not quite the same concept as a record variable, even though such a function might use a record variable to hold its result. In both cases the actual row structure is unknown when the function is written, but for a function returning `record` the actual structure is determined when the calling query is parsed, whereas a record variable can change its row structure on-the-fly.

## 42.4. Expressions

All expressions used in PL/oraSQL statements are processed using the server's main SQL executor. For example, when you write a PL/oraSQL statement like

```
IF expression THEN ...
```

For example, if we have declared two integer variables `x` and `y`, and we write

```
IF x < y THEN ...
```

## 42.5. Basic Statements

In this section and the following ones, we describe all the statement types that are explicitly understood by PL/oraSQL. Anything not recognized as one of these statement types is presumed to be an SQL command and is sent to the main database engine to execute.

## 42.5.1. Assignment

An assignment of a value to a PL/oraSQL variable is written as:

```
variable := expression;
```

As explained previously, the expression in such a statement is evaluated by means of an SQL SELECT command sent to the main database engine. The expression must yield a single value (possibly a row value, if the variable is a row or record variable). The target variable can be a simple variable (optionally qualified with a block name), a field of a row or record variable, or an element of an array that is a simple variable or field.

Examples:

```
tax := subtotal * 0.06;
my_record.user_id := 20;
```

## 42.5.2. Executing a Query with a Single-Row Result

The result of a SQL command yielding a single row (possibly of multiple columns) can be assigned to a record variable, row-type variable, or list of scalar variables. This is done by writing the base SQL command and adding an INTO clause. For example,

```
SELECT select_expressions INTO target FROM ...;
INSERT ... RETURNING expressions INTO target;
UPDATE ... RETURNING expressions INTO target;
DELETE ... RETURNING expressions INTO target;
```

where *target* can be a record variable, a row variable, or a comma-separated list of simple variables and record/row fields. PL/oraSQL variables will be substituted into the rest of the query, and the plan is cached, just as described above for commands that do not return rows. This works for SELECT, INSERT/UPDATE/DELETE with RETURNING, and utility commands that return row-set results (such as EXPLAIN). Except for the INTO clause, the SQL command is the same as it would be written outside PL/oraSQL.

### Tip

Note that this interpretation of SELECT with INTO is quite different from LightDB's regular SELECT INTO command, wherein the INTO target is a newly created table. If you want to create a table from a SELECT result inside a PL/oraSQL function, use the syntax CREATE TABLE ... AS SELECT.

If a row or a variable list is used as target, the query's result columns must exactly match the structure of the target as to number and data types, or else a run-time error occurs. When a record variable is the target, it automatically configures itself to the row type of the query result columns.

The INTO clause can appear almost anywhere in the SQL command. Customarily it is written either just before or just after the list of *select\_expressions* in a SELECT command, or at the end of the command for other command types. It is recommended that you follow this convention in case the PL/oraSQL parser becomes stricter in future versions.

If STRICT is not specified in the INTO clause, then *target* will be set to the first row returned by the query, or to nulls if the query returned no rows. (Note that “the first row” is not well-defined unless

you've used ORDER BY.) Any result rows after the first row are discarded. You can check the special SQL%FOUND variable to determine whether a row was returned:

```
DROP TABLE t1;
DROP SEQUENCE t1_seq;

CREATE TABLE t1 (
  id NUMBER(10),
  description VARCHAR2(50),
  CONSTRAINT t1_pk PRIMARY KEY (id)
);

CREATE SEQUENCE t1_seq;

INSERT INTO t1 VALUES (t1_seq.nextval, 'ONE');
INSERT INTO t1 VALUES (t1_seq.nextval, 'TWO');
INSERT INTO t1 VALUES (t1_seq.nextval, 'THREE');
```

The RETURNING INTO clause allows us to return column values for rows affected by DML statements. The returned data could be a single column. For example, When we insert data using a sequence to generate our primary key value, we can return the primary key value as follows.

```
DECLARE
  l_id t1.id%TYPE;
BEGIN
  INSERT INTO t1 VALUES (t1_seq.nextval, 'FOUR')
  RETURNING id INTO l_id;
  COMMIT;

  DBMS_OUTPUT.put_line('ID=' || l_id);
END;
/
```

For example, The syntax is also available for update and delete statements.

```
DECLARE
  l_id t1.id%TYPE;
BEGIN
  UPDATE t1
  SET   description = description
  WHERE description = 'FOUR'
  RETURNING id INTO l_id;

  DBMS_OUTPUT.put_line('UPDATE ID=' || l_id);

  DELETE FROM t1
  WHERE description = 'FOUR'
  RETURNING id INTO l_id;

  DBMS_OUTPUT.put_line('DELETE ID=' || l_id);

  COMMIT;
END;
/
```

### 42.5.3. Execute a DML Query with with\_clause

PLoraSQL supports common table expressions (cte), which are used in anonymous blocks, stored procedures, functions, and packages. The cte can be followed by the INSERT, UPDATE, and DELETE clauses. If it does followed by the SELECT statement, which must contain into\_clause, otherwise an error will be reported. DML operations are not allowed in functions. with\_clause can also be used as a subquery, but recursion is not supported. Common Table Expression. For example:

```
CREATE TABLE company(
  ID INT          NOT NULL,
  NAME           TEXT    NOT NULL,
  AGE           INT     NOT NULL,
  ADDRESS       CHAR(50),
  SALARY        REAL
);
INSERT INTO company VALUES (1, 'Paul', 32, 'California',
  20000.00 );
INSERT INTO company VALUES (2, 'Allen', 25, 'Texas', 15000.00 );
INSERT INTO company VALUES (3, 'Teddy', 23, 'Norway', 20000.00 );
INSERT INTO company VALUES (4, 'Mark', 25, 'Rich-Mond ',
  65000.00 );
INSERT INTO company VALUES (5, 'David', 27, 'Texas', 85000.00 );
INSERT INTO company VALUES (6, 'Kim', 22, 'South-Hall', 45000.00 );
INSERT INTO company VALUES (7, 'James', 24, 'Houston', 10000.00 );
```

with\_clause used in anonymous blocks, For example:

```
declare
v_count varchar(100);
begin
with tmp as (select * from company where id=2) select * into
  v_count from tmp;
DBMS_OUTPUT.PUT_LINE(v_count);
end;
/
```

with\_clause used in function, For example:

```
create or replace function hs_with_f
return int
as
v_count INTEGER;
begin
with tmp as (select * from company where id=2) select id into
  v_count from tmp;
return v_count;
end;
/

select hs_with_f();
```

with\_clause are used in stored procedures, For example:

```
create or replace procedure hs_with_p as
v_count varchar(100);
begin
```

```
with tmp as (select * from company where id=2) select id into
v_count from tmp;
DBMS_OUTPUT.PUT_LINE(v_count);
end;
/
```

```
call hs_with_p();
```

with\_clause used in the package, For example:

```
create or replace package hs_with_pkg
is
v_count varchar(100);
function hs_with_f return int;
procedure hs_with_p;
end;
/
```

```
create or replace package body hs_with_pkg is
function hs_with_f return int as
begin
with tmp as (select * from company where id=2) select id into
v_count from tmp;
return v_count;
end;
```

```
procedure hs_with_p as
begin
with tmp as (select * from company where id=3) select id into
v_count from tmp;
DBMS_OUTPUT.PUT_LINE(v_count);
end;
```

```
begin
with tmp as (select * from company where id=4) select id into
v_count from tmp;
DBMS_OUTPUT.PUT_LINE(v_count);
end;
/
```

```
select hs_with_pkg.hs_with_f;
call hs_with_pkg.hs_with_p;
```

## 42.5.4. Execute a DML Query in plorasql

PLoraSQL supports DML, which are used in anonymous blocks, stored procedures, functions, and packages. DML includes INSERT, UPDATE, and DELETE clauses. If it has a SELECT statement, which must contain into\_clause, otherwise an error will be reported. For example:

```
create table dml_table(id int, name varchar2(100), job
varchar2(100), age int);
insert into dml_table values (1, 'asda', 'gfdgd', 12);
insert into dml_table values (2, 'sdfsd', 'cvxvx', 14);
insert into dml_table values (3, 'uyiy', 'mmbv', 16);
```

```
create or replace function support_dml return int as
begin
```

```

update dml_table set id = 4 where name = 'uyiy';
return 12;
end;
/
select support_dml() from dual;

declare
retcode int := 1;
begin
retcode := support_dml();
dbms_output.put_line(retcode);
end;
/

```

## 42.5.5. Executing Dynamic Commands

Oftentimes you will want to generate dynamic commands inside your PL/oraSQL functions, that is, commands that will involve different tables or different data types each time they are executed. PL/oraSQL's normal attempts to cache plans for commands will not work in such scenarios. To handle this sort of problem, the EXECUTE IMMEDIATE statement is provided:

```

EXECUTE IMMEDIATE command-string [ INTO target ] [ USING expression
[ , ... ] ];

```

where *command-string* is an expression yielding a string (of type varchar) containing the command to be executed. The optional *target* is a record variable, a row variable, or a comma-separated list of simple variables and record/row fields, into which the results of the command will be stored. The optional USING expressions supply values to be inserted into the command.

No substitution of PL/oraSQL variables is done on the computed command string. Any required variable values must be inserted in the command string as it is constructed; or you can use parameters as described below.

Also, there is no plan caching for commands executed via EXECUTE IMMEDIATE . Instead, the command is always planned each time the statement is run. Thus the command string can be dynamically created within the function to perform actions on different tables and columns.

The INTO clause specifies where the results of a SQL command returning rows should be assigned. If a row or variable list is provided, it must exactly match the structure of the query's results (when a record variable is used, it will configure itself to match the result structure automatically). If multiple rows are returned, only the first will be assigned to the INTO variable. If no rows are returned, NULL is assigned to the INTO variable(s). If no INTO clause is specified, the query results are discarded.

If the STRICT option is given, an error is reported unless the query produces exactly one row.

The command string can use parameter values, which are referenced in the command as :inserted\_by, :inserted, etc. These symbols refer to values supplied in the USING clause. This method is often preferable to inserting data values into the command string as varchar: it avoids run-time overhead of converting the values to varchar and back, and it is much less prone to SQL-injection attacks since there is no need for quoting or escaping. An example is:

```

EXECUTE IMMEDIATE 'SELECT count(*) FROM mytable WHERE inserted_by
= :inserted_by AND inserted <= :inserted'
INTO c
USING checked_user, checked_date;

```

An EXECUTE IMMEDIATE with a simple constant command string and some USING parameters, as in the first example above, is functionally equivalent to just writing the command directly in PL/

oraSQL and allowing replacement of PL/oraSQL variables to happen automatically. The important difference is that EXECUTE IMMEDIATE will re-plan the command on each execution, generating a plan that is specific to the current parameter values; whereas PL/oraSQL may otherwise create a generic plan and cache it for re-use. In situations where the best plan depends strongly on the parameter values, it can be helpful to use EXECUTE IMMEDIATE to positively ensure that a generic plan is not selected.

SELECT INTO is not currently supported within EXECUTE IMMEDIATE; instead, execute a plain SELECT command and specify INTO as part of the EXECUTE IMMEDIATE itself.

The using clause uses the variables used can be added with variable types in and out. in type variables indicate that the input variable cannot be changed and out type variable indicates that the input variable can be changed. An example is:

```
CREATE OR REPLACE PROCEDURE TargetProcedure(
    p_input1 IN VARCHAR2,
    p_input2 IN NUMBER,
    p_output1 OUT VARCHAR2,
    p_output2 OUT NUMBER
) AS
BEGIN
    DBMS_Output.PUT_LINE('TargetProcedure begin-> p_input1 '||' is:
' ||p_input1);
    DBMS_Output.PUT_LINE('TargetProcedure begin-> p_input2 '||' is:
' ||p_input2);
    DBMS_Output.PUT_LINE('TargetProcedure begin-> p_output1 '||'
is: ' ||p_output1);
    DBMS_Output.PUT_LINE('TargetProcedure begin-> p_output2 '||'
is: ' ||p_output2);
    p_output1 := 'Response from TargetProcedure: ' || p_input1;
    p_output2 := p_input2 * 10;
    DBMS_Output.PUT_LINE('TargetProcedure end-> p_input1 '||' is:
' ||p_input1);
    DBMS_Output.PUT_LINE('TargetProcedure end-> p_input2 '||' is:
' ||p_input2);
    DBMS_Output.PUT_LINE('TargetProcedure end-> p_output1 '||' is:
' ||p_output1);
    DBMS_Output.PUT_LINE('TargetProcedure end-> p_output2 '||' is:
' ||p_output2);
END TargetProcedure;
/
CREATE OR REPLACE PROCEDURE MainProcedure(
    main_input1 IN VARCHAR2,
    main_input2 IN NUMBER,
    main_output1 OUT VARCHAR2,
    main_output2 OUT NUMBER
) AS
BEGIN
    main_output2 := 0;
    main_output1 := 'Operation successful';
    -- Use EXECUTE IMMEDIATE to execute dynamic SQL and pass
parameters
    DBMS_Output.PUT_LINE('MainProcedure begin-> main_input1 '||'
is: ' ||main_input1);
    DBMS_Output.PUT_LINE('MainProcedure begin-> main_input2 '||'
is: ' ||main_input2);
    DBMS_Output.PUT_LINE('MainProcedure begin-> main_output1 '||'
is: ' ||main_output1);
```



```

        DBMS_Output.PUT_LINE('MainProcedure begin-> main_output2 '||'
is: '||main_output2);
        EXECUTE IMMEDIATE 'BEGIN
TargetProcedure(:p_input1, :p_input2, :p_output1, :p_output2);
END;'
        USING IN main_input1, IN main_input2, OUT main_output1, OUT
main_output2;
        DBMS_Output.PUT_LINE('MainProcedure end-> main_input1 '||' is:
' ||main_input1);
        DBMS_Output.PUT_LINE('MainProcedure end-> main_input2 '||' is:
' ||main_input2);
        DBMS_Output.PUT_LINE('MainProcedure end-> main_output1 '||' is:
' ||main_output1);
        DBMS_Output.PUT_LINE('MainProcedure end-> main_output2 '||' is:
' ||main_output2);
END MainProcedure;
/
call MainProcedure('xiaoming',123,'xiaohong',234);

```

## 42.5.6. Doing Nothing At All

Sometimes a placeholder statement that does nothing is useful. For example, it can indicate that one arm of an if/then/else chain is deliberately empty. For this purpose, use the NULL statement:

```
NULL;
```

For example, the following two fragments of code are equivalent:

```

declare
y int := 10;
x int := 10;
BEGIN
    NULL;
END;
/

```

## 42.6. Control Structures

Control structures are probably the most useful (and important) part of PL/oraSQL. With PL/oraSQL's control structures, you can manipulate LightDB data in a very flexible and powerful way.

### 42.6.1. Returning from a Function

There is one command available that allow you to return data from a function: RETURN.

#### 42.6.1.1. RETURN

```
RETURN expression;
```

RETURN with an expression terminates the function and returns the value of *expression* to the caller. This form is used for PL/oraSQL functions that do not return a set.

If you declared the function with output parameters, write just RETURN with no expression. The current values of the output parameter variables will be returned. In addition, you can specify any return value through RETURN, including variables, constants, expressions, etc.

The return value of a function cannot be left undefined. If control reaches the end of the top-level block of the function without hitting a RETURN statement, a run-time error will occur. In those cases a RETURN statement is automatically executed if the top-level block finishes.

Some examples:

```
-- functions returning a scalar type
RETURN 1 + 2;
RETURN scalar_var;
```

## 42.6.2. Returning from a Procedure

A procedure does not have a return value. A procedure can therefore end without a RETURN statement. If you wish to use a RETURN statement to exit the code early, write just RETURN with no expression.

Stored procedure parameters are decorated with out, and you can end the stored procedure with only return without a return value.

If the procedure has output parameters, the final values of the output parameter variables will be returned to the caller.

## 42.6.3. Calling a Procedure

A PL/oraSQL function, procedure, or Anonymous block can call a procedure. For example:

```
CREATE PROCEDURE triple(x in int, y out int)
AS
BEGIN
    y := x * 3;
END;
/

DECLARE
    myvar int := 5;
    myresult int := 10;
BEGIN
    triple(myvar, myresult);
    DBMS_OUTPUT.PUT_LINE('myresult = ' || myresult); -- prints 15
END;
/
```

## 42.6.4. Conditionals

IF and CASE statements let you execute alternative commands based on certain conditions. PL/oraSQL has three forms of IF:

- IF ... THEN ... END IF
- IF ... THEN ... ELSE ... END IF
- IF ... THEN ... ELSIF ... THEN ... ELSE ... END IF

and two forms of CASE:

- CASE ... WHEN ... THEN ... ELSE ... END CASE
- CASE WHEN ... THEN ... ELSE ... END CASE

### 42.6.4.1. IF-THEN

```
IF boolean-expression THEN
    statements
END IF;
```

IF-THEN statements are the simplest form of IF. The statements between THEN and END IF will be executed if the condition is true. Otherwise, they are skipped.

Example:

```
IF v_user_id <> 0 THEN
    UPDATE users SET email = v_email WHERE user_id = v_user_id;
END IF;
```

### 42.6.4.2. IF-THEN-ELSE

```
IF boolean-expression THEN
    statements
ELSE
    statements
END IF;
```

IF-THEN-ELSE statements add to IF-THEN by letting you specify an alternative set of statements that should be executed if the condition is not true. (Note this includes the case where the condition evaluates to NULL.)

Examples:

```
IF parentid IS NULL OR parentid = ''
THEN
    RETURN fullname;
ELSE
    RETURN hp_true_filename(parentid) || '/' || fullname;
END IF;
```

```
IF v_count > 0 THEN
    INSERT INTO users_count (count) VALUES (v_count);
    RETURN 't';
ELSE
    RETURN 'f';
END IF;
```

### 42.6.4.3. IF-THEN-ELSIF

```
IF boolean-expression THEN
    statements
[ ELIF boolean-expression THEN
    statements
]
[ ELIF boolean-expression THEN
    statements
    ...
]
```

```
[ ELSE
    statements ]
END IF;
```

Sometimes there are more than just two alternatives. IF-THEN-ELSIF provides a convenient method of checking several alternatives in turn. The IF conditions are tested successively until the first one that is true is found. Then the associated statement(s) are executed, after which control passes to the next statement after END IF. (Any subsequent IF conditions are *not* tested.) If none of the IF conditions is true, then the ELSE block (if any) is executed.

Here is an example:

```
IF number = 0 THEN
    result := 'zero';
ELSIF number > 0 THEN
    result := 'positive';
ELSIF number < 0 THEN
    result := 'negative';
ELSE
    -- hmm, the only other possibility is that number is null
    result := 'NULL';
END IF;
```

The key word ELSIF can also be spelled ELSEIF.

An alternative way of accomplishing the same task is to nest IF-THEN-ELSE statements, as in the following example:

```
IF demo_row.sex = 'm' THEN
    pretty_sex := 'man';
ELSE
    IF demo_row.sex = 'f' THEN
        pretty_sex := 'woman';
    END IF;
END IF;
```

However, this method requires writing a matching END IF for each IF, so it is much more cumbersome than using ELSIF when there are many alternatives.

#### 42.6.4.4. Simple CASE

```
CASE search-expression
    WHEN expression [, expression [ ... ]] THEN
        statements
    [ WHEN expression [, expression [ ... ]] THEN
        statements
    ... ]
    [ ELSE
        statements ]
END CASE;
```

The simple form of CASE provides conditional execution based on equality of operands. The *search-expression* is evaluated (once) and successively compared to each *expression* in the WHEN clauses. If a match is found, then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no match is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE\_NOT\_FOUND exception is raised.

Here is a simple example:

```
CASE x
  WHEN 1, 2 THEN
    msg := 'one or two';
  ELSE
    msg := 'other value than one or two';
END CASE;
```

#### 42.6.4.5. Searched CASE

```
CASE
  WHEN boolean-expression THEN
    statements
  [ WHEN boolean-expression THEN
    statements
    ... ]
  [ ELSE
    statements ]
END CASE;
```

The searched form of CASE provides conditional execution based on truth of Boolean expressions. Each WHEN clause's *boolean-expression* is evaluated in turn, until one is found that yields true. Then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no true result is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE\_NOT\_FOUND exception is raised.

Here is an example:

```
CASE
  WHEN x BETWEEN 0 AND 10 THEN
    msg := 'value is between zero and ten';
  WHEN x BETWEEN 11 AND 20 THEN
    msg := 'value is between eleven and twenty';
END CASE;
```

This form of CASE is entirely equivalent to IF-THEN-ELSIF, except for the rule that reaching an omitted ELSE clause results in an error rather than doing nothing.

### 42.6.5. Simple Loops

With the LOOP, EXIT, CONTINUE, WHILE, FOR, and FOREACH statements, you can arrange for your PL/oraSQL function to repeat a series of commands.

#### 42.6.5.1. LOOP

```
[ <<label>> ]
LOOP
  statements
END LOOP [ label ];
```

LOOP defines an unconditional loop that is repeated indefinitely until terminated by an EXIT or RETURN statement. The optional *label* can be used by EXIT and CONTINUE statements within nested loops to specify which loop those statements refer to.

**Tip**

Label name cannot be the unreserved keyword *label*.

### 42.6.5.2. EXIT

```
EXIT [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the innermost loop is terminated and the statement following `END LOOP` is executed next. If *label* is given, it must be the label of the current or some outer level of nested loop or block. Then the named loop or block is terminated and control continues with the statement after the loop's/block's corresponding `END`.

If `WHEN` is specified, the loop exit occurs only if *boolean-expression* is true. Otherwise, control passes to the statement after `EXIT`.

`EXIT` can be used with all types of loops; it is not limited to use with unconditional loops.

Examples:

```
LOOP
  -- some computations
  IF count > 0 THEN
    EXIT; -- exit loop
  END IF;
END LOOP;
```

```
LOOP
  -- some computations
  EXIT WHEN count > 0; -- same result as previous example
END LOOP;
```

### 42.6.5.3. CONTINUE

```
CONTINUE [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the next iteration of the innermost loop is begun. That is, all statements remaining in the loop body are skipped, and control returns to the loop control expression (if any) to determine whether another loop iteration is needed. If *label* is present, it specifies the label of the loop whose execution will be continued.

If `WHEN` is specified, the next iteration of the loop is begun only if *boolean-expression* is true. Otherwise, control passes to the statement after `CONTINUE`.

`CONTINUE` can be used with all types of loops; it is not limited to use with unconditional loops.

Examples:

```
LOOP
  -- some computations
  EXIT WHEN count > 100;
  CONTINUE WHEN count < 50;
  -- some computations for count IN [50 .. 100]
END LOOP;
```

#### 42.6.5.4. WHILE

```
[ <<label>> ]
WHILE boolean-expression LOOP
    statements
END LOOP [ label ];
```

The WHILE statement repeats a sequence of statements so long as the *boolean-expression* evaluates to true. The expression is checked just before each entry to the loop body.

For example:

```
WHILE amount_owed > 0 AND gift_certificate_balance > 0 LOOP
    -- some computations here
END LOOP;

WHILE NOT done LOOP
    -- some computations here
END LOOP;
```

#### 42.6.5.5. FOR (Integer Variant)

```
[ <<label>> ]
FOR name IN [ REVERSE ] expression .. expression [ BY expression ]
LOOP
    statements
END LOOP [ label ];
```

This form of FOR creates a loop that iterates over a range of integer values. The variable *name* is automatically defined as type `integer` and exists only inside the loop (any existing definition of the variable name is ignored within the loop). The two expressions giving the lower and upper bound of the range are evaluated once when entering the loop. If the BY clause isn't specified the iteration step is 1, otherwise it's the value specified in the BY clause, which again is evaluated once on loop entry. If REVERSE is specified then the step value is subtracted, rather than added, after each iteration.

Some examples of integer FOR loops:

```
FOR i IN 1..10 LOOP
    -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the
    loop
END LOOP;

FOR i IN REVERSE 10..1 LOOP
    -- i will take on the values 10,9,8,7,6,5,4,3,2,1 within the
    loop
END LOOP;

FOR i IN REVERSE 10..1 BY 2 LOOP
    -- i will take on the values 10,8,6,4,2 within the loop
END LOOP;
```

If the lower bound is greater than the upper bound (or less than, in the REVERSE case), the loop body is not executed at all. No error is raised.

If a *label* is attached to the FOR loop then the integer loop variable can be referenced with a qualified name, using that *label*.

## 42.6.6. GOTO Statement

The GOTO statement transfers control to a label unconditionally. The label must be unique in its scope and must precede an executable statement or a PL/oraSQL block. When run, the GOTO statement transfers control to the labeled statement or block.

The syntax is:

```
GOTO labelName ;
```

### 42.6.6.1. Restrictions on GOTO Statement

- A GOTO statement cannot transfer control into an IF statement, CASE statement, LOOP statement, or sub-block.
- A GOTO statement cannot transfer control from one IF statement clause to another, or from one CASE statement WHEN clause to another.
- A GOTO statement cannot transfer control out of a subprogram.
- A GOTO statement cannot transfer control into an exception handler.
- A GOTO statement cannot transfer control from an exception handler back into the current block.
- Keywords of LightDB cannot be label name.

### 42.6.6.2. Examples

The example can be run under ltsql. Enter the ltsql and execute the following command.

```
create database test_oracle lightdb_syntax_compatible_type oracle;
\c test_oracle
select dbms_output.serveroutput(true);
```

#### 42.6.6.2.1. Example 1 GOTO Statement

```
DECLARE
  p VARCHAR2(30);
  n PLS_INTEGER := 37;
BEGIN
  FOR j in 2..ROUND(SQRT(n)) LOOP
    IF n % j = 0 THEN
      p := ' is not a prime number';
      GOTO print_now;
    END IF;
  END LOOP;

  p := ' is a prime number';

  <<print_now>>
  DBMS_OUTPUT.PUT_LINE(TO_CHAR(n) || p);
END;
/
```

result:



37 is a prime number

#### 42.6.6.2.2. Example 2 GOTO NULL

```
DECLARE
  done  BOOLEAN;
  j     int;
BEGIN
  done := true;
  FOR i IN 1..50 LOOP
    IF done THEN
      j := 100;
      GOTO end_loop;
    END IF;
  END LOOP;
  <<end_loop>>
  NULL;
  DBMS_OUTPUT.PUT_LINE(j);
END;
/
```

```
result:
      100
```

#### 42.6.6.2.3. Example 3 GOTO block

```
BEGIN
  DBMS_OUTPUT.PUT_LINE('out block 1');
  goto testlabel;
  DBMS_OUTPUT.PUT_LINE('out block 2');
  <<testlabel>>
  BEGIN
    DBMS_OUTPUT.PUT_LINE('in block 1');
    goto testlabel2;
    DBMS_OUTPUT.PUT_LINE('in block 2');
  END;
  DBMS_OUTPUT.PUT_LINE('out block 3');
  <<testlabel2>>
  DBMS_OUTPUT.PUT_LINE('out block 4');
END;
/
```

```
result:
out block 1
in block 1
out block 4
```

#### 42.6.6.2.4. Example 4 Statement Cannot Transfer Control into IF Statement

The GOTO statement transfers control into an IF statement, causing an error.

```
DECLARE
  done BOOLEAN := TRUE;
BEGIN
```

```

GOTO update_row;

IF done THEN
  <<update_row>>
  NULL;
END IF;
END;
/

result:
  ERROR:  illegal GOTO statement; this GOTO cannot branch to
  label "update_row"
  CONTEXT:  PL/oraSQL function inline_code_block

```

## 42.6.7. Looping through Query Results

Using a different type of FOR loop, you can iterate through the results of a query and manipulate that data accordingly. The syntax is:

```

[ <<label>> ]
FOR target IN query LOOP
  statements
END LOOP [ label ];

```

The *target* is a record variable, row variable, or comma-separated list of scalar variables. The *target* is successively assigned each row resulting from the *query* and the loop body is executed for each row. Here is an example:

```

create table refresh_mvview (mv_schema varchar(100), mv_name
  varchar(100), owner varchar(100));
insert into refresh_mvview values ('asd', 'sdf', 'dfg');
CREATE OR REPLACE FUNCTION refresh_mvviews(id int) RETURN integer IS
BEGIN
  DBMS_OUTPUT.PUT_LINE('Refreshing all materialized views...');

  FOR mvviews IN (SELECT mv_schema, mv_name, owner FROM
refresh_mvview)
  LOOP
    -- Now "mvviews" has one record with information about the
    materialized view
    DBMS_OUTPUT.PUT_LINE('Refreshing materialized view ' ||
mvviews.mv_schema||'. ' ||
mvviews.mv_name|| ' (owner: %)...' ||
mvviews.owner);
  END LOOP;
  DBMS_OUTPUT.PUT_LINE('Done refreshing materialized views. ');
  RETURN id;
END;
/

```

If the loop is terminated by an EXIT statement, the last assigned row value is still accessible after the loop.

The *query* used in this type of FOR statement can be any SQL command that returns rows to the caller: SELECT is the most common case, but you can also use INSERT, UPDATE, or DELETE with a RETURNING clause. Some utility commands such as EXPLAIN will work too.

PL/oraSQL variables are substituted into the query text, and the query plan is cached for possible reuse.

The FOR-IN-EXECUTE-IMMEDIATE statement is another way to iterate over rows:

```
[ <<label>> ]
FOR target IN EXECUTE IMMEDIATE text_expression [ USING expression
  [, ... ] ] LOOP
  statements
END LOOP [ label ];
```

This is like the previous form, except that the source query is specified as a string expression, which is evaluated and replanned on each entry to the FOR loop. This allows the programmer to choose the speed of a preplanned query or the flexibility of a dynamic query, just as with a plain EXECUTE IMMEDIATE statement. As with EXECUTE IMMEDIATE, parameter values can be inserted into the dynamic command via USING.

Another way to specify the query whose results should be iterated through is to declare it as a cursor. This is described in Section 42.7.3.2.

## 42.6.8. Trapping Errors

By default, any error occurring in a PL/oraSQL function aborts execution of the function and the surrounding transaction. You can trap errors and recover from them by using a BEGIN block with an EXCEPTION clause. The syntax is an extension of the normal syntax for a BEGIN block:

```
[ DECLARE
  declarations ]
BEGIN
  statements
EXCEPTION
  WHEN condition [ OR condition ... ] THEN
    handler_statements
  [ WHEN condition [ OR condition ... ] THEN
    handler_statements
    ... ]
END;
```

If no error occurs, this form of block simply executes all the *statements*, and then control passes to the next statement after END. But if an error occurs within the *statements*, further processing of the *statements* is abandoned, and control passes to the EXCEPTION list. The list is searched for the first *condition* matching the error that occurred. If a match is found, the corresponding *handler\_statements* are executed, and then control passes to the next statement after END. If no match is found, the error propagates out as though the EXCEPTION clause were not there at all: the error can be caught by an enclosing block with EXCEPTION, or if there is none it aborts processing of the function.

The special condition name OTHERS matches every error type. Condition names are not case-sensitive.

### Tip

A block containing an EXCEPTION clause is significantly more expensive to enter and exit than a block without one. Therefore, don't use EXCEPTION without need.

## 42.7. Cursors

Rather than executing a whole query at once, it is possible to set up a *cursor* that encapsulates the query, and then read the query result a few rows at a time. One reason for doing this is to avoid memory overrun when the result contains a large number of rows. (However, PL/oraSQL users do not normally need to worry about that, since FOR loops automatically use a cursor internally to avoid memory problems.) A more interesting usage is to return a reference to a cursor that a function has created, allowing the caller to read the rows. This provides an efficient way to return large row sets from functions.

A *cursor* is a pointer to a private SQL area that stores information about processing a specific SELECT or DML statement.

A *cursor* that is constructed and managed by PL/oraSQL is an implicit cursor. A cursor that you construct and manage is an explicit cursor. You can get information about any session cursor from its attributes (which you can reference in procedural statements, but not in SQL statements).

### 42.7.1. Implicit cursors

An *implicit cursor* is a session cursor that is constructed and managed by PL/oraSQL. PL/oraSQL opens an *implicit cursor* every time you run a SELECT or DML statement. You cannot control an *implicit cursor*, but you can get information from its attributes.

An *implicit cursor* closes after its associated statement runs; however, its attribute values remain available until another SELECT or DML statement runs.

The most recently run SELECT or DML statement might be in a different scope. To save an attribute value for later use, assign it to a local variable immediately. Otherwise, other operations, such as subprogram invocations, might change the value of the attribute before you can test it.

#### 42.7.1.1. SQL%ISOPEN Attribute: Is the Cursor Open?

SQL%ISOPEN always returns FALSE, because an *implicit cursor* always closes after its associated statement runs.

#### 42.7.1.2. SQL%FOUND Attribute: Were Any Rows Affected?

SQL%FOUND returns:

- NULL if no SELECT or DML statement has run,
- TRUE if a SELECT statement returned one or more rows or a DML statement affected one or more rows,
- FALSE otherwise.

uses SQL%FOUND to determine if a DELETE statement affected any rows. For example:

```
create table employees(salary int, job_id varchar(100),
  employee_id int, last_name varchar(100), first_name varchar(100),
  department_id int, hire_date date);
create table departments(department_id int, department_name
  varchar(100), location_id int, staff int);
create table locations(country_id varchar(100), city
  varchar(100), location_id int);
create table jobs(job_title varchar(100), job_id varchar(100));
```

```

insert into employees values (12308, 'SA_REP', 100, 'huaxiang',
    'zhao', 2345, TO_DATE('31-DEC-2005', 'DD-MON-YYYY'));
insert into employees values (12301, 'AD_FG', 12301, 'huahai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12302, 'SA_REP', 12302, 'huaduo',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12302, 'S[HT]_CLERK', 12302,
    'huashuai', 'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12302, 'AD_FG', 100, 'huashuai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12304, 'AD_FG', 100, 'huashuai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12305, 'AD_FG', 100, 'huashuai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12306, 'AD_FG', 100, 'huashuai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12307, 'AD_FG', 100, 'huashuai',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));
insert into employees values (12308, 'AD_MAN', 100, 'huaxiang',
    'zhao', 2345, TO_DATE('31-DEC-2004', 'DD-MON-YYYY'));

insert into departments values (110, 'asd', 1700, 2345);
insert into departments values (2345, 'asd', 1800, 2345);
insert into departments values (110, 'asd', 1900, 2345);
insert into departments values (110, 'AD_FG', 12302, 2345);

insert into locations values ('JP', 'Japan', 1700);
insert into locations values ('Toronto', 'Canada', 1800);
insert into locations values ('WH', 'Whitehorse', 1900);

insert into jobs values ('sdadf', 'AD_FG');

DROP TABLE dept_temp;
CREATE TABLE dept_temp AS
    SELECT * FROM departments;

DECLARE
    dept_no NUMBER := 12;
BEGIN
    DELETE FROM dept_temp
    WHERE department_id = dept_no;

    IF SQL%FOUND THEN
        DBMS_OUTPUT.PUT_LINE ('Delete succeeded for department number '
            || dept_no);
    ELSE
        DBMS_OUTPUT.PUT_LINE ('No department number ' || dept_no);
    END IF;
END;
/

```

### 42.7.1.3. SQL%NOTFOUND Attribute: Were Any Rows Affected?

SQL%NOTFOUND (the logical opposite of SQL%FOUND) returns:

- NULL if no SELECT or DML statement has run,

- FALSE if a SELECT statement returned one or more rows or a DML statement affected one or more rows.

#### 42.7.1.4. SQL%ROWCOUNT Attribute: How Many Rows Were Affected?

SQL%ROWCOUNT returns:

- NULL if no SELECT or DML statement has run,
- Otherwise, the number of rows returned by a SELECT statement or affected by a DML statement (an INTEGER).

uses SQL%ROWCOUNT to determine the number of rows that were deleted. For example:

```
DROP TABLE employees_temp;
CREATE TABLE employees_temp AS
  SELECT * FROM employees;

DECLARE
  mgr_no int := 123005;
  rowcount int := 0;
BEGIN
  DELETE FROM employees_temp WHERE employee_id = mgr_no;
  rowcount := SQL%ROWCOUNT;
  DBMS_OUTPUT.PUT_LINE ('Number of employees deleted: ' ||
rowcount);
END;
/
```

### 42.7.2. Explicit cursors

An *explicit cursor* is a session cursor that is constructed and managed. You must declare and define an explicit cursor, giving it a name and associating it with a query (typically, the query returns multiple rows). Then you can process the query result set in either of these ways:

- Open the explicit cursor, fetch rows from the result set, and close the explicit cursor,
- Use the explicit cursor in a cursor FOR LOOP statement.

Unlike an *implicit cursor*, you can reference an *explicit cursor* or cursor variable by its name. Therefore, an explicit cursor or cursor variable is called a named cursor.

#### 42.7.2.1. Declaring and Defining *Explicit Cursors*

You can either declare an explicit cursor first and then define it later in the same block, subprogram, or package, or declare and define it at the same time.

An explicit cursor declaration, which only declares a cursor, has this syntax:

```
CURSOR cursor_name parameter_list RETURN return_type;
```

An explicit cursor definition has this syntax:

```
CURSOR cursor_name parameter_list RETURN return_type IS  
select_statement;
```

To actually use the `explicit cursor`, you can define it directly without declaring it.

declares and defines three explicit cursors. For example:

```
DECLARE  
  CURSOR c1 RETURN departments%ROWTYPE;      -- Declare c1  
  
  CURSOR c2 IS                                -- Declare and define c2  
    SELECT employee_id, job_id, salary FROM employees  
    WHERE salary > 2000;  
  
  CURSOR c1 RETURN departments%ROWTYPE IS    -- Define c1,  
    SELECT * FROM departments              -- repeating return type  
    WHERE department_id = 110;  
  
  CURSOR c3 RETURN locations%ROWTYPE;      -- Declare c3  
  
  CURSOR c3 IS                                -- Define c3,  
    SELECT * FROM locations                -- omitting return type  
    WHERE country_id = 'JP';  
BEGIN  
  NULL;  
END;  
/
```

### 42.7.2.2. Opening and Closing Explicit Cursors

After declaring and defining an explicit cursor, you can open it with the `OPEN` statement. Cursor names ignore case.

Both of the following uses open cursor `c_tmp`, for example:

```
open C_tmp;  
open c_tmp;
```

You close an open explicit cursor with the `CLOSE` statement, thereby allowing its resources to be reused. After closing a cursor, you cannot fetch records from its result set or reference its attributes.

### 42.7.2.3. Fetching Data with Explicit Cursors

After opening an explicit cursor, you can fetch the rows of the query result set with the `FETCH` statement. The basic syntax of a `FETCH` statement that returns one row is:

```
FETCH cursor_name INTO into_clause;
```

The `into_clause` is either a list of variables or a single record variable. For each column that the query returns, the variable list or record must have a corresponding type-compatible variable or field. The `%TYPE` and `%ROWTYPE` attributes are useful for declaring variables and records for use in `FETCH` statements.

The `FETCH` statement retrieves the current row of the result set, stores the column values of that row into the variables or record, and advances the cursor to the next row.

Typically, you use the `FETCH` statement inside a `LOOP` statement, which you exit when the `FETCH` statement runs out of rows. To detect this exit condition, use the cursor attribute `%NOTFOUND`. PL/oraSQL does not raise an exception when a `FETCH` statement returns no rows.

fetches the result sets of two explicit cursors one row at a time, using `FETCH` and `%NOTFOUND` inside `LOOP` statements. The first `FETCH` statement retrieves column values into variables. The second `FETCH` statement retrieves column values into a record. The variables and record are declared with `%TYPE` and `%ROWTYPE`, respectively. For example:

```

DECLARE
  CURSOR c1 IS
    SELECT last_name, job_id FROM employees
    WHERE REGEXP_LIKE (job_id, 'S[HT]_CLERK')
    ORDER BY last_name;

  v_lastname employees.last_name%TYPE; -- variable for last_name
  v_jobid employees.job_id%TYPE; -- variable for job_id

  CURSOR c2 IS
    SELECT * FROM employees
    WHERE REGEXP_LIKE (job_id, '[ACADFIMKSA]_M[ANGR]')
    ORDER BY job_id;

  v_employees employees%ROWTYPE; -- record variable for row of
table

BEGIN
  OPEN c1;
  LOOP -- Fetches 2 columns into variables
    FETCH c1 INTO v_lastname, v_jobid;
    EXIT WHEN c1%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (RPAD(v_lastname, 25, ' ') || v_jobid);
  END LOOP;
  CLOSE c1;
  DBMS_OUTPUT.PUT_LINE ('-----');

  OPEN c2;
  LOOP -- Fetches entire row into the v_employees record
    FETCH c2 INTO v_employees;
    EXIT WHEN c2%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (RPAD(v_employees.last_name, 25, ' ') ||
v_employees.job_id);
  END LOOP;
  CLOSE c2;
END;
/

```

fetches the first five rows of a result set into five records, using five `FETCH` statements, each of which fetches into a different record variable. The record variables are declared with `%ROWTYPE`. For example:

```

DECLARE
  CURSOR c IS
    SELECT e.job_id, j.job_title
    FROM employees e, jobs j
    WHERE e.job_id = j.job_id AND e.employee_id = 100
    ORDER BY last_name;

```



```

-- Record variables for rows of cursor result set:

job1 c%ROWTYPE;
job2 c%ROWTYPE;
job3 c%ROWTYPE;
job4 c%ROWTYPE;
job5 c%ROWTYPE;

BEGIN
  OPEN c;
  FETCH c INTO job1; -- fetches first row
  FETCH c INTO job2; -- fetches second row
  FETCH c INTO job3; -- fetches third row
  FETCH c INTO job4; -- fetches fourth row
  FETCH c INTO job5; -- fetches fifth row
  CLOSE c;

  DBMS_OUTPUT.PUT_LINE (job1.job_title || ' (' || job1.job_id ||
  ')');
  DBMS_OUTPUT.PUT_LINE (job2.job_title || ' (' || job2.job_id ||
  ')');
  DBMS_OUTPUT.PUT_LINE (job3.job_title || ' (' || job3.job_id ||
  ')');
  DBMS_OUTPUT.PUT_LINE (job4.job_title || ' (' || job4.job_id ||
  ')');
  DBMS_OUTPUT.PUT_LINE (job5.job_title || ' (' || job5.job_id ||
  ')');
END;
/

```

#### 42.7.2.4. Variables in Explicit Cursor Queries

An explicit cursor query can reference any variable in its scope. When you open an explicit cursor, PL/oraSQL evaluates any variables in the query and uses those values when identifying the result set. Changing the values of the variables later does not change the result set.

the explicit cursor query references the variable `factor`. When the cursor opens, `factor` has the value 2. Therefore, `sal_multiple` is always 2 times `sal`, despite that `factor` is incremented after every fetch. For example:

```

DECLARE
  sal          employees.salary%TYPE;
  sal_multiple employees.salary%TYPE;
  factor       INTEGER := 2;

  CURSOR c1 IS
    SELECT salary, salary*factor FROM employees
    WHERE job_id LIKE 'AD_%';

BEGIN
  OPEN c1; -- PL/SQL evaluates factor

  LOOP
    FETCH c1 INTO sal, sal_multiple;
    EXIT WHEN c1%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);
  
```

```

        DBMS_OUTPUT.PUT_LINE ('sal          = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
        factor := factor + 1;  -- Does not affect sal_multiple
    END LOOP;

    CLOSE c1;
END;
/

```

Variable in Explicit Cursor Query—Result Set Change. For example:

```

DECLARE
    sal          employees.salary%TYPE;
    sal_multiple employees.salary%TYPE;
    factor       INTEGER := 2;

    CURSOR c1 IS
        SELECT salary, salary*factor FROM employees
        WHERE job_id LIKE 'AD_%';

BEGIN
    DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);
    OPEN c1;  -- PL/SQL evaluates factor
    LOOP
        FETCH c1 INTO sal, sal_multiple;
        EXIT WHEN c1%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE ('sal          = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
    END LOOP;
    CLOSE c1;

    factor := factor + 1;

    DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);
    OPEN c1;  -- PL/SQL evaluates factor
    LOOP
        FETCH c1 INTO sal, sal_multiple;
        EXIT WHEN c1%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE ('sal          = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
    END LOOP;
    CLOSE c1;
END;
/

```

### 42.7.2.5. When Explicit Cursor Queries Need Column Aliases

When an explicit cursor query includes a virtual column (an expression), that column must have an alias if either of the following is true:

You close an open explicit cursor with the `CLOSE` statement, thereby allowing its resources to be reused. After closing a cursor, you cannot fetch records from its result set or reference its attributes. If you try, PL/oraSQL raises the predefined exception `INVALID_CURSOR`.

- You use the cursor to fetch into a record that was declared with `%ROWTYPE`,
- You want to reference the virtual column in your program.

The virtual column in the explicit cursor needs an alias for both of the preceding reasons. For example:

```

DECLARE
  CURSOR c1 IS
    SELECT employee_id,
           (salary * .05) raise
    FROM employees
    WHERE job_id LIKE '%_MAN'
    ORDER BY employee_id;
  emp_rec c1%ROWTYPE;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO emp_rec;
    EXIT WHEN c1%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE ('Raise for employee #' ||
emp_rec.employee_id || ' is $' || emp_rec.raise);
  END LOOP;
  CLOSE c1;
END;
/

```

### 42.7.2.6. Explicit Cursors that Accept Parameters

You can create an explicit cursor that has formal parameters, and then pass different actual parameters to the cursor each time you open it. In the cursor query, you can use a formal cursor parameter anywhere that you can use a constant. Outside the cursor query, you cannot reference formal cursor parameters.

Creates an explicit cursor whose two formal parameters represent a job and its maximum salary. When opened with a specified job and maximum salary, the cursor query selects the employees with that job who are overpaid (for each such employee, the query selects the first and last name and amount overpaid). Next, the example creates a procedure that prints the cursor query result set (for information about procedures, see PL/SQL Subprograms). Finally, the example opens the cursor with one set of actual parameters, prints the result set, closes the cursor, opens the cursor with different actual parameters, prints the result set, and closes the cursor. For example:

```

DECLARE
  CURSOR c (job VARCHAR2, max_sal NUMBER) IS
    SELECT last_name, first_name, (salary - max_sal) overpayment
    FROM employees
    WHERE job_id = job
    AND salary > max_sal
    ORDER BY salary;

  last_name_  employees.last_name%TYPE;
  first_name_ employees.first_name%TYPE;
  overpayment_ employees.salary%TYPE;
BEGIN
  DBMS_OUTPUT.PUT_LINE ('-----');
  DBMS_OUTPUT.PUT_LINE ('Overpaid Stock Clerks:');
  DBMS_OUTPUT.PUT_LINE ('-----');
  OPEN c('ST_CLERK', 5000);
  LOOP
    FETCH c INTO last_name_, first_name_, overpayment_;
    EXIT WHEN c%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (last_name_ || ',' || first_name_ || ',
(by' || overpayment_ || '));
  END LOOP;

```

```

CLOSE c;

DBMS_OUTPUT.PUT_LINE ('-----');
DBMS_OUTPUT.PUT_LINE ('Overpaid Sales Representatives:');
DBMS_OUTPUT.PUT_LINE ('-----');
OPEN c('SA_REP', 10000);
LOOP
    FETCH c INTO last_name_, first_name_, overpayment_;
    EXIT WHEN c%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (last_name_ || ',' || first_name_ || ',
(by' || overpayment_ || ')');
END LOOP;
CLOSE c;
END;
/

```

### 42.7.2.7. Formal Cursor Parameters with Default Values

When you create an explicit cursor with formal parameters, you can specify default values for them. When a formal parameter has a default value, its corresponding actual parameter is optional. If you open the cursor without specifying the actual parameter, then the formal parameter has its default value.

```
parameter_name [IN] data_type [:= / default expression]
```

The application scenarios are stored procedures, functions, anonymous blocks and packages. Compared with Oracle, there are some differences. For example, for `data_type`, Oracle supports the declaration of `char` in the cursor parameter string, but the default value of lightdb's `char` length is 1, so for strings whose length exceeds 1, you need to specify the `char` length, `char(100)`. But for variable-length character types, such as `varchar`, `varchar2`, etc., the usage is the same as oracle. And does not support oracle types: `string`, `long`, `raw`, `long raw`, `rowid`, `timestamp with local time`, etc. The constant type defined by constant is not supported in the package.

Expressions also have some differences compared to Oracle.

- Boolean Expressions
  - The package supports functions that return boolean types, boolean expressions and boolean literals (NULL supported by oracle does not support)#
  - Functions, stored procedures, and anonymous blocks support functions that return boolean types, boolean constants, Boolean variables, boolean expressions, and boolean literals (NULL supported by oracle does not support).
- Character Expressions
  - The package supports functions that return values of type `characer` and `characer` literals,
  - Functions, stored procedures, and anonymous blocks support functions that return values of type `characer`, `characer` constants, `characer` variables, `characer` expressions, and `characer` literals.
- Date Expressions
  - The package supports functions that return values of type `date` and `date` literals,
  - Functions, stored procedures, and anonymous blocks support functions that return values of type `date`, `date` constants, `date` variables, `date` expressions, and `date` literals.
- Numeric Expressions

- Not supported in package: collection, named\_cursor, numeric\_constant, numeric\_variable, placeholder, SQL% cursor attribute, \*\* (operator not supported),
- Not supported in functions, stored procedures, anonymous blocks: collection, named\_cursor, placeholder, SQL% cursor attribute, \*\* (operator not supported).
- Case Expressions
  - search\_case\_expression and simple\_case\_expression are supported in packages, functions, stored procedures, anonymous blocks.

Creates an explicit cursor whose formal parameter represents a location ID. The default value of the parameter is the location ID of company headquarters. For example:

```

DECLARE
  CURSOR c (location NUMBER DEFAULT 1700) IS
    SELECT d.department_name,
           e.last_name manager,
           l.city
    FROM departments d, employees e, locations l
    WHERE l.location_id = location
          AND l.location_id = d.location_id
          AND d.department_id = e.department_id
    ORDER BY d.department_id;
  dept_name departments.department_name%TYPE;
  mgr_name employees.last_name%TYPE;
  city_name locations.city%TYPE;
BEGIN
  DBMS_OUTPUT.PUT_LINE ('DEPARTMENTS AT HEADQUARTERS: ');
  DBMS_OUTPUT.PUT_LINE ('-----');
  OPEN c;
  LOOP
    FETCH c INTO dept_name, mgr_name, city_name;
    EXIT WHEN c%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (dept_name || ' (Manager: ' || mgr_name ||
  ')');
  END LOOP;
  DBMS_OUTPUT.PUT_LINE ('-----');
  CLOSE c;

  DBMS_OUTPUT.PUT_LINE ('DEPARTMENTS IN CANADA: ');
  DBMS_OUTPUT.PUT_LINE ('-----');
  OPEN c(1800); -- Toronto
  LOOP
    FETCH c INTO dept_name, mgr_name, city_name;
    EXIT WHEN c%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (dept_name || ' (Manager: ' || mgr_name ||
  ')');
  END LOOP;
  CLOSE c;
  OPEN c(1900); -- Whitehorse
  LOOP
    FETCH c INTO dept_name, mgr_name, city_name;
    EXIT WHEN c%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE (dept_name || ' (Manager: ' || mgr_name ||
  ')');
  END LOOP;

```

```

    CLOSE c;
END;
/

```

If you add formal parameters to a cursor, and you specify default values for the added parameters, then you need not change existing references to the cursor. For example:

```

DECLARE
    CURSOR c (job VARCHAR2, max_sal NUMBER,
             hired DATE DEFAULT TO_DATE('31-DEC-1999', 'DD-MON-
YYYY')) IS
    SELECT last_name, first_name, (salary - max_sal) overpayment
    FROM employees
    WHERE job_id = job
    AND salary > max_sal
    AND hire_date > hired
    ORDER BY salary;
    last_name_   employees.last_name%TYPE;
    first_name_  employees.first_name%TYPE;
    overpayment_ employees.salary%TYPE;
BEGIN
    DBMS_OUTPUT.PUT_LINE ('-----');
    DBMS_OUTPUT.PUT_LINE ('Overpaid Sales Representatives Hired After
2004:');
    DBMS_OUTPUT.PUT_LINE ('-----');
    OPEN c('SA_REP', 10000);
    LOOP
        FETCH c INTO last_name_, first_name_, overpayment_;
        EXIT WHEN c%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE (last_name_ || ', (by ' || overpayment_ ||
')');
    END LOOP;
    CLOSE c;
END;
/

```

## 42.7.2.8. Explicit Cursor Attributes

The syntax for the value of an explicit cursor attribute is `cursor_name` immediately followed by attribute (for example, `c1%ISOPEN`).

You close an open explicit cursor with the `CLOSE` statement, thereby allowing its resources to be reused. After closing a cursor, you cannot fetch records from its result set or reference its attributes. If you try, PL/oraSQL raises the predefined exception `INVALID_CURSOR`.

### 42.7.2.8.1. %ISOPEN Attribute: Is the Cursor Open?

`%ISOPEN` returns `true`, if its explicit cursor is open. `false` otherwise.

opens the explicit cursor `c1` only if it is not open and closes it only if it is open. For example:

```

DECLARE
    CURSOR c1 IS
    SELECT last_name, salary FROM employees
    WHERE ROWNUM < 11;

    the_name employees.last_name%TYPE;

```

```

    the_salary employees.salary%TYPE;
BEGIN
    IF NOT c1%ISOPEN THEN
        OPEN c1;
    END IF;

    FETCH c1 INTO the_name, the_salary;

    IF c1%ISOPEN THEN
        CLOSE c1;
    END IF;
END;
/

```

To use ROWNUM, the value of lightdb\_dblevel\_syntax\_compatible\_type must be oracle.

#### 42.7.2.8.2. %FOUND Attribute: Were Any Rows Affected?

%FOUND returns:

- NULL after the explicit cursor is opened but before the first fetch,
- TRUE if the most recent fetch from the explicit cursor returned a row,
- FALSE otherwise.

loops through a result set, printing each fetched row and exiting when there are no more rows to fetch. For example:

```

DECLARE
    CURSOR c1 IS
        SELECT last_name, salary FROM employees
        WHERE ROWNUM < 11
        ORDER BY last_name;

    my_ename    employees.last_name%TYPE;
    my_salary   employees.salary%TYPE;
BEGIN
    OPEN c1;
    LOOP
        FETCH c1 INTO my_ename, my_salary;
        IF c1%FOUND THEN -- fetch succeeded
            DBMS_OUTPUT.PUT_LINE ('Name = ' || my_ename || ' salary = '
|| my_salary);
        ELSE -- fetch failed
            EXIT;
        END IF;
    END LOOP;
END;
/

```

#### 42.7.2.8.3. %NOTFOUND Attribute: Were Any Rows Affected?

%NOTFOUND (the logical opposite of %FOUND) returns:

- NULL after the explicit cursor is opened but before the first fetch,
- FALSE if the most recent fetch from the explicit cursor returned a row,

- TRUE otherwise.

%NOTFOUND is useful for exiting a loop when FETCH fails to return a row. For example:

```

DECLARE
  CURSOR c1 IS
    SELECT last_name FROM employees
    WHERE ROWNUM < 11
    ORDER BY last_name;
  rowcount int;
  name_1 employees.last_name%TYPE;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO name_1;
    EXIT WHEN c1%NOTFOUND;
    rowcount := c1%ROWCOUNT;
    DBMS_OUTPUT.PUT_LINE (rowcount || '. ' || name_1);
    IF c1%ROWCOUNT = 5 THEN
      DBMS_OUTPUT.PUT_LINE ('--- Fetched 5th row ---');
    END IF;
  END LOOP;
  CLOSE c1;
END;
/

```

#### 42.7.2.8.4. %ROWCOUNT Attribute: How Many Rows Were Affected?

%ROWCOUNT returns:

- Zero after the explicit cursor is opened but before the first fetch,
- Otherwise, the number of rows fetched (an INTEGER).

numbers and prints the rows that it fetches and prints a message after fetching the fifth row. For example:

```

DECLARE
  CURSOR c1 IS
    SELECT last_name FROM employees
    WHERE ROWNUM < 11
    ORDER BY last_name;

  name_1 employees.last_name%TYPE;
  rowcount int;
BEGIN
  OPEN c1;
  LOOP
    FETCH c1 INTO name_1;
    EXIT WHEN c1%NOTFOUND OR c1%NOTFOUND IS NULL;
    rowcount := c1%ROWCOUNT;
    DBMS_OUTPUT.PUT_LINE (rowcount || '. ' || name_1);
    IF c1%ROWCOUNT = 5 THEN
      DBMS_OUTPUT.PUT_LINE ('--- Fetched 5th row ---');
    END IF;
  END LOOP;
  CLOSE c1;

```



```
END ;  
/
```

## 42.7.3. Processing Query Result Sets

In PL/oraSQL, as in traditional database programming, you use cursors to process query result sets. However, in PL/oraSQL, you can use either implicit or explicit cursors.

The former need less code, but the latter are more flexible. For example, explicit cursors can accept parameters.

The following PL/oraSQL statements use implicit cursors that PL/oraSQL defines and manages for you:

- `SELECT INTO`,
- Implicit cursor `FOR LOOP`.

The following PL/oraSQL statements use explicit cursors:

- Explicit cursor `FOR LOOP`,
- `OPEN`, `FETCH`, and `CLOSE`.

### 42.7.3.1. Processing Query Result Sets With `SELECT INTO` Statements

Using an implicit cursor, the `SELECT INTO` statement retrieves values from one or more database tables (as the SQL `SELECT` statement does) and stores them in variables (which the SQL `SELECT` statement does not do).

#### 42.7.3.1.1. Handling Single-Row Result Sets

If you expect the query to return only one row, then use the `SELECT INTO` statement to store values from that row in either one or more scalar variables, or one record variable.

If the query might return multiple rows, but you care about only the *n*th row, then restrict the result set to that row with the clause `WHERE ROWNUM=n`.

#### 42.7.3.1.2. Handling Large Multiple-Row Result Sets

If you must assign a large quantity of table data to variables, LightDB recommends using the `SELECT INTO` statement with the `BULK COLLECT` clause.

### 42.7.3.2. Processing Query Result Sets With `Cursor FOR LOOP` Statements

The `cursor FOR LOOP` statement lets you run a `SELECT` statement and then immediately loop through the rows of the result set.

This statement can use either an implicit or explicit cursor (but not a cursor variable).

If you use the `SELECT` statement only in the `cursor FOR LOOP` statement, then specify the `SELECT` statement inside the `cursor FOR LOOP` statement. Implicit Cursor `FOR LOOP` Statement. For example:

```
BEGIN  
  FOR item IN (  
    select last_name, job_id  
    FROM employees
```

```
        WHERE job_id LIKE '%CLERK%'
        AND employee_id > 120
    )
    LOOP
        DBMS_OUTPUT.PUT_LINE ('Name = ' || item.last_name || ', Job = '
|| item.job_id);
    END LOOP;
END;
/
```

Explicit Cursor FOR LOOP Statement. For example:

```
DECLARE
    CURSOR c1 IS
        SELECT last_name, job_id FROM employees
        WHERE job_id LIKE '%CLERK%' AND employee_id > 120
        ORDER BY last_name;
BEGIN
    FOR item IN c1
    LOOP
        DBMS_OUTPUT.PUT_LINE ('Name = ' || item.last_name || ', Job = '
|| item.job_id);
    END LOOP;
END;
/
```

Passing Parameters to Explicit Cursor FOR LOOP Statement. For example:

```
DECLARE
    CURSOR c1 (job VARCHAR2, max_wage NUMBER) IS
        SELECT * FROM employees
        WHERE job_id = job
        AND salary > max_wage;
BEGIN
    FOR person IN c1('ST_CLERK', 3000)
    LOOP
        -- process data record
        DBMS_OUTPUT.PUT_LINE ('Name = ' || person.last_name || ',
salary = ' || person.salary || ', Job id= ' || person.job_id);
    END LOOP;
END;
/
```

Cursor FOR LOOP References Virtual Columns. For example:

```
BEGIN
    FOR item IN (
        SELECT first_name || ' ' || last_name AS full_name,
               salary * 10 AS dream_salary
        FROM employees
        WHERE ROWNUM < 6
        ORDER BY dream_salary DESC, last_name ASC
    ) LOOP
        DBMS_OUTPUT.PUT_LINE (item.full_name || ' dreams of making ' ||
item.dream_salary);
    END LOOP;
END;
```

```
END;  
/
```

### 42.7.3.3. Processing Query Result Sets with Subqueries

If you process a query result set by looping through it and running another query for each row, then you can improve performance by removing the second query from inside the loop and making it a subquery of the first query.

While an ordinary subquery is evaluated for each table, a `correlated` subquery is evaluated for each row.

Subquery in FROM Clause of Parent Query. For example:

```
DECLARE  
  CURSOR c1 IS  
    SELECT t1.department_id, t1.department_name, t2.staff  
    FROM departments t1,  
         ( SELECT department_id, COUNT(*) AS staff  
           FROM employees  
           GROUP BY department_id  
         ) t2  
    WHERE (t1.department_id = t2.department_id) AND t2.staff > 5  
    ORDER BY t2.staff;  
  
BEGIN  
  FOR dept IN c1  
  LOOP  
    DBMS_OUTPUT.PUT_LINE ('Department = ' || dept.department_name  
  || ', staff = ' || dept.staff);  
  END LOOP;  
END;  
/
```

Correlated Subquery. For example:

```
DECLARE  
  CURSOR c1 IS  
    SELECT department_id, last_name, salary  
    FROM employees t  
    WHERE salary >= ( SELECT AVG(salary)  
                      FROM employees  
                      WHERE t.department_id = department_id  
                    )  
    ORDER BY department_id, last_name;  
BEGIN  
  FOR person IN c1  
  LOOP  
    DBMS_OUTPUT.PUT_LINE ('Making above-average salary = ' ||  
  person.last_name);  
  END LOOP;  
END;  
/
```

### 42.7.4. Cursor Variables

A cursor variable is like an explicit cursor, except that:

- It is not limited to one query. You can open a cursor variable for a query, process the result set, and then use the cursor variable for another query.
- You can assign a value to it.
- You can use it in an expression.
- It can be a subprogram parameter. You can use cursor variables to pass query result sets between subprograms.
- It can be a host variable. You can use cursor variables to pass query result sets between PL/oraSQL stored subprograms and their clients.
- It cannot accept parameters. You cannot pass parameters to a cursor variable, but you can pass whole queries to it. The queries can include variables.

### 42.7.4.1. Creating Cursor Variables

To create a cursor variable, either declare a variable of the predefined type `SYS_REFCURSOR` or define a `REF CURSOR` type and then declare a variable of that type.

The basic syntax of a `REF CURSOR` type definition is:

```
TYPE type_name IS REF CURSOR RETURN return_type%TYPE
```

Cursor Variable Declarations. For example:

```
DECLARE
  TYPE empcurtyp IS REF CURSOR RETURN employees%ROWTYPE;
  TYPE genericcurtyp IS REF CURSOR;

  cursor1 empcurtyp;
  cursor2 genericcurtyp;
  my_cursor SYS_REFCURSOR;

  TYPE deptcurtyp IS REF CURSOR RETURN departments%ROWTYPE;
  dept_cv deptcurtyp; -- strong cursor variable
BEGIN
  NULL;
END;
/
```

Cursor Variable with User-Defined Return Type. For example:

```
DECLARE
  TYPE EmpRecTyp IS RECORD (
    employee_id NUMBER,
    last_name VARCHAR2(25),
    salary NUMBER(8,2));

  TYPE EmpCurTyp IS REF CURSOR RETURN EmpRecTyp;
  emp_cv EmpCurTyp;
BEGIN
  NULL;
END;
/
```

A variable of cursor type created using `CREATE DOMAIN`. For example:

```

CREATE DOMAIN mycursor AS refcursor;
SELECT dbms_output.serveroutput(true);
DECLARE
    employee_cursor mycursor;

    v_employee_name VARCHAR2(50);
BEGIN
    OPEN employee_cursor for SELECT first_name FROM employees_curs
    WHERE employee_id = 1500;

    LOOP
        FETCH employee_cursor INTO v_employee_name;
        EXIT WHEN employee_cursor%NOTFOUND;

        DBMS_OUTPUT.PUT_LINE('Employee Name: ' || v_employee_name);
    END LOOP;

    CLOSE employee_cursor;
END;
/

```

Use `sys_refcursor` as a parameter variable. For example:

```

CREATE TABLE customer_address
(
    ca_address_sk          integer          not null,
    ca_address_id         char(16)         not null,
    ca_street_number      char(10)         ,
    ca_street_name        varchar(60)      ,
    ca_street_type        char(15)         ,
    ca_suite_number       char(10)         ,
    ca_city               varchar(60)      ,
    ca_county             varchar(30)      ,
    ca_state              char(2)          ,
    ca_zip                char(10)         ,
    ca_country            varchar(20)      ,
    ca_gmt_offset         decimal(5,2)     ,
    ca_location_type      char(20)        ,
    PRIMARY KEY (ca_address_sk)
);

DECLARE
    i_id          integer := 1;
    address_id    char(16);
    street_number char(10);
    street_name   varchar(60);
    street_type   char(15);
    suite_number  char(10);
    city          varchar(60);
    county        varchar(30);
    state         char(2);
    zip          char(10);
    country       varchar(20);
    gmt_offset    decimal(5,2);
    location_type char(20);

```

```

BEGIN
  -- insert
  address_id      := 'address_id';
  street_number   := '3588' ;
  street_name     := 'street_name';
  street_type     := 'street_type';
  suite_number    := '1';
  city            := 'Hang Zhou';
  county          := 'Bin Jiang';
  state           := 'CN';
  zip             := '000000';
  country         := 'China';
  gmt_offset      := 1.02;
  location_type   := 'location_type';

  INSERT INTO customer_address(ca_address_sk, ca_address_id,
  ca_street_number, ca_street_name, ca_street_type, ca_suite_number,
  ca_city, ca_county, ca_state, ca_zip, ca_country, ca_gmt_offset,
  ca_location_type)
  VALUES (i_id, address_id, street_number, street_name,
  street_type, suite_number, city, county, state, zip, country,
  gmt_offset, location_type);
END;
/

CREATE OR REPLACE PROCEDURE getCustomerAddress(cur OUT
  sys_refcursor) IS
BEGIN
  OPEN cur FOR SELECT * FROM customer_address;
END;
/

DECLARE
  ad  sys_refcursor;
  res customer_address%rowtype;
BEGIN
  getCustomerAddress(ad);

  LOOP
    FETCH ad INTO res;
    EXIT WHEN ad%NOTFOUND;
    dbms_output.put_line('ca_address_sk: ' ||
  res.ca_address_sk);
    dbms_output.put_line('ca_address_id: ' ||
  res.ca_address_id);
    dbms_output.put_line('ca_street_number: ' ||
  res.ca_street_number);
    dbms_output.put_line('ca_street_name: ' ||
  res.ca_street_name);
    dbms_output.put_line('ca_street_type: ' ||
  res.ca_street_type);
    dbms_output.put_line('ca_suite_number: ' ||
  res.ca_suite_number);
    dbms_output.put_line('ca_city: ' || res.ca_city);
    dbms_output.put_line('ca_county: ' || res.ca_county);
    dbms_output.put_line('ca_state: ' || res.ca_state);
    dbms_output.put_line('ca_zip: ' || res.ca_zip);
    dbms_output.put_line('ca_country: ' || res.ca_country);
  
```

```

        dbms_output.put_line('ca_gmt_offset:' ||
res.ca_gmt_offset);
        dbms_output.put_line('ca_location_type:' ||
res.ca_location_type);
    END LOOP;
END;
/

```

## 42.7.4.2. Opening and Closing Cursor Variables

After declaring a cursor variable, you can open it with the `OPEN FOR` statement, which does the following:

- Associates the cursor variable with a query (typically, the query returns multiple rows). The query can include placeholders for bind variables, whose values you specify in the `USING` clause of the `OPEN FOR` statement.
- Allocates database resources to process the query.
- Processes the query; that is:
  - Identifies the result set. If the query references variables, their values affect the result set.
  - If the query has a `FOR UPDATE` clause, locks the rows of the result set.
- Positions the cursor before the first row of the result set.

## 42.7.4.3. Fetching Data with Cursor Variables

After opening a cursor variable, you can fetch the rows of the query result set with the `FETCH` statement. The return type of the cursor variable must be compatible with the `into_clause` of the `FETCH` statement.

The first `iOPEN FOR` statement includes the query itself. The second `OPEN FORi` statement references a variable whose value is a query. For example:

```

DECLARE
    cv SYS_REFCURSOR; -- cursor variable

    v_lastname employees.last_name%TYPE; -- variable for last_name
    v_jobid employees.job_id%TYPE; -- variable for job_id

    query_2 VARCHAR2(200) :=
        'SELECT * FROM employees
        WHERE REGEXP_LIKE (job_id, ''[ACADFIMKSA]_M[ANGR]'')
        ORDER BY job_id';

    v_employees employees%ROWTYPE; -- record variable row of table

BEGIN
    OPEN cv FOR
        SELECT last_name, job_id FROM employees
        WHERE REGEXP_LIKE (job_id, 'S[HT]_CLERK')
        ORDER BY last_name;

    LOOP -- Fetches 2 columns into variables
        FETCH cv INTO v_lastname, v_jobid;
    END LOOP;
END;

```

```

EXIT WHEN cv%NOTFOUND;
DBMS_OUTPUT.PUT_LINE (RPAD(v_lastname, 25, ' ') || v_jobid);
END LOOP;

DBMS_OUTPUT.PUT_LINE ('-----');

CLOSE cv;

OPEN cv FOR query_2;

LOOP -- Fetches entire row into the v_employees record
  FETCH cv INTO v_employees;
  EXIT WHEN cv%NOTFOUND;
  DBMS_OUTPUT.PUT_LINE (RPAD(v_employees.last_name, 25, ' ') ||
v_employees.job_id);
END LOOP;

CLOSE cv;
END;
/

```

#### 42.7.4.4. Assigning Values to Cursor Variables

You can assign to a PL/oraSQL cursor variable the value of another PL/oraSQL cursor variable or host cursor variable.

```
target_cursor_variable := source_cursor_variable;
```

If `source_cursor_variable` is open, then after the assignment, `target_cursor_variable` is also open. The two cursor variables point to the same SQL work area.

If `source_cursor_variable` is not open, opening `target_cursor_variable` after the assignment does not open `source_cursor_variable`.

Fetching from Cursor Variable into Collections. For example:

```

DECLARE
  TYPE empcurtyp IS REF CURSOR;
  emp_cv empcurtyp;
  emp_cf empcurtyp;
  item employees%rowtype;
BEGIN
  OPEN emp_cv FOR SELECT * FROM employees WHERE job_id = 'SA_REP'
ORDER BY salary DESC;
  OPEN emp_cf FOR SELECT * FROM employees;
  emp_cf := emp_cv;
  LOOP
    FETCH emp_cf INTO item;
    DBMS_OUTPUT.PUT_LINE ('Name = ' || item.last_name || ', salary =
' || item.salary);
    EXIT WHEN emp_cf%notfound;
  END LOOP;
  CLOSE emp_cf;
END;
/

```



## 42.7.4.5. Variables in Cursor Variable Queries

The query associated with a cursor variable can reference any variable in its scope.

When you open a cursor variable with the OPEN FOR statement, PL/oraSQL evaluates any variables in the query and uses those values when identifying the result set. Changing the values of the variables later does not change the result set.

Fetching from Cursor Variable into Collections. For example:

```
DECLARE
    sal            employees.salary%TYPE;
    sal_multiple   employees.salary%TYPE;
    factor         INTEGER := 2;

    cv SYS_REFCURSOR;

BEGIN
    OPEN cv FOR
        SELECT salary, salary*factor
        FROM employees
        WHERE job_id LIKE 'AD_%';    -- PL/SQL evaluates factor

    LOOP
        FETCH cv INTO sal, sal_multiple;
        EXIT WHEN cv%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);
        DBMS_OUTPUT.PUT_LINE ('sal      = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
        factor := factor + 1;    -- Does not affect sal_multiple
    END LOOP;

    CLOSE cv;
END;
/
```

Fetching from Cursor Variable into Collections. For example:

```
DECLARE
    sal            employees.salary%TYPE;
    sal_multiple   employees.salary%TYPE;
    factor         INTEGER := 2;

    cv SYS_REFCURSOR;

BEGIN
    DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);

    OPEN cv FOR
        SELECT salary, salary*factor
        FROM employees
        WHERE job_id LIKE 'AD_%';    -- PL/SQL evaluates factor

    LOOP
        FETCH cv INTO sal, sal_multiple;
        EXIT WHEN cv%NOTFOUND;
```

```

        DBMS_OUTPUT.PUT_LINE ('sal          = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
    END LOOP;

    factor := factor + 1;

    DBMS_OUTPUT.PUT_LINE ('factor = ' || factor);

    CLOSE cv;

    OPEN cv FOR
        SELECT salary, salary*factor
        FROM employees
        WHERE job_id LIKE 'AD_%';    -- PL/SQL evaluates factor

    LOOP
        FETCH cv INTO sal, sal_multiple;
        EXIT WHEN cv%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE ('sal          = ' || sal);
        DBMS_OUTPUT.PUT_LINE ('sal_multiple = ' || sal_multiple);
    END LOOP;

    CLOSE cv;
END;
/

```

#### 42.7.4.6. Cursor Variable Attributes

A cursor variable has the same attributes as an explicit cursor (see Explicit Cursor Attributes.). The syntax for the value of a cursor variable attribute is `cursor_variable_name` immediately followed by attribute (for example, `cv%ISOPEN`). If a cursor variable is not open, referencing any attribute except `%ISOPEN` raises the predefined exception `INVALID_CURSOR`.

## 42.8. Collections

In a collection, the internal components always have the same data type, and are called elements. You can access each element of a collection variable by its unique index, with this syntax: `variable_name(index)`. To create a collection variable, you either define a collection type and then create a variable of that type or use `%TYPE`.

A collection type defined in a PL/oraSQL block is a local type. It is available only in the block, and is stored in the database only if the block is in a standalone or package subprogram.

A collection type defined at schema level is a standalone type. You create it with the "CREATE TYPE Statement". It is stored in the database until you drop it with the "DROP TYPE Statement".

A collection type defined in a package specification is a public item. You can reference it from outside the package by qualifying it with the package name (`package_name.type_name`). It is stored in the database until you drop the package.

### 42.8.1. Associative Arrays

An *associative array* is a set of key-value pairs. Each key is a unique index, used to locate the associated value with the syntax `variable_name(index)`.

The data type of index can be either a string type (VARCHAR) or INTEGER. Indexes are stored in sort order, not creation order.

For example, defines a type of *associative array* indexed by string, declares a variable of that type, populates the variable with three elements, changes the value of one element, and prints the values (in sort order, not creation order).

```
DECLARE
  -- Associative array indexed by integer:
  TYPE population IS TABLE OF varchar  -- Associative array type
    INDEX BY integer;                  -- indexed by string

  city_population  population;          -- Associative array variable
  i                integer;

BEGIN
  -- Add elements (key-value pairs) to associative array:
  city_population('2') := 'Smallville';
  city_population('5') := 'Midland';
  city_population('3') := 'Megalopolis';

  FOR i IN 1..6 LOOP
    IF city_population.EXISTS(i) THEN
      dbms_output.put_line ('city_population(' || i || ') ' || '
exists');
    ELSE
      dbms_output.put_line ('city_population(' || i || ') ' || '
does not exist');
    END IF;
  END LOOP;

END;
/
```

## 42.8.2. Nested Tables

In the database, a nested table is a column type that stores an unspecified number of rows in no particular order.

When you retrieve a nested table value from the database into a PL/oraSQL nested table variable, PL/oraSQL gives the rows consecutive indexes, starting at 1. Using these indexes, you can access the individual rows of the nested table variable. The syntax is `variable_name(index)`. The indexes and row order of a nested table might not remain stable as you store and retrieve the nested table from the database.

The amount of memory that a nested table variable occupies can increase or decrease dynamically, as you add or delete elements.

Example: Nested Table of Local Type

```
DECLARE
TYPE Roster IS TABLE OF VARCHAR(15);  -- nested table type

-- nested table variable initialized with constructor:
names2 Roster := Roster('D Caruso', 'J Hamil', 'D Piro', 'R
Singh');

BEGIN
  DBMS_OUTPUT.PUT_LINE('Initial Values:');
```

```

    FOR i IN names2.FIRST .. names2.LAST LOOP -- For first to last
element
        DBMS_OUTPUT.PUT_LINE(names2(i));
    END LOOP;

    DBMS_OUTPUT.PUT_LINE('-----');
    names2(5) := 'P Perez'; -- add one element
    FOR i IN names2.FIRST .. names2.LAST LOOP -- For first to last
element
        DBMS_OUTPUT.PUT_LINE(names2(i));
    END LOOP;
END;
/

```

Example: Nested Table of Standalone Type

```

CREATE TYPE names2 IS TABLE OF VARCHAR(15);

DECLARE
    nt names2 ;
BEGIN
    nt(1) = 'D Caruso';
    nt(2) = 'J Hamil';
    nt(3) = 'R Singh';
    DBMS_OUTPUT.PUT_LINE(nt(2));
END;
/

```

### 42.8.3. Varrays

Variable-sized array is an array whose element count can vary from zero (empty) to the declared maximum size, and overruns are also supported here.

To access the elements of a mutable array, use the syntax `variable_name(index)`. When storing and retrieving mutable arrays in the database, their indexes and element order will remain stable.

As you add or delete elements, the amount of memory occupied by the mutable array variable can dynamically increase or decrease.

Currently, only local varrays are supported, not global varrays .

Example: varrays of local type

```

DECLARE
    TYPE Roster IS VARRAY(10) OF VARCHAR(15); -- varray type

    -- varray variable initialized with constructor:
    names2 Roster := Roster('D Caruso', 'J Hamil', 'D Piro', 'R
Singh');

BEGIN
    DBMS_OUTPUT.PUT_LINE('Initial Values:');
    FOR i IN names2.FIRST .. names2.LAST LOOP -- For first to last
element
        DBMS_OUTPUT.PUT_LINE(names2(i));
    END LOOP;

    DBMS_OUTPUT.PUT_LINE('-----');

```

```

names2.extend;
names2(5) := 'P Perez'; -- add one element
FOR i IN names2.FIRST .. names2.LAST LOOP -- For first to last
element
    DBMS_OUTPUT.PUT_LINE(names2(i));
END LOOP;
END;
/

```

## 42.8.4. Collection Methods

A collection method is a PL/oraSQL subprogram—either a function that returns information about a collection or a procedure that operates on a collection. Collection methods make collections easier to use and your applications easier to maintain.

Table 42.1 shows collection methods.

**Table 42.1. Collection methods**

Method	Description
DELETE	Deletes elements from collection.
EXTEND	Adds elements to end of nested table.
EXISTS	Returns TRUE if and only if specified element of nested table exists.
FIRST	Returns first index in collection.
LAST	Returns last index in collection.
COUNT	Returns number of elements in collection.

The basic syntax of a collection method invocation is:

```
collection_name.method
```

## 42.9. Transaction Management

In procedures invoked by the CALL command as well as in anonymous code blocks, it is possible to end transactions using the commands COMMIT and ROLLBACK. A new transaction is started automatically after a transaction is ended using these commands, so there is no separate START TRANSACTION command. (Note that BEGIN and END have different meanings in PL/oraSQL.)

Here is a simple example:

```

CREATE OR REPLACE PROCEDURE transaction_test1(b int) IS
BEGIN
    FOR i IN 0..9 LOOP
        INSERT INTO test1 (a) VALUES (i);
        IF i < b THEN
            COMMIT;
        ELSE
            ROLLBACK;
        END IF;
    END LOOP;
END;
/

CALL transaction_test1(3);

```

## 42.9.1. Operations Cursor With Transactions

This summary mainly introduces the combination of cursor operations and transaction operations (commit and rollback). Specifically divided into the following five categories:

- Function
  - Call function in function: not supported.
  - Function call process: not supported.
  - Functions and stored procedures in the function package:
    - Transfer function: not supported;
    - Package adjustment process: not supported.
- Stored procedure
  - Calling a function in a stored procedure: not supported.
  - Stored procedure call procedure: support.
  - Functions and stored procedures in the package are called in the stored procedure:
    - Transfer function: not supported;
    - Package adjustment process: not supported.
- Anonymous block
  - Call function in anonymous block: not supported.
  - Anonymous block mid-tuning process: support.
  - Functions and stored procedures in the call package in the anonymous block:
    - Transfer function: not supported;
    - Package adjustment process: not supported.
- Functions in the package
  - Package function call function: not supported.
  - Package function call stored procedure: not supported.
  - The package function calls the functions and stored procedures in the package:
    - Transfer function: not supported;
    - Package adjustment process: not supported.
- Stored Procedures in Packages
  - Package stored procedure caller: not supported.
  - Package stored procedure call stored procedure: support.
  - Package stored procedures transfer functions and stored procedures in packages:
    - Transfer function: not supported;

- Package adjustment process: not supported.

**Tip**

Cursor operations and transaction operations (commit and rollback) are used in combination, and the value of `lightdb_dblevel_syntax_compatible_type` is `oracle` and `search_path` need to be set as follows: `SET search_path TO public, oracle;`

**Tip**

Calling functions in the same way as stored procedures is not supported in anonymous blocks, such as:

```
create or replace function func return int as
begin
  dbms_output.put_line ('This is just a test');
end;
/

begin
  func();
  dbms_output.put_line ('This is just a test');
end;
/
```

**Tip**

Package Notes on Cursor Declarations and Definitions:

- When declaring a package, the cursor cannot be declared directly in the package;
- When defining a package body, you cannot define a cursor variable directly in the global area of the package body.

**Tip**

Currently stored procedures and plugin `auto_explain` cannot be used together.

Example: Stored procedure call procedure

```
--preconditional
-- the value of lightdb_dblevel_syntax_compatible_type must be
  oracle
create extension IF NOT EXISTS orafce;
SET search_path TO public, oracle;

create table ltbench_accounts(id int, abalance int);
```

```
--insert
declare
  irevert int := 9999;
  icount int := 1000;
begin
  loop
    execute immediate 'insert into ltbench_accounts
values(:er,:rt)' using irevert, icount;
    icount := icount - 1;
    irevert := irevert -1;
    exit when icount < 1;
  end loop;
end;
/

--commit#rollback
create or replace procedure tt_try_proc as
  CURSOR c1 IS
    SELECT * FROM ltbench_accounts;

  CURSOR c2 IS
    SELECT * FROM ltbench_accounts;

  emp_rec ltbench_accounts%ROWTYPE;
BEGIN
  OPEN c2;
  OPEN c1;
  UPDATE ltbench_accounts SET id = 25 WHERE abalance = 12;
  rollback;
  UPDATE ltbench_accounts SET id = 17 WHERE abalance = 13;
  commit;
  LOOP
    FETCH c1 INTO emp_rec;
    EXIT WHEN c1%NOTFOUND;
    dbms_output.put_line ('emp_rec.id = ' || emp_rec.id ||
'emp_rec.abalance = ' || emp_rec.abalance);
    UPDATE ltbench_accounts SET id = 23 WHERE abalance = 12;
    rollback;
  END LOOP;
  LOOP
    FETCH c2 INTO emp_rec;
    EXIT WHEN c2%NOTFOUND;
    dbms_output.put_line ('emp_rec.id = ' || emp_rec.id ||
'emp_rec.abalance = ' || emp_rec.abalance);
    UPDATE ltbench_accounts SET id = 18 WHERE abalance = 13;
    commit;
  END LOOP;
  commit;
  rollback;
END;
/

--call procedure in procedure
create or replace procedure tt_try_dproc as
begin
  tt_try_proc();
  dbms_output.put_line ('This is just a test');
end;
```



```
/
call tt_try_dproc();
```

Example: stored procedures in the package are called in the stored procedure

```
--preconditional
create table test(x int, y varchar(100));
insert into test values(1, 'One');
insert into test values(2, 'Two');
insert into test values(3, 'Three');

--create package
create or replace package pkg is
  CURSOR c1 IS SELECT x,y FROM test;
  function c_open return int;
  function c_fetch return int;
  procedure c_open_fetch;
end;
/

--create package boby
create or replace package body pkg IS
  function c_open return int as
  begin
    OPEN c1;
    return 0;
  end;

--The fetch in the package, the cursor will not be cleared
  function c_fetch return int AS
  v_x test.x%TYPE;
  v_y test.y%TYPE;
  begin
    LOOP
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
    END LOOP;
    --CLOSE c1;
    return 0;
  end;

  procedure c_open_fetch as
  v_x test.x%TYPE;
  v_y test.y%TYPE;
  BEGIN
    OPEN c1;
    COMMIT;
    LOOP
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
      IF c1%FOUND THEN
        UPDATE test SET x = 4 WHERE y = 'Two';
        ROLLBACK;
      END IF;
    END LOOP;
  END;
```

```
        END IF;
    END LOOP;
    CLOSE c1;
end;

begin
    dbms_output.put_line('initializer');
    --same as oracle, package not support dml, commit and roolback.
    --UPDATE test SET x = 5 WHERE y = 'Two';
    --COMMIT;
end;
/

--procedure of package callled by procedure
create or replace procedure tt_try_proc as
begin
    pkg.c_open_fetch();
    dbms_output.put_line ('This is just a test');
end;
/

call tt_try_proc();
```

Example: Anonymous block mid-tuning process

```
begin
    tt_try_proc();
end;
/
```

Example: stored procedures in the call package in the anonymous block

```
--procedure of package called by anonymous block
begin
    pkg.c_open_fetch();
    dbms_output.put_line ('This is just a test');
end;
/
```

Example: Package stored procedure call stored procedure

```
--create package
create or replace package pkg_proc is
    CURSOR c1 IS SELECT x,y FROM test;
    procedure c_proc;
end;
/

--create package boby
```

```
create or replace package body pkg_proc IS
  procedure c_proc as
    v_x test.x%TYPE;
    v_y test.y%TYPE;
  BEGIN
    OPEN c1;
    COMMIT;
    LOOP
      tt_try_proc();
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
      IF c1%FOUND THEN
        UPDATE test SET x = 4 WHERE y = 'Two';
        ROLLBACK;
      END IF;
    END LOOP;
    CLOSE c1;
  end;

begin
  dbms_output.put_line('initializer');
  UPDATE test SET x = 5 WHERE y = 'Two';
  COMMIT;
end;
/

call pkg_proc.c_proc();
```

Example: Package stored procedures transfer stored procedures in packages

```
--procedure of package called by procedure of package
--create package of pkg_proc
create or replace package pkg_proc is
  CURSOR c1 IS SELECT x,y FROM test;
  procedure c_proc;
end;
/

--create package boby of pkg_proc
create or replace package body pkg_proc IS
  procedure c_proc as
    v_x test.x%TYPE;
    v_y test.y%TYPE;
  BEGIN
    OPEN c1;
    COMMIT;
    LOOP
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
      IF c1%FOUND THEN
        UPDATE test SET x = 4 WHERE y = 'Two';
        ROLLBACK;
      END IF;
    END LOOP;
  end;
```

```

        END IF;
    END LOOP;
    CLOSE c1;
end;

begin
    dbms_output.put_line('initializer');
    UPDATE test SET x = 5 WHERE y = 'Two';
    COMMIT;
end;
/

--create package of pkg_call_proc
create or replace package pkg_call_proc is
    CURSOR c1 IS SELECT x,y FROM test;
    procedure c_call_proc;
end;
/

--create package body of pkg_call_proc
create or replace package body pkg_call_proc IS
    procedure c_call_proc as
        v_x test.x%TYPE;
        v_y test.y%TYPE;
    BEGIN
        OPEN c1;
        COMMIT;
        LOOP
            pkg_proc.c_proc();
            FETCH c1 INTO v_x, v_y;
            EXIT WHEN c1%NOTFOUND;
            dbms_output.put_line( v_x || '.' || v_y);
            IF c1%FOUND THEN
                UPDATE test SET x = 4 WHERE y = 'Two';
                ROLLBACK;
            END IF;
        END LOOP;
        CLOSE c1;
    end;

begin
    dbms_output.put_line('initializer');
    UPDATE test SET x = 5 WHERE y = 'Two';
    COMMIT;
end;
/

call pkg_call_proc.c_call_proc();

```

Example: When declaring a package, the cursor cannot be declared directly in the package

```

--Declare cursors in packages using sys_refcursor
--error

```

```
create or replace package pkg is
  c1 sys_refcursor;
  function c_open return int;
  function c_fetch return int;
  procedure c_open_fetch;
end;
/
```

Example: When defining a package body, you cannot define a cursor variable directly in the global area of the package body

```
--Declare the cursor in the package body using sys_refcursor
create or replace package pkg is
  function c_open return int;
  function c_fetch return int;
  procedure c_open_fetch;
end;
/
```

```
--error
create or replace package body pkg IS
  c1 sys_refcursor;
  function c_open return int as
  begin
    OPEN c1 for SELECT x,y FROM test;
    return 0;
  end;

  function c_fetch return int AS
  v_x test.x%TYPE;
  v_y test.y%TYPE;
  begin
    LOOP
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
    END LOOP;
    --CLOSE c1;
    return 0;
  end;

  procedure c_open_fetch as
  v_x test.x%TYPE;
  v_y test.y%TYPE;
  BEGIN
    OPEN c1 for SELECT x,y FROM test;
    COMMIT;
    LOOP
      FETCH c1 INTO v_x, v_y;
      EXIT WHEN c1%NOTFOUND;
      dbms_output.put_line( v_x || '.' || v_y);
      IF c1%FOUND THEN
        UPDATE test SET x = 4 WHERE y = 'Two';
        ROLLBACK;
      END IF;
    END LOOP;
  END;
```

```
        END IF;
        END LOOP;
    CLOSE c1;
end;

begin
    dbms_output.put_line('initializer');
    UPDATE test SET x = 5 WHERE y = 'Two';
    COMMIT;
end;
/
```

## 42.9.2. AUTONOMOUS TRANSACTION Pragma

The `AUTONOMOUS_TRANSACTION` pragma changes the way a subprogram works within a transaction. A subprogram marked with this pragma can do SQL operations and commit or roll back those operations, without committing or rolling back the data in the main transaction.

This is a new feature since version 23.2, you can apply this pragma to functions and procedures. It is only a syntax compatible feature for the current implementation.

Syntax

```
PRAGMA AUTONOMOUS_TRANSACTION;
```

Examples as below:

```
CREATE OR REPLACE PROCEDURE
    example_pragma_autonomous_transaction_procedure()
IS
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
    NULL;
END;
/
```

```
CREATE OR REPLACE FUNCTION
    example_pragma_autonomous_transaction_func()
RETURN void
IS
    PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
    NULL;
END;
/
```

## 42.10. Packages

This section journeys into the “Oracle Style Package” for LightDB. A package, by very definition, is an object or a group of objects packed together. In terms of databases, this translates into a named schema object that packages within itself a logically grouped collection of procedures, functions, variables, cursors, user-defined record types, and reference records.

## 42.10.1. Package Overview

### 42.10.1.1. The Need for Packages

Like similar constructs in various other programming languages, there are good reasons for using packages with SQL. In this section, we are going to cover a few.

- **Reliability and Reusability of Code Packages** provide the ability to create modular objects that encapsulate code. This makes the overall design and implementation simpler. The ability to encapsulate variables, related types, stored procedures/functions, and cursors, essentially allows creating a self-contained module that is simple and easy to understand, maintain and use. Encapsulation comes into play through the exposure of a package interface, rather than its implementation details, i.e., package body. This, therefore, benefits in many ways. Furthermore it allows applications and users to refer to a consistent interface and not worry about the contents of its body. Also, it prevents users from making any decisions based on code implementation as that's never exposed to them.
- **Ease of Use** The ability to create a consistent functional interface in LightDB helps simplify application development by allowing the compilation of packages without their bodies. Beyond the development phase, the package allows a user to manage access control on the entire package rather than individual objects. This is rather valuable especially if the package contains lots of schema objects.
- **Performance** Packages are loaded into memory for maintenance and therefore utilize minimal I/O resources. Recompilation is simple and only limited to object(s) changed; dependent objects are not recompiled.
- **Additional Features** In addition to performance and ease of use, packages offer session-wide persistence for variables and cursors. This means variables and cursors have the same lifetime as a database session and are destroyed when the session is destroyed.

### 42.10.1.2. Package Components

Package consists of two components. Package specification and Package body.

**Package Specification** Any object within the package that is to be used from the outside is specified in the package specification section. This is the publicly accessible interface we have been referring to in earlier sections. It does not contain the definition or implementation of them, i.e. the functions and the procedures. It only has their headers defined without the body definitions. The variables can be initialized. The following is the list of objects that can be listed in the package specification:

- Functions
- Procedures
- Cursors
- Types
- Variables
- Record types
- Associative Arrays
- Nested Tables

**Package Body** the body contains all the implementation code of a package, including the public interfaces and the private objects. A package body is optional if the specification does not contain any subprogram or cursor.

It must contain the definition of the subprograms declared in specification and the corresponding definitions must match.

A package body can contain its own subprogram and type declarations of any internal objects not specified in the specifications. These objects are then considered private. Private objects cannot be accessed from outside the package.

In addition to subprogram definitions, it can optionally contain an initializer block that initializes the variables declared in specification and is executed only once when the first call to the package is made in a session.

## 42.10.2. Create Package

### 42.10.2.1. CREATE PACKAGE

CREATE PACKAGE — Define a new package specification.

Syntax

```
CREATE [ OR REPLACE ] PACKAGE [schema.]package_name [IS | AS]
    item_list[, item_list ...]
END [package_name];
```

item\_list:

```
[
    function_declaration      |
    procedure_declaration     |
    type_definition           |
    cursor_declaration        |
    item_declaration          |
]
```

function\_declaration:

```
FUNCTION function_name [(parameter_declaration[, ...])] RETURN
datatype;
```

procedure\_declaration:

```
PROCEDURE procedure_name [(parameter_declaration[, ...])]
```

type\_definition:

```
record_type_definition      |
ref_cursor_type_definition
```

cursor\_declaration:

```
CURSOR name [(cur_param_decl[, ...])] RETURN rowtype;
```

item\_declaration:

```
cursor_declaration          |
cursor_variable_declaration |
record_variable_declaration |
variable_declaration        |
```

record\_type\_definition:

```
TYPE record_type IS RECORD ( variable_declaration [,
variable_declaration]... );
```



```

ref_cursor_type_definition:
    TYPE type IS REF CURSOR [ RETURN type%ROWTYPE ];

cursor_variable_declaration:
    curvar curtype;

record_variable_declaration:
    recvar { record_type | rowtype_attribute | record_type%TYPE };

variable_declaration:
    varname datatype [ [ NOT NULL ] := expr ];

parameter_declaration:
    parameter_name [IN] datatype [[:= | DEFAULT] expr]

```

#### Description

Creates the package specification that contains public declarations. The declared items in the package specification are accessible from anywhere in the package and to any other subprograms in the same database.

CREATE PACKAGE defines a new package. CREATE OR REPLACE PACKAGE will either create a new package or replace an existing definition.

If a schema name is included, then the package is created in the specified schema. Otherwise, it is created in the current schema. The name of the new package must be unique within the schema.

When CREATE OR REPLACE PACKAGE is used to replace an existing package, the ownership and permissions of the package do not change. All other package properties are assigned the values specified or implied in the command. Only the owner and member of the owning roles are allowed to replace the packages.

The user that creates the package becomes the owner of the package.

### 42.10.2.2. CREATE PACKAGE BODY

CREATE PACKAGE BODY — Define a new package definition.

#### Syntax

```

CREATE [ OR REPLACE ] PACKAGE BODY [schema.]package_name [IS | AS]
    [item_list[, item_list ...]] |
    item_list_2 [, item_list_2 ...]
    [initialize_section]
END [package_name];

```

```

initialize_section:
    BEGIN statement[, ...]

```

```

item_list:
[
    function_declaration |
    procedure_declaration |
    type_definition |
    cursor_declaration |
    item_declaration

```

```

]

item_list_2:
[
    function_declaration
    function_definition
    procedure_declaration
    procedure_definition
    cursor_definition
]

function_definition:
    FUNCTION function_name [(parameter_declaration[, ...])] RETURN
    datatype [IS | AS]
    [declare_section] body;

procedure_definition:
    PROCEDURE procedure_name [(parameter_declaration[, ...])] [IS |
    AS]
    [declare_section] body;

cursor_definition:
    CURSOR name [(cur_param_decl[, ...])] RETURN rowtype IS
    select_statement;

body:
    BEGIN statement[, ...] END [name];

statement:
    [LABEL] pl_statments[, ...];

```

#### Description

CREATE PACKAGE BODY defines the package body for a package. CREATE OR REPLACE PACKAGE body will either create a new package body for the package or replace an existing package body definition. Package specification must be created first to create the package body. The package body contains the implementation of every cursor and subprogram declared in the package specification created through “CREATE PACKAGE”. objects defined in a package body are only accessible to outside the package if their specification is listed in the package specification. For all objects that are only defined in the package body and are not included in the package specification, they become private members to the package and are not accessible outside of the package. Both the package and its body must be created in the same schema.

### 42.10.2.3. Parameters

`package_name` The name (optionally schema-qualified) of the package to create.

`item_list` This is the list of items that can be part of a package.

`procedure_declaration` The procedure signature, i.e. `procedure_name(argument_list )`. `procedure_declaration` can appear in both package specification and package body. Procedure declarations listed in the Package specification makes the procedure public and accessible from outside of the package. While the procedure declared in the package body is considered as a forward declaration and becomes a private member to the package.

`procedure_definition` Implementation/definition of the package procedure. `procedure_definition` can only be provided in the package body. Procedure access specifier is

determined by procedure declaration and the procedures defined in the package body without corresponding declaration automatically becomes private to the package.

`function_declaration` The function signature and its return type, i.e. `function_name(argument_list) RETURN return_type;`

`function_declaration` can appear in both package specification and package body. Function declarations listed in the Package specification makes the function public and accessible from outside the package. While the function declaration in the package body is considered as a forward declaration and becomes a private member to the package.

`function_definition` Implementation/definition of the package function. `function_definition` can only be provided in the package body. Function access specifier is determined by function declaration and the function defined in the package body without corresponding declaration automatically becomes private to the package.

`type_definition` Either a RECORD, or CURSOR type definition.

`cursor_declaration` CURSOR declaration along with its arguments and return type as the desired ROWTYPE.

`item_declaration` Allows declaration of: Cursors, Cursor variables, Record variable, Variables.

`parameter_declaration` Defines the syntax for declaring a parameter. The keyword “IN” if specified indicates that this is an input parameter. The DEFAULT keyword followed by an expression (or value) may only be specific for an input parameter.

`declare_section` This contains all the elements that are local to the function or procedure and can be referenced within its body.

`body` The body consists of the SQL statements or PL control structures that are supported by plorasql language.

## 42.10.3. Create and Access Packages

### 42.10.3.1. Create Packages

In the previous sections, we have gone through the syntax that dictates the structure of a package. In this section, we are going to take this a step further by understanding the construction process of a package and how we can access its public elements.

As a package is created, LightDB will compile it and report any issues it may find. Once the package is successfully compiled, it becomes ready for use.

### 42.10.3.2. Accessing Package Elements

A package is instantiated and initialized when it is referenced for the first time in a session. The following actions are performed in the same order during this process:

- Assignment of initial values to public variables
- Execution of the initializer block of the package

There are several ways to access package elements:

- Package functions can be utilized just as any other function in a SELECT statement or from other PL blocks
- Package procedure can be invoked directly using CALL or from other PL blocks

- Package variables can be directly read and written using the package name qualification in a PL block.
- Direct Access Using Dot Notation: In the dot notation, elements can be accessed in the following manner:
  - `package_name.func('foo');`
  - `package_name.proc('foo');`
  - `package_name.variable;`  
These statements can be used from inside a PL block or in a SELECT statement if the element is a function.
- SQL Call Statement: Another way is to use the CALL statement. The CALL statement executes a standalone procedure in a type or package.
  - `CALL package_name.proc('foo');`

### 42.10.3.3. Understanding Scope of Visibility

The scope of variables declared in a PL/oraSQL block is limited to that block. If it has nested blocks, then it will be a global variable to the nested blocks.

Similarly, if both blocks declare the same name variable, then inside of the nested block, its own declared variable is visible and the parent one becomes invisible. To access the parent variable, that variable must be fully qualified.

Consider the following code snippet.

Example: Visibility and Qualifying Variable Names

```
-- blk_1
DECLARE
  x INT;
  y INT;
BEGIN
  -- both blk_1.x and blk_1.y are visible
  -- blk_2
  DECLARE
    x INT;
    z INT;
  BEGIN
    -- blk_2.x, y and z are visible
    -- to access blk_1.x it has to be a qualified name.
    blk_1.x := 0; NULL;
    NULL;
  END;
  -- both x and y are visible
END;
/
```

The above example shows how you must fully qualify a variable name in case a nested package contains a variable with the same name.

Variable name qualification helps in resolving possible confusion that gets introduced by scope precedence in the following scenarios:

- Package and nested packages variables: without qualification, nested takes precedence
- Package variable and column names: without qualification, column name takes precedence
- Function or procedure variable and package variable: without qualification, package variable takes precedence.

## 42.10.4. Examples

create package example.

```
CREATE TABLE test(x INT, y VARCHAR2(100));
create table rectype(a int,b varchar2(100));
INSERT INTO test VALUES (1, 'One');
INSERT INTO test VALUES (2, 'Two');
INSERT INTO test VALUES (3, 'Three');
```

```
CREATE OR REPLACE PACKAGE example
AS
  -- Declare type, cursor:
  CURSOR curtype RETURN rectype%rowtype;

  rec rectype%rowtype;

  -- Declare subprograms:
  FUNCTION somefunc (v int) RETURN NUMBER;

  -- Overload preceding subprogram:
  PROCEDURE xfunc (emp_id NUMBER);
  PROCEDURE xfunc (emp_email VARCHAR2);
END;
/
```

create package body example.

```
CREATE OR REPLACE PACKAGE BODY example
AS
  nelems NUMBER; -- variable in this package

  -- Define cursor declared in package specification:
  CURSOR curtype RETURN rectype%rowtype IS SELECT x, y FROM test
ORDER BY x;
  -- Define subprograms declared in package specification:
  FUNCTION somefunc (v int) RETURN NUMBER
  IS
    id NUMBER := 0;
  BEGIN
    OPEN curtype;
    FETCH curtype INTO rec;
    RETURN rec.a;
  END;

  PROCEDURE xfunc (emp_id NUMBER) IS
  BEGIN
    NULL;
  END;
```

```
PROCEDURE xfunc (emp_email VARCHAR2) IS
BEGIN
    NULL;
END;

END;
/
```

## 42.10.5. Limitations

Record types are supported as package variables, however they can only be used within package elements i.e., Package function/procedure can utilize them. They can not be accessed outside the package.

It is not recommended to use package types for table building and function/procedure statements(external to the package), as this may lead to some issues.

Table and package with the same name cannot exist in the same schema. Same as oracle.

```
lightdb@postgres=# create table t1(key1 int);
CREATE TABLE
lightdb@postgres=# create package t1 IS
    key1 real;
    end;
/
ERROR: relation "t1" already exists
HINT: A relation has the same name, so you must use a name that
doesn't conflict with any existing relation.
lightdb@postgres=# drop table t1;
DROP TABLE
lightdb@postgres=# create package t1 IS
    key1 real;
    end;
/
CREATE PACKAGE
lightdb@postgres=# create table t1(key1 int);
ERROR: package "t1" already exists
HINT: A package has the same name, so you must use a name that
doesn't conflict with any existing package.
lightdb@postgres=#
```

Schema and package cannot have the same name.

```
lightdb@postgres=# create package t1 IS
    key1 real;
    end;
/
CREATE PACKAGE
lightdb@postgres=# create schema t1;
ERROR: package name "t1" exists, schema name is forbid same with
package name.
lightdb@postgres=# drop package t1;
DROP PACKAGE
lightdb@postgres=# create schema t1;
```

```
CREATE SCHEMA
lightdb@postgres=# create package t1 IS
    key1 real;
    end;
/
ERROR:  schema name "t1" exists, package name is forbid same with
    schema name.
lightdb@postgres=#
```

## 42.11. Table function

Table function can perform row to column operations on array data, and parameter types can be arrays or nested tables, or function return values (arrays/nested tables). It can also be used in query statements. To adapt to the table function of Oracle Database, if the table function is used in the from clause and the data returned by the table function is a single column, the column name is changed to column\_value. This feature takes effect in Oracle compatibility mode.

Array Example:

```
select table(array[1,2,3]) as a;
```

Nested Table Example:

```
create type kk is table of int;
select table(kk(1,2,3)) as a;
```

Example of function return value#

```
create table t1(a int, b int);
insert into t1 (values (1,1), (2,2), (3,3));
```

```
create or replace package pkg
as
    type nt is table of t1%rowtype;
    res nt;
    function myfunc() return nt;
end;
/

create or replace package body pkg
as
    function myfunc() return nt
    is
    begin
        res(1) := ROW(1,1);
        res(2) := ROW(2,2);
        res(3) := ROW(3,3);
        return res;
    end;
end;
/

select * from table(pkg.myfunc());
```

Example of using query statements:

```
create type kk is table of int;
create table t100 (a int, b kk);
insert into t100 values(1, kk(1, 2));
insert into t100 values(2, kk(3, 4, 5));
select a, b_table from t100, table(b) b_table;
```

## 42.12. Error Handling

This chapter explains how to handle PLoraSQL compile-time warnings and PLoraSQL runtime errors. The latter are called exceptions.

### 42.12.1. Overview of Exception Handling

Exceptions (PLoraSQL runtime errors) can arise from design faults, coding mistakes, hardware failures, and many other sources. You cannot anticipate all possible exceptions, but you can write exception handlers that let your program to continue to operate in their presence.

Any PLoraSQL block can have an exception-handling part, which can have one or more exception handlers. For example, an exception-handling part could have this syntax:

```
EXCEPTION
  WHEN ex_name_1 THEN statements_1          -- Exception
  handler
  WHEN ex_name_2 OR ex_name_3 THEN statements_2  -- Exception
  handler
  WHEN OTHERS THEN statements_3             -- Exception
  handler
END;
```

When an exception is raised in the executable part of the block, the executable part stops and control transfers to the exception-handling part. If `ex_name_1` was raised, then `statements_1` run. If either `ex_name_2` or `ex_name_3` was raised, then `statements_2` run. If any other exception was raised, then `statements_3` run.

After an exception handler runs, control transfers to the next statement of the enclosing block. If there is no enclosing block, then:

- If the exception handler is in a subprogram, then control returns to the invoker, at the statement after the invocation
- If the exception handler is in an anonymous block, then control transfers to the host environment

#### 42.12.1.1. Exception Categories

The exception categories are:

- **Internally defined** The runtime system raises internally defined exceptions implicitly (automatically)
- **Predefined** A predefined exception is an internally defined exception that PLoraSQL has given a name
- **User-defined** You can declare your own exceptions in the declarative part of any PLoraSQL anonymous block, subprogram, or package



## 42.12.1.2. Advantages of Exception Handlers

Using exception handlers for error-handling makes programs easier to write and understand, and reduces the likelihood of unhandled exceptions. Without exception handlers, you must check for every possible error, everywhere that it might occur, and then handle it. It is easy to overlook a possible error or a place where it might occur, especially if the error is not immediately detectable. Error-handling code is scattered throughout the program. With exception handlers, you need not know every possible error or everywhere that it might occur. You need only include an exception-handling part in each block where errors might occur. In the exception-handling part, you can include exception handlers for both specific and unknown errors. If an error occurs anywhere in the block (including inside a sub-block), then an exception handler handles it. Error-handling code is isolated in the exception-handling parts of the blocks.

Currently PLoraSQL only supports predefined errors.

## 42.12.2. Predefined Exceptions

Predefined exceptions are internally defined exceptions that have predefined names. The runtime system raises predefined exceptions implicitly (automatically). Because predefined exceptions have names, you can write exception handlers specifically for them.

There are 7 predefined errors currently supported:

- INVALID\_CURSOR
- CASE\_NOT\_FOUND
- DUP\_VAL\_ON\_INDEX
- NOT\_DATA\_FOUND
- TOO\_MANY\_ROWS
- ZERO\_DIVIDE
- LOGIN\_DENIED

### 42.12.2.1. INVALID\_CURSOR

INVALID\_CURSOR mainly contend for two situations: explicit cursor and cursor variables.

#### 42.12.2.1.1. Explicit Cursor

- You close an open explicit cursor with the CLOSE statement, thereby allowing its resources to be reused. After closing a cursor, you cannot fetch records from its result set or reference its attributes. If you try, PLoraSQL raises the predefined exception INVALID\_CURSOR.
- If an explicit cursor is not open, referencing any attribute except %ISOPEN raises the predefined exception INVALID\_CURSOR.

for example. After closing a cursor variable, you cannot fetch records from its result set or reference its attributes.

```
--preconditional
create table employees(id int, name varchar2(100), job
  varchar2(100));
insert into employees values (22091401, 'sunli', 'actress');
insert into employees values (22091402, 'dengchao', 'actor');
insert into employees values (22091403, 'lishizhen', 'doctor');
```

```
insert into employees values (22091404, 'zhangsanfeng', 'martial
artist');

create or replace function invalid_cursor_f return int as
  cursor c1 is select * from employees;
  emp_cur employees%rowtype;
begin
  open c1;
  loop
    fetch c1 into emp_cur;
    exit when c1%notfound;
    close c1;
  end loop;
  close c1;
EXCEPTION
  WHEN invalid_cursor THEN
    DBMS_OUTPUT.PUT_LINE('invalid cursor');
    return 1;
end;
/

select invalid_cursor_f();
```

for example, If an explicit cursor is not open, referencing any attribute except %ISOPEN raises the predefined exception INVALID\_CURSOR.

```
create or replace function invalid_cursor_f return int as
  cursor c1 is select * from employees;
  emp_cur employees%rowtype;
  ora_found boolean := false;
begin
  ora_found := c1%found;
EXCEPTION
  WHEN invalid_cursor THEN
    DBMS_OUTPUT.PUT_LINE('invalid cursor');
    return 1;
end;
/

select invalid_cursor_f();
```

**Tip**

Error handling with PLoraSQL, and the value of  
lightdb\_dblevel\_syntax\_compatible\_type is oracle.

#### 42.12.2.1.2. Cursor Variables

- When you no longer need a cursor variable, close it with the CLOSE statement, thereby allowing its resources to be reused. After closing a cursor variable, you cannot fetch records from its result set or reference its attributes. If you try, PLoraSQL raises the predefined exception INVALID\_CURSOR.
- A cursor variable has the same attributes as an explicit cursor. The syntax for the value of a cursor variable attribute is cursor\_variable\_name immediately followed by attribute (for example,

cv%ISOPEN). If a cursor variable is not open, referencing any attribute except %ISOPEN raises the predefined exception INVALID\_CURSOR

for example, After closing a cursor variable, you cannot fetch records from its result set or reference its attributes.

```
create or replace function invalid_cursor_f return int as
  c1 sys_refcursor;
  emp_cur employees%rowtype;
begin
  open c1 for select * from employees;
  loop
    fetch c1 into emp_cur;
    exit when c1%notfound;
    close c1;
  end loop;
  close c1;
EXCEPTION
  WHEN invalid_cursor THEN
    DBMS_OUTPUT.PUT_LINE('invalid cursor');
    return 1;
end;
/

select invalid_cursor_f();
```

for example, If a cursor variable is not open, referencing any attribute except %ISOPEN raises the predefined exception INVALID\_CURSOR.

```
create or replace function invalid_cursor_f return int as
  c1 sys_refcursor;
  emp_cur employees%rowtype;
  ora_isopen boolean := false;
begin
  ora_isopen := c1%isopen;
  return 1;
exception
  when INVALID_CURSOR then
    dbms_output.put_line('this is a normal error');
end;
/

select invalid_cursor_f();
```

## 42.12.2.2. CASE\_NOT\_FOUND

case statement, if the necessary conditional branch is not included in the when clause, it will trigger. There are two cases of simple\_case\_statement and search\_case\_statment.

for example, simple\_case\_statement.

```
create or replace function case_not_found_f return int as
  grade CHAR(1);
BEGIN
```

```

grade := 'G';

CASE grade
  WHEN 'A' THEN DBMS_OUTPUT.PUT_LINE('Excellent');
  WHEN 'B' THEN DBMS_OUTPUT.PUT_LINE('Very Good');
  WHEN 'C' THEN DBMS_OUTPUT.PUT_LINE('Good');
  WHEN 'D' THEN DBMS_OUTPUT.PUT_LINE('Fair');
  WHEN 'F' THEN DBMS_OUTPUT.PUT_LINE('Poor');
END CASE;
EXCEPTION
  WHEN CASE_NOT_FOUND THEN
    DBMS_OUTPUT.PUT_LINE('No such grade');
  return 1;
END;
/

select case_not_found_f();

```

for example, search\_case\_statement.

```

create or replace function case_not_found_f return int as
  grade CHAR(1);
BEGIN
  grade := 'G';

  CASE
    WHEN grade = 'A' THEN DBMS_OUTPUT.PUT_LINE('Excellent');
    WHEN grade = 'B' THEN DBMS_OUTPUT.PUT_LINE('Very Good');
    WHEN grade = 'C' THEN DBMS_OUTPUT.PUT_LINE('Good');
    WHEN grade = 'D' THEN DBMS_OUTPUT.PUT_LINE('Fair');
    WHEN grade = 'F' THEN DBMS_OUTPUT.PUT_LINE('Poor');
  END CASE;
EXCEPTION
  WHEN CASE_NOT_FOUND THEN
    DBMS_OUTPUT.PUT_LINE('No such grade');
  return 1;
END;
/

select case_not_found_f();

```

### 42.12.2.3. DUP\_VAL\_ON\_INDEX

Triggered when a duplicate value is inserted into the column corresponding to the unique index.

for example:

```

--preconditional
CREATE TABLE emp_name AS SELECT id, name FROM employees;

CREATE UNIQUE INDEX empname_ix ON emp_name (id);

create or replace procedure dup_val_on_index_p as
  emp_id      NUMBER(10);
  emp_name    VARCHAR2(100);

```

```
BEGIN
  SELECT id, name INTO emp_id, emp_name FROM employees WHERE id =
  22091401;

  INSERT INTO emp_name (id, name) VALUES (emp_id, emp_name);

EXCEPTION
  WHEN DUP_VAL_ON_INDEX THEN
    ROLLBACK;
    DBMS_OUTPUT.PUT_LINE('Inserts were rolled back');
END;
/

call dup_val_on_index_p();
```

#### 42.12.2.4. NOT\_DATA\_FOUND

Triggered when no row is returned when select into is executed.

for example:

```
-- no_data_found
-- select into
-- number of record selected is zero
create or replace function no_data_found_f return int as
  v_emp int;
begin
  select id into v_emp from employees where id = 22091501;
EXCEPTION
  WHEN no_data_found THEN
    DBMS_OUTPUT.PUT_LINE('No data found');
    return 1;
end;
/

select no_data_found_f();
```

#### 42.12.2.5. TOO\_MANY\_ROWS

When a select into statement is executed, it will fire if more than one row is returned.

for example:

```
create or replace function too_many_rows_f return int as
  v_emp int;
begin
  select id into v_emp from employees;

EXCEPTION
  WHEN no_data_found THEN
    DBMS_OUTPUT.PUT_LINE('No data found');
  WHEN too_many_rows THEN
    DBMS_OUTPUT.PUT_LINE('Too Many Rows');

  return 1;
```

```
end;  
/  
  
select too_many_rows_f();
```

### 42.12.2.6. LOGIN\_DENIED

You can use raise to throw the predefined exception and handle the problem after the exception. (not triggered in plorasql, but in lightdb)

for example:

```
create or replace function login_denied_f return int as  
begin  
    raise login_denied;  
exception  
    when login_denied then  
        dbms_output.put_line('this is a login_denied message.. good  
luck the next time');  
        return 1;  
end;  
/  
  
select login_denied_f();
```

### 42.12.2.7. ZERO\_DIVIDE

Triggered when a non-zero number divided by 0 event occurs.

for example:

```
create or replace function zero_divide_f return int as  
    a int := 10;  
    b int := 0;  
begin  
    a := a / b;  
exception  
    when zero_divide then  
        dbms_output.put_line('this is a normal error');  
    return 1;  
end;  
/  
  
select zero_divide_f();
```

#### Tip

1. Error handling does not support handling problem summary:

- The dynamic SQL in the anonymous block contains the anonymous block of commit and rollback, which is not supported;
- The dynamic SQL in the stored procedure contains anonymous blocks of commit and rollback, which is not supported;

- Stored procedures in the package and anonymous blocks containing commit and rollback in dynamic SQL in anonymous blocks are not supported.
- 2. There is a problem with the execution order of functions, stored procedures, and anonymous blocks in the package;
- 3. Currently plorasql does not support savepoint.

### 42.12.3. Raising Exceptions Explicitly

To raise an exception explicitly, use either the RAISE statement or RAISE\_APPLICATION\_ERROR procedure.

You can invoke the RAISE\_APPLICATION\_ERROR procedure only from a stored subprogram or method. Typically, you invoke this procedure to raise a user-defined exception and return its error code and error message to the invoker.

To invoke RAISE\_APPLICATION\_ERROR, use this syntax:

```
RAISE_APPLICATION_ERROR (error_code, message[, {TRUE | FALSE}]);
```

The error\_code is an integer in the range -20000..-20999. If you specify TRUE, PL/oraSQL will not print message. Otherwise, PL/oraSQL will print message. The FALSE is default.

### 42.12.4. support DBMS\_UTILITY built-in package format\_error\_backtrace

The DBMS\_UTILITY.format\_error\_backtrace function is a critical subprogram to call when logging exceptions. It returns a string that traces the error back to the line on which it was raised! The back trace function always only traces back to the most recently raised exception. The maximum length that the error allows to return is 10000.

Use function of DBMS\_UTILITY.format\_error\_backtrace, for example:

```
--preconditional
create table test_error_stack(id number primary key);
insert into test_error_stack values (1);
create table t_errlog(operate_error_msg varchar(1000));

create or replace procedure pr_error_code_test1 is
    v_backtrace    varchar(1000);
    v_error        varchar(1000);
begin
    INSERT INTO test_error_stack values (2);
    INSERT INTO test_error_stack values (1);
    commit;
    exception when others then
        insert into t_errlog(operate_error_msg) select
to_char(dbms_utility.format_error_backtrace);
        commit;
        rollback;
    end pr_error_code_test1;
/
```

```
call pr_error_code_test1();
select * from t_errlog;

--Use function calls alone
select select to_char(dbms_utility.format_error_backtrace)
```

## 42.12.5. support SQLCODE

Supports obtaining integer error codes when throwing exceptions. The error code of this integer can be converted into a string error code of length 5. The conversion function `SQLCODE_TO_SQLSTATE` in `orafce`. String error code of length 5 in Appendix A.

for example:

```
declare
    a text;
    b int;
begin
    raise exception 'sqlcode test';
exception
    when others then
        a := sqlstate;
        b := sqlcode;
        raise notice 'sqlstate: %, sqlcode: %, sqlcode: %', a, b,
            sqlcode;
end;
/
select SQLCODE_TO_SQLSTATE(16777248);
```

## 42.13. Object name search rule

1. When local variable in package and column name table are the same name, the column names take precedence.

```
create table test(a int);
insert into test values(1);

CREATE OR REPLACE function GET_AVG_PRICE()
    RETURN text IS

    a int;
BEGIN

    select a /*column*/ into a /*package variable */
    from test limit 1;
    dbms_output.put_line(a);

    return a || ' ';
END GET_AVG_PRICE;
/
```

2. When local variable in package and table name are the same name, the table names take precedence.



```
create table tn (id int);

create package tn IS
id text;
end;
/

CREATE OR REPLACE function abc()
RETURN text IS

a tn.id%type; -- int
v text;
BEGIN
select pg_typeof(a) into v ;
dbms_output.put_line(v);

return v;
END abc;
/
```

In addition, package name and schema name are not allowed to be duplicated, so there is no conflict.

## 42.14. Enhancements for Oracle

1. Function enhancement: support for rollback and commit.

```
create table table_func_rbk(a int, b int);
insert into table_func_rbk values(100,100);
insert into table_func_rbk values(200,200);
select * from table_func_rbk order by a;

create or replace function func_rollback1(a int) return int
is
begin
insert into table_func_rbk values(300,300);
commit;
insert into table_func_rbk values(400,400);
rollback;
update table_func_rbk set a = 400 where a = 300;
rollback;
delete from table_func_rbk where a = 100;
rollback;
return a;
end;
/
select func_rollback1(100);
select * from table_func_rbk order by a;

create or replace function func_rollback1(a int) return int
is
begin
insert into table_func_rbk values('asdadasda');
```

```
exception
when others then
  insert into table_func_rbk values(300,300);
  commit;
  insert into table_func_rbk values(400,400);
  rollback;
  update table_func_rbk set a = 400 where a = 300;
  rollback;
  delete from table_func_rbk where a = 100;
  rollback;
  return a;
end;
/
select func_rollback1(100);
select * from table_func_rbk order by a;

drop table table_func_rbk;
drop function func_rollback1;
```

---

# Chapter 43. Server Programming Interface

The *Server Programming Interface* (SPI) gives writers of user-defined C functions the ability to run SQL commands inside their functions or procedures. SPI is a set of interface functions to simplify access to the parser, planner, and executor. SPI also does some memory management.

## Note

The available procedural languages provide various means to execute SQL commands from functions. Most of these facilities are based on SPI, so this documentation might be of use for users of those languages as well.

Note that if a command invoked via SPI fails, then control will not be returned to your C function. Rather, the transaction or subtransaction in which your C function executes will be rolled back. (This might seem surprising given that the SPI functions mostly have documented error-return conventions. Those conventions only apply for errors detected within the SPI functions themselves, however.) It is possible to recover control after an error by establishing your own subtransaction surrounding SPI calls that might fail.

SPI functions return a nonnegative result on success (either via a returned integer value or in the global variable `SPI_result`, as described below). On error, a negative result or `NULL` will be returned.

Source code files that use SPI must include the header file `executor/spi.h`.

## 43.1. Interface Functions

## SPI\_connect

SPI\_connect, SPI\_connect\_ext — connect a C function to the SPI manager

## Synopsis

```
int SPI_connect(void)
```

```
int SPI_connect_ext(int options)
```

## Description

SPI\_connect opens a connection from a C function invocation to the SPI manager. You must call this function if you want to execute commands through SPI. Some utility SPI functions can be called from unconnected C functions.

SPI\_connect\_ext does the same but has an argument that allows passing option flags. Currently, the following option values are available:

SPI\_OPT\_NONATOMIC

Sets the SPI connection to be *nonatomic*, which means that transaction control calls (SPI\_commit, SPI\_rollback) are allowed. Otherwise, calling those functions will result in an immediate error.

SPI\_connect() is equivalent to SPI\_connect\_ext(0).

## Return Value

SPI\_OK\_CONNECT

on success

SPI\_ERROR\_CONNECT

on error

## SPI\_finish

SPI\_finish — disconnect a C function from the SPI manager

## Synopsis

```
int SPI_finish(void)
```

## Description

SPI\_finish closes an existing connection to the SPI manager. You must call this function after completing the SPI operations needed during your C function's current invocation. You do not need to worry about making this happen, however, if you abort the transaction via `eLog(ERROR)`. In that case SPI will clean itself up automatically.

## Return Value

SPI\_OK\_FINISH

if properly disconnected

SPI\_ERROR\_UNCONNECTED

if called from an unconnected C function

## SPI\_execute

SPI\_execute — execute a command

### Synopsis

```
int SPI_execute(const char * command, bool read_only, long count)
```

### Description

SPI\_execute executes the specified SQL command for *count* rows. If *read\_only* is true, the command must be read-only, and execution overhead is somewhat reduced.

This function can only be called from a connected C function.

If *count* is zero then the command is executed for all rows that it applies to. If *count* is greater than zero, then no more than *count* rows will be retrieved; execution stops when the count is reached, much like adding a LIMIT clause to the query. For example,

```
SPI_execute("SELECT * FROM foo", true, 5);
```

will retrieve at most 5 rows from the table. Note that such a limit is only effective when the command actually returns rows. For example,

```
SPI_execute("INSERT INTO foo SELECT * FROM bar", false, 5);
```

inserts all rows from bar, ignoring the *count* parameter. However, with

```
SPI_execute("INSERT INTO foo SELECT * FROM bar RETURNING *", false, 5);
```

at most 5 rows would be inserted, since execution would stop after the fifth RETURNING result row is retrieved.

You can pass multiple commands in one string; SPI\_execute returns the result for the command executed last. The *count* limit applies to each command separately (even though only the last result will actually be returned). The limit is not applied to any hidden commands generated by rules.

When *read\_only* is false, SPI\_execute increments the command counter and computes a new *snapshot* before executing each command in the string. The snapshot does not actually change if the current transaction isolation level is SERIALIZABLE or REPEATABLE READ, but in READ COMMITTED mode the snapshot update allows each command to see the results of newly committed transactions from other sessions. This is essential for consistent behavior when the commands are modifying the database.

When *read\_only* is true, SPI\_execute does not update either the snapshot or the command counter, and it allows only plain SELECT commands to appear in the command string. The commands are executed using the snapshot previously established for the surrounding query. This execution mode is somewhat faster than the read/write mode due to eliminating per-command overhead. It also allows genuinely *stable* functions to be built: since successive executions will all use the same snapshot, there will be no change in the results.

It is generally unwise to mix read-only and read-write commands within a single function using SPI; that could result in very confusing behavior, since the read-only queries would not see the results of any database updates done by the read-write queries.

The actual number of rows for which the (last) command was executed is returned in the global variable `SPI_processed`. If the return value of the function is `SPI_OK_SELECT`, `SPI_OK_INSERT_RETURNING`, `SPI_OK_DELETE_RETURNING`, or `SPI_OK_UPDATE_RETURNING`, then you can use the global pointer `SPITupleTable *SPI_tuptable` to access the result rows. Some utility commands (such as `EXPLAIN`) also return row sets, and `SPI_tuptable` will contain the result in these cases too. Some utility commands (`COPY`, `CREATE TABLE AS`) don't return a row set, so `SPI_tuptable` is `NULL`, but they still return the number of rows processed in `SPI_processed`.

The structure `SPITupleTable` is defined thus:

```
typedef struct SPITupleTable
{
    /* Public members */
    TupleDesc    tupdesc;          /* tuple descriptor */
    HeapTuple    *vals;           /* array of tuples */
    uint64       numvals;         /* number of valid tuples */

    /* Private members, not intended for external callers */
    uint64       allocated;       /* allocated length of vals array */
    /*
    MemoryContext tuptabcxt;     /* memory context of result table */
    /*
    slist_node   next;           /* link for internal bookkeeping */
    SubTransactionId subid;      /* subxact in which tuptable was
    created */
} SPITupleTable;
```

The fields `tupdesc`, `vals`, and `numvals` can be used by SPI callers; the remaining fields are internal. `vals` is an array of pointers to rows. The number of rows is given by `numvals` (for somewhat historical reasons, this count is also returned in `SPI_processed`). `tupdesc` is a row descriptor which you can pass to SPI functions dealing with rows.

`SPI_finish` frees all `SPITupleTables` allocated during the current C function. You can free a particular result table earlier, if you are done with it, by calling `SPI_freetuptable`.

## Arguments

`const char * command`

string containing command to execute

`bool read_only`

true for read-only execution

`long count`

maximum number of rows to return, or 0 for no limit

## Return Value

If the execution of the command was successful then one of the following (nonnegative) values will be returned:

`SPI_OK_SELECT`

if a `SELECT` (but not `SELECT INTO`) was executed

SPI\_OK\_SELINTO

if a `SELECT INTO` was executed

SPI\_OK\_INSERT

if an `INSERT` was executed

SPI\_OK\_DELETE

if a `DELETE` was executed

SPI\_OK\_UPDATE

if an `UPDATE` was executed

SPI\_OK\_INSERT\_RETURNING

if an `INSERT RETURNING` was executed

SPI\_OK\_DELETE\_RETURNING

if a `DELETE RETURNING` was executed

SPI\_OK\_UPDATE\_RETURNING

if an `UPDATE RETURNING` was executed

SPI\_OK\_UTILITY

if a utility command (e.g., `CREATE TABLE`) was executed

SPI\_OK\_REWRITTEN

if the command was rewritten into another kind of command (e.g., `UPDATE` became an `INSERT`) by a rule.

On error, one of the following negative values is returned:

SPI\_ERROR\_ARGUMENT

if *command* is `NULL` or *count* is less than 0

SPI\_ERROR\_COPY

if `COPY TO stdout` or `COPY FROM stdin` was attempted

SPI\_ERROR\_TRANSACTION

if a transaction manipulation command was attempted (`BEGIN`, `COMMIT`, `ROLLBACK`, `SAVEPOINT`, `PREPARE TRANSACTION`, `COMMIT PREPARED`, `ROLLBACK PREPARED`, or any variant thereof)

SPI\_ERROR\_OPUNKNOWN

if the command type is unknown (shouldn't happen)

SPI\_ERROR\_UNCONNECTED

if called from an unconnected C function

## Notes

All SPI query-execution functions set both `SPI_processed` and `SPI_tuptable` (just the pointer, not the contents of the structure). Save these two global variables into local C function variables if



you need to access the result table of `SPI_execute` or another query-execution function across later calls.

## SPI\_exec

SPI\_exec — execute a read/write command

## Synopsis

```
int SPI_exec(const char * command, long count)
```

## Description

SPI\_exec is the same as SPI\_execute, with the latter's *read\_only* parameter always taken as false.

## Arguments

```
const char * command
```

string containing command to execute

```
long count
```

maximum number of rows to return, or 0 for no limit

## Return Value

See SPI\_execute.

## SPI\_execute\_with\_args

SPI\_execute\_with\_args — execute a command with out-of-line parameters

### Synopsis

```
int SPI_execute_with_args(const char *command,
                          int nargs, Oid *argtypes,
                          Datum *values, const char *nulls,
                          bool read_only, long count)
```

### Description

SPI\_execute\_with\_args executes a command that might include references to externally supplied parameters. The command text refers to a parameter as  $\$n$ , and the call specifies data types and values for each such symbol. *read\_only* and *count* have the same interpretation as in SPI\_execute.

The main advantage of this routine compared to SPI\_execute is that data values can be inserted into the command without tedious quoting/escaping, and thus with much less risk of SQL-injection attacks.

Similar results can be achieved with SPI\_prepare followed by SPI\_execute\_plan; however, when using this function the query plan is always customized to the specific parameter values provided. For one-time query execution, this function should be preferred. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

### Arguments

const char \* *command*

command string

int *nargs*

number of input parameters ( $\$1$ ,  $\$2$ , etc.)

Oid \* *argtypes*

an array of length *nargs*, containing the OIDs of the data types of the parameters

Datum \* *values*

an array of length *nargs*, containing the actual parameter values

const char \* *nulls*

an array of length *nargs*, describing which parameters are null

If *nulls* is NULL then SPI\_execute\_with\_args assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

bool *read\_only*

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

## Return Value

The return value is the same as for `SPI_execute`.

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

## SPI\_prepare

SPI\_prepare — prepare a statement, without executing it yet

## Synopsis

```
SPIPlanPtr SPI_prepare(const char * command, int nargs, Oid  
* argtypes)
```

## Description

SPI\_prepare creates and returns a prepared statement for the specified command, but doesn't execute the command. The prepared statement can later be executed repeatedly using SPI\_execute\_plan.

When the same or a similar command is to be executed repeatedly, it is generally advantageous to perform parse analysis only once, and might furthermore be advantageous to re-use an execution plan for the command. SPI\_prepare converts a command string into a prepared statement that encapsulates the results of parse analysis. The prepared statement also provides a place for caching an execution plan if it is found that generating a custom plan for each execution is not helpful.

A prepared command can be generalized by writing parameters (\$1, \$2, etc.) in place of what would be constants in a normal command. The actual values of the parameters are then specified when SPI\_execute\_plan is called. This allows the prepared command to be used over a wider range of situations than would be possible without parameters.

The statement returned by SPI\_prepare can be used only in the current invocation of the C function, since SPI\_finish frees memory allocated for such a statement. But the statement can be saved for longer using the functions SPI\_keepplan or SPI\_saveplan.

## Arguments

const char \* *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid \* *argtypes*

pointer to an array containing the OIDs of the data types of the parameters

## Return Value

SPI\_prepare returns a non-null pointer to an SPIPlan, which is an opaque struct representing a prepared statement. On error, NULL will be returned, and SPI\_result will be set to one of the same error codes used by SPI\_execute, except that it is set to SPI\_ERROR\_ARGUMENT if *command* is NULL, or if *nargs* is less than 0, or if *nargs* is greater than 0 and *argtypes* is NULL.

## Notes

If no parameters are defined, a generic plan will be created at the first use of SPI\_execute\_plan, and used for all subsequent executions as well. If there are parameters, the first few uses of SPI\_execute\_plan will generate custom plans that are specific to the supplied parameter

values. After enough uses of the same prepared statement, `SPI_execute_plan` will build a generic plan, and if that is not too much more expensive than the custom plans, it will start using the generic plan instead of re-planning each time. If this default behavior is unsuitable, you can alter it by passing the `CURSOR_OPT_GENERIC_PLAN` or `CURSOR_OPT_CUSTOM_PLAN` flag to `SPI_prepare_cursor`, to force use of generic or custom plans respectively.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, LightDB will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of `search_path` changes from one use to the next, the statement will be re-parsed using the new `search_path`. (This latter behavior is new as of LightDB 9.3.) See `PREPARE` for more information about the behavior of prepared statements.

This function should only be called from a connected C function.

`SPIPlanPtr` is declared as a pointer to an opaque struct type in `spi.h`. It is unwise to try to access its contents directly, as that makes your code much more likely to break in future revisions of LightDB.

The name `SPIPlanPtr` is somewhat historical, since the data structure no longer necessarily contains an execution plan.

## SPI\_prepare\_cursor

SPI\_prepare\_cursor — prepare a statement, without executing it yet

## Synopsis

```
SPIPlanPtr SPI_prepare_cursor(const char * command, int nargs,  
                             Oid * argtypes, int cursorOptions)
```

## Description

SPI\_prepare\_cursor is identical to SPI\_prepare, except that it also allows specification of the planner's "cursor options" parameter. This is a bit mask having the values shown in nodes/parsenodes.h for the options field of DeclareCursorStmt. SPI\_prepare always takes the cursor options as zero.

## Arguments

const char \* *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid \* *argtypes*

pointer to an array containing the OIDs of the data types of the parameters

int *cursorOptions*

integer bit mask of cursor options; zero produces default behavior

## Return Value

SPI\_prepare\_cursor has the same return conventions as SPI\_prepare.

## Notes

Useful bits to set in *cursorOptions* include CURSOR\_OPT\_SCROLL, CURSOR\_OPT\_NO\_SCROLL, CURSOR\_OPT\_FAST\_PLAN, CURSOR\_OPT\_GENERIC\_PLAN, and CURSOR\_OPT\_CUSTOM\_PLAN. Note in particular that CURSOR\_OPT\_HOLD is ignored.

## SPI\_prepare\_params

SPI\_prepare\_params — prepare a statement, without executing it yet

### Synopsis

```
SPIPlanPtr SPI_prepare_params(const char * command,
                             ParserSetupHook parserSetup,
                             void * parserSetupArg,
                             int cursorOptions)
```

### Description

SPI\_prepare\_params creates and returns a prepared statement for the specified command, but doesn't execute the command. This function is equivalent to SPI\_prepare\_cursor, with the addition that the caller can specify parser hook functions to control the parsing of external parameter references.

### Arguments

const char \* *command*

command string

ParserSetupHook *parserSetup*

Parser hook setup function

void \* *parserSetupArg*

pass-through argument for *parserSetup*

int *cursorOptions*

integer bit mask of cursor options; zero produces default behavior

### Return Value

SPI\_prepare\_params has the same return conventions as SPI\_prepare.



## SPI\_getargcount

`SPI_getargcount` — return the number of arguments needed by a statement prepared by `SPI_prepare`

## Synopsis

```
int SPI_getargcount(SPIPlanPtr plan)
```

## Description

`SPI_getargcount` returns the number of arguments needed to execute a statement prepared by `SPI_prepare`.

## Arguments

`SPIPlanPtr plan`

prepared statement (returned by `SPI_prepare`)

## Return Value

The count of expected arguments for the *plan*. If the *plan* is `NULL` or invalid, `SPI_result` is set to `SPI_ERROR_ARGUMENT` and -1 is returned.

## SPI\_getargtypeid

`SPI_getargtypeid` — return the data type OID for an argument of a statement prepared by `SPI_prepare`

## Synopsis

```
Oid SPI_getargtypeid(SPIPlanPtr plan, int argIndex)
```

## Description

`SPI_getargtypeid` returns the OID representing the type for the *argIndex*'th argument of a statement prepared by `SPI_prepare`. First argument is at index zero.

## Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

int *argIndex*

zero based index of the argument

## Return Value

The type OID of the argument at the given index. If the *plan* is NULL or invalid, or *argIndex* is less than 0 or not less than the number of arguments declared for the *plan*, `SPI_result` is set to `SPI_ERROR_ARGUMENT` and `InvalidOid` is returned.

## SPI\_is\_cursor\_plan

`SPI_is_cursor_plan` — return true if a statement prepared by `SPI_prepare` can be used with `SPI_cursor_open`

## Synopsis

```
bool SPI_is_cursor_plan(SPIPlanPtr plan)
```

## Description

`SPI_is_cursor_plan` returns true if a statement prepared by `SPI_prepare` can be passed as an argument to `SPI_cursor_open`, or false if that is not the case. The criteria are that the *plan* represents one single command and that this command returns tuples to the caller; for example, `SELECT` is allowed unless it contains an `INTO` clause, and `UPDATE` is allowed only if it contains a `RETURNING` clause.

## Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

## Return Value

true or false to indicate if the *plan* can produce a cursor or not, with `SPI_result` set to zero. If it is not possible to determine the answer (for example, if the *plan* is NULL or invalid, or if called when not connected to SPI), then `SPI_result` is set to a suitable error code and false is returned.

## SPI\_execute\_plan

SPI\_execute\_plan — execute a statement prepared by SPI\_prepare

### Synopsis

```
int SPI_execute_plan(SPIPlanPtr plan, Datum * values, const char
* nulls,
                    bool read_only, long count)
```

### Description

SPI\_execute\_plan executes a statement prepared by SPI\_prepare or one of its siblings. *read\_only* and *count* have the same interpretation as in SPI\_execute.

### Arguments

SPIPlanPtr *plan*

prepared statement (returned by SPI\_prepare)

Datum \* *values*

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char \* *nulls*

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If *nulls* is NULL then SPI\_execute\_plan assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

bool *read\_only*

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

### Return Value

The return value is the same as for SPI\_execute, with the following additional possible error (negative) results:

SPI\_ERROR\_ARGUMENT

if *plan* is NULL or invalid, or *count* is less than 0

SPI\_ERROR\_PARAM

if *values* is NULL and *plan* was prepared with some parameters

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

## SPI\_execute\_plan\_with\_paramlist

`SPI_execute_plan_with_paramlist` — execute a statement prepared by `SPI_prepare`

### Synopsis

```
int SPI_execute_plan_with_paramlist(SPIPlanPtr plan,
                                   ParamListInfo params,
                                   bool read_only,
                                   long count)
```

### Description

`SPI_execute_plan_with_paramlist` executes a statement prepared by `SPI_prepare`. This function is equivalent to `SPI_execute_plan` except that information about the parameter values to be passed to the query is presented differently. The `ParamListInfo` representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in `ParamListInfo`.

### Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

`ParamListInfo` *params*

data structure containing parameter types and values; NULL if none

bool *read\_only*

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

### Return Value

The return value is the same as for `SPI_execute_plan`.

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute_plan` if successful.

## SPI\_execp

SPI\_execp — execute a statement in read/write mode

## Synopsis

```
int SPI_execp(SPIPlanPtr plan, Datum * values, const char * nulls,
              long count)
```

## Description

SPI\_execp is the same as SPI\_execute\_plan, with the latter's *read\_only* parameter always taken as false.

## Arguments

SPIPlanPtr *plan*

prepared statement (returned by SPI\_prepare)

Datum \* *values*

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char \* *nulls*

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If *nulls* is NULL then SPI\_execp assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

long *count*

maximum number of rows to return, or 0 for no limit

## Return Value

See SPI\_execute\_plan.

SPI\_processed and SPI\_tuptable are set as in SPI\_execute if successful.

## SPI\_cursor\_open

SPI\_cursor\_open — set up a cursor using a statement created with SPI\_prepare

### Synopsis

```
Portal SPI_cursor_open(const char * name, SPIPlanPtr plan,
                      Datum * values, const char * nulls,
                      bool read_only)
```

### Description

SPI\_cursor\_open sets up a cursor (internally, a portal) that will execute a statement prepared by SPI\_prepare. The parameters have the same meanings as the corresponding parameters to SPI\_execute\_plan.

Using a cursor instead of executing the statement directly has two benefits. First, the result rows can be retrieved a few at a time, avoiding memory overrun for queries that return many rows. Second, a portal can outlive the current C function (it can, in fact, live to the end of the current transaction). Returning the portal name to the C function's caller provides a way of returning a row set as result.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

### Arguments

const char \* name

name for portal, or NULL to let the system select a name

SPIPlanPtr plan

prepared statement (returned by SPI\_prepare)

Datum \* values

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char \* nulls

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If nulls is NULL then SPI\_cursor\_open assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a '\0' terminator.

bool read\_only

true for read-only execution

### Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via elog.



## SPI\_cursor\_open\_with\_args

SPI\_cursor\_open\_with\_args — set up a cursor using a query and parameters

### Synopsis

```
Portal SPI_cursor_open_with_args(const char *name,  
                                const char *command,  
                                int nargs, Oid *argtypes,  
                                Datum *values, const char *nulls,  
                                bool read_only, int cursorOptions)
```

### Description

SPI\_cursor\_open\_with\_args sets up a cursor (internally, a portal) that will execute the specified query. Most of the parameters have the same meanings as the corresponding parameters to SPI\_prepare\_cursor and SPI\_cursor\_open.

For one-time query execution, this function should be preferred over SPI\_prepare\_cursor followed by SPI\_cursor\_open. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

### Arguments

const char \* *name*

name for portal, or NULL to let the system select a name

const char \* *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid \* *argtypes*

an array of length *nargs*, containing the OIDs of the data types of the parameters

Datum \* *values*

an array of length *nargs*, containing the actual parameter values

const char \* *nulls*

an array of length *nargs*, describing which parameters are null

If *nulls* is NULL then SPI\_cursor\_open\_with\_args assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

`bool read_only`

true for read-only execution

`int cursorOptions`

integer bit mask of cursor options; zero produces default behavior

## **Return Value**

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via `elog`.

## SPI\_cursor\_open\_with\_paramlist

SPI\_cursor\_open\_with\_paramlist — set up a cursor using parameters

### Synopsis

```
Portal SPI_cursor_open_with_paramlist(const char *name,  
                                     SPIPlanPtr plan,  
                                     ParamListInfo params,  
                                     bool read_only)
```

### Description

SPI\_cursor\_open\_with\_paramlist sets up a cursor (internally, a portal) that will execute a statement prepared by SPI\_prepare. This function is equivalent to SPI\_cursor\_open except that information about the parameter values to be passed to the query is presented differently. The ParamListInfo representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in ParamListInfo.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

### Arguments

const char \* *name*

name for portal, or NULL to let the system select a name

SPIPlanPtr *plan*

prepared statement (returned by SPI\_prepare)

ParamListInfo *params*

data structure containing parameter types and values; NULL if none

bool *read\_only*

true for read-only execution

### Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via elog.

## SPI\_cursor\_find

SPI\_cursor\_find — find an existing cursor by name

### Synopsis

```
Portal SPI_cursor_find(const char * name)
```

### Description

SPI\_cursor\_find finds an existing portal by name. This is primarily useful to resolve a cursor name returned as text by some other function.

### Arguments

```
const char * name
```

name of the portal

### Return Value

pointer to the portal with the specified name, or NULL if none was found

## SPI\_cursor\_fetch

SPI\_cursor\_fetch — fetch some rows from a cursor

### Synopsis

```
void SPI_cursor_fetch(Portal portal, bool forward, long count)
```

### Description

SPI\_cursor\_fetch fetches some rows from a cursor. This is equivalent to a subset of the SQL command `FETCH` (see `SPI_scroll_cursor_fetch` for more functionality).

### Arguments

Portal *portal*

portal containing the cursor

bool *forward*

true for fetch forward, false for fetch backward

long *count*

maximum number of rows to fetch

### Return Value

SPI\_processed and SPI\_tuptable are set as in SPI\_execute if successful.

### Notes

Fetching backward may fail if the cursor's plan was not created with the `CURSOR_OPT_SCROLL` option.

## SPI\_cursor\_move

SPI\_cursor\_move — move a cursor

### Synopsis

```
void SPI_cursor_move(Portal portal, bool forward, long count)
```

### Description

SPI\_cursor\_move skips over some number of rows in a cursor. This is equivalent to a subset of the SQL command MOVE (see SPI\_scroll\_cursor\_move for more functionality).

### Arguments

Portal *portal*

portal containing the cursor

bool *forward*

true for move forward, false for move backward

long *count*

maximum number of rows to move

### Notes

Moving backward may fail if the cursor's plan was not created with the CURSOR\_OPT\_SCROLL option.

## SPI\_scroll\_cursor\_fetch

SPI\_scroll\_cursor\_fetch — fetch some rows from a cursor

### Synopsis

```
void SPI_scroll_cursor_fetch(Portal portal,
    FetchDirection direction,
                               long count)
```

### Description

SPI\_scroll\_cursor\_fetch fetches some rows from a cursor. This is equivalent to the SQL command FETCH.

### Arguments

Portal *portal*

portal containing the cursor

FetchDirection *direction*

one of FETCH\_FORWARD, FETCH\_BACKWARD, FETCH\_ABSOLUTE or FETCH\_RELATIVE

long *count*

number of rows to fetch for FETCH\_FORWARD or FETCH\_BACKWARD; absolute row number to fetch for FETCH\_ABSOLUTE; or relative row number to fetch for FETCH\_RELATIVE

### Return Value

SPI\_processed and SPI\_tuptable are set as in SPI\_execute if successful.

### Notes

See the SQL FETCH command for details of the interpretation of the *direction* and *count* parameters.

Direction values other than FETCH\_FORWARD may fail if the cursor's plan was not created with the CURSOR\_OPT\_SCROLL option.

## SPI\_scroll\_cursor\_move

SPI\_scroll\_cursor\_move — move a cursor

### Synopsis

```
void SPI_scroll_cursor_move(Portal portal,
    FetchDirection direction,
                           long count)
```

### Description

SPI\_scroll\_cursor\_move skips over some number of rows in a cursor. This is equivalent to the SQL command MOVE.

### Arguments

Portal *portal*

portal containing the cursor

FetchDirection *direction*

one of FETCH\_FORWARD, FETCH\_BACKWARD, FETCH\_ABSOLUTE or FETCH\_RELATIVE

long *count*

number of rows to move for FETCH\_FORWARD or FETCH\_BACKWARD; absolute row number to move to for FETCH\_ABSOLUTE; or relative row number to move to for FETCH\_RELATIVE

### Return Value

SPI\_processed is set as in SPI\_execute if successful. SPI\_tuptable is set to NULL, since no rows are returned by this function.

### Notes

See the SQL FETCH command for details of the interpretation of the *direction* and *count* parameters.

Direction values other than FETCH\_FORWARD may fail if the cursor's plan was not created with the CURSOR\_OPT\_SCROLL option.



## SPI\_cursor\_close

SPI\_cursor\_close — close a cursor

### Synopsis

```
void SPI_cursor_close(Portal portal)
```

### Description

SPI\_cursor\_close closes a previously created cursor and releases its portal storage.

All open cursors are closed automatically at the end of a transaction. SPI\_cursor\_close need only be invoked if it is desirable to release resources sooner.

### Arguments

Portal *portal*

portal containing the cursor

## SPI\_keepplan

SPI\_keepplan — save a prepared statement

### Synopsis

```
int SPI_keepplan(SPIPlanPtr plan)
```

### Description

SPI\_keepplan saves a passed statement (prepared by SPI\_prepare) so that it will not be freed by SPI\_finish nor by the transaction manager. This gives you the ability to reuse prepared statements in the subsequent invocations of your C function in the current session.

### Arguments

SPIPlanPtr *plan*

the prepared statement to be saved

### Return Value

0 on success; SPI\_ERROR\_ARGUMENT if *plan* is NULL or invalid

### Notes

The passed-in statement is relocated to permanent storage by means of pointer adjustment (no data copying is required). If you later wish to delete it, use SPI\_freeplan on it.

## SPI\_saveplan

SPI\_saveplan — save a prepared statement

## Synopsis

```
SPIPlanPtr SPI_saveplan(SPIPlanPtr plan)
```

## Description

SPI\_saveplan copies a passed statement (prepared by SPI\_prepare) into memory that will not be freed by SPI\_finish nor by the transaction manager, and returns a pointer to the copied statement. This gives you the ability to reuse prepared statements in the subsequent invocations of your C function in the current session.

## Arguments

```
SPIPlanPtr plan
```

the prepared statement to be saved

## Return Value

Pointer to the copied statement; or NULL if unsuccessful. On error, SPI\_result is set thus:

```
SPI_ERROR_ARGUMENT
```

if *plan* is NULL or invalid

```
SPI_ERROR_UNCONNECTED
```

if called from an unconnected C function

## Notes

The originally passed-in statement is not freed, so you might wish to do SPI\_freeplan on it to avoid leaking memory until SPI\_finish.

In most cases, SPI\_keepplan is preferred to this function, since it accomplishes largely the same result without needing to physically copy the prepared statement's data structures.

## SPI\_register\_relation

SPI\_register\_relation — make an ephemeral named relation available by name in SPI queries

### Synopsis

```
int SPI_register_relation(EphemeralNamedRelation enr)
```

### Description

SPI\_register\_relation makes an ephemeral named relation, with associated information, available to queries planned and executed through the current SPI connection.

### Arguments

EphemeralNamedRelation *enr*

the ephemeral named relation registry entry

### Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

SPI\_OK\_REL\_REGISTER

if the relation has been successfully registered by name

On error, one of the following negative values is returned:

SPI\_ERROR\_ARGUMENT

if *enr* is NULL or its name field is NULL

SPI\_ERROR\_UNCONNECTED

if called from an unconnected C function

SPI\_ERROR\_REL\_DUPLICATE

if the name specified in the name field of *enr* is already registered for this connection

## SPI\_unregister\_relation

SPI\_unregister\_relation — remove an ephemeral named relation from the registry

### Synopsis

```
int SPI_unregister_relation(const char * name)
```

### Description

SPI\_unregister\_relation removes an ephemeral named relation from the registry for the current connection.

### Arguments

```
const char * name
```

the relation registry entry name

### Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

```
SPI_OK_REL_UNREGISTER
```

if the tuplestore has been successfully removed from the registry

On error, one of the following negative values is returned:

```
SPI_ERROR_ARGUMENT
```

if *name* is NULL

```
SPI_ERROR_UNCONNECTED
```

if called from an unconnected C function

```
SPI_ERROR_REL_NOT_FOUND
```

if *name* is not found in the registry for the current connection

## SPI\_register\_trigger\_data

SPI\_register\_trigger\_data — make ephemeral trigger data available in SPI queries

### Synopsis

```
int SPI_register_trigger_data(TriggerData *tdata)
```

### Description

SPI\_register\_trigger\_data makes any ephemeral relations captured by a trigger available to queries planned and executed through the current SPI connection. Currently, this means the transition tables captured by an AFTER trigger defined with a REFERENCING OLD/NEW TABLE AS ... clause. This function should be called by a PL trigger handler function after connecting.

### Arguments

TriggerData \*tdata

the TriggerData object passed to a trigger handler function as fcinfo->context

### Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

SPI\_OK\_TD\_REGISTER

if the captured trigger data (if any) has been successfully registered

On error, one of the following negative values is returned:

SPI\_ERROR\_ARGUMENT

if tdata is NULL

SPI\_ERROR\_UNCONNECTED

if called from an unconnected C function

SPI\_ERROR\_REL\_DUPLICATE

if the name of any trigger data transient relation is already registered for this connection

## 43.2. Interface Support Functions

The functions described here provide an interface for extracting information from result sets returned by SPI\_execute and other SPI functions.

All functions described in this section can be used by both connected and unconnected C functions.

## SPI\_fname

SPI\_fname — determine the column name for the specified column number

## Synopsis

```
char * SPI_fname(TupleDesc rowdesc, int colnumber)
```

## Description

SPI\_fname returns a copy of the column name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

## Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

## Return Value

The column name; NULL if `colnumber` is out of range. SPI\_result set to SPI\_ERROR\_NOATTRIBUTE on error.

## SPI\_fnumber

SPI\_fnumber — determine the column number for the specified column name

## Synopsis

```
int SPI_fnumber(TupleDesc rowdesc, const char * colname)
```

## Description

SPI\_fnumber returns the column number for the column with the specified name.

If *colname* refers to a system column (e.g., *ctid*) then the appropriate negative column number will be returned. The caller should be careful to test the return value for exact equality to `SPI_ERROR_NOATTRIBUTE` to detect an error; testing the result for less than or equal to 0 is not correct unless system columns should be rejected.

## Arguments

`TupleDesc rowdesc`

input row description

`const char * colname`

column name

## Return Value

Column number (count starts at 1 for user-defined columns), or `SPI_ERROR_NOATTRIBUTE` if the named column was not found.



## SPI\_getvalue

`SPI_getvalue` — return the string value of the specified column

## Synopsis

```
char * SPI_getvalue(HeapTuple row, TupleDesc rowdesc,  
int colnumber)
```

## Description

`SPI_getvalue` returns the string representation of the value of the specified column.

The result is returned in memory allocated using `palloc`. (You can use `pfree` to release the memory when you don't need it anymore.)

## Arguments

`HeapTuple row`

input row to be examined

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

## Return Value

Column value, or `NULL` if the column is null, `colnumber` is out of range (`SPI_result` is set to `SPI_ERROR_NOATTRIBUTE`), or no output function is available (`SPI_result` is set to `SPI_ERROR_NOOUTFUNC`).

## SPI\_getbinval

SPI\_getbinval — return the binary value of the specified column

## Synopsis

```
Datum SPI_getbinval(HeapTuple row, TupleDesc rowdesc,  
    int colnumber,  
                    bool * isnull)
```

## Description

SPI\_getbinval returns the value of the specified column in the internal form (as type Datum).

This function does not allocate new space for the datum. In the case of a pass-by-reference data type, the return value will be a pointer into the passed row.

## Arguments

HeapTuple *row*

input row to be examined

TupleDesc *rowdesc*

input row description

int *colnumber*

column number (count starts at 1)

bool \* *isnull*

flag for a null value in the column

## Return Value

The binary value of the column is returned. The variable pointed to by *isnull* is set to true if the column is null, else to false.

SPI\_result is set to SPI\_ERROR\_NOATTRIBUTE on error.

## SPI\_gettype

SPI\_gettype — return the data type name of the specified column

## Synopsis

```
char * SPI_gettype(TupleDesc rowdesc, int colnumber)
```

## Description

SPI\_gettype returns a copy of the data type name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

## Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

## Return Value

The data type name of the specified column, or `NULL` on error. `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE` on error.

## SPI\_gettypeid

SPI\_gettypeid — return the data type OID of the specified column

## Synopsis

```
Oid SPI_gettypeid(TupleDesc rowdesc, int colnumber)
```

## Description

SPI\_gettypeid returns the OID of the data type of the specified column.

## Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

## Return Value

The OID of the data type of the specified column or `InvalidOid` on error. On error, `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE`.

## SPI\_getrelname

SPI\_getrelname — return the name of the specified relation

## Synopsis

```
char * SPI_getrelname(Relation rel)
```

## Description

SPI\_getrelname returns a copy of the name of the specified relation. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

## Arguments

Relation *rel*

input relation

## Return Value

The name of the specified relation.

## SPI\_getnspname

SPI\_getnspname — return the namespace of the specified relation

## Synopsis

```
char * SPI_getnspname(Relation rel)
```

## Description

SPI\_getnspname returns a copy of the name of the namespace that the specified Relation belongs to. This is equivalent to the relation's schema. You should pfree the return value of this function when you are finished with it.

## Arguments

Relation *rel*

input relation

## Return Value

The name of the specified relation's namespace.

## SPI\_result\_code\_string

SPI\_result\_code\_string — return error code as string

### Synopsis

```
const char * SPI_result_code_string(int code);
```

### Description

SPI\_result\_code\_string returns a string representation of the result code returned by various SPI functions or stored in SPI\_result.

### Arguments

int code

result code

### Return Value

A string representation of the result code.

## 43.3. Memory Management

LightDB allocates memory within *memory contexts*, which provide a convenient method of managing allocations made in many different places that need to live for differing amounts of time. Destroying a context releases all the memory that was allocated in it. Thus, it is not necessary to keep track of individual objects to avoid memory leaks; instead only a relatively small number of contexts have to be managed. `palloc` and related functions allocate memory from the “current” context.

`SPI_connect` creates a new memory context and makes it current. `SPI_finish` restores the previous current memory context and destroys the context created by `SPI_connect`. These actions ensure that transient memory allocations made inside your C function are reclaimed at C function exit, avoiding memory leakage.

However, if your C function needs to return an object in allocated memory (such as a value of a pass-by-reference data type), you cannot allocate that memory using `palloc`, at least not while you are connected to SPI. If you try, the object will be deallocated by `SPI_finish`, and your C function will not work reliably. To solve this problem, use `SPI_palloc` to allocate memory for your return object. `SPI_palloc` allocates memory in the “upper executor context”, that is, the memory context that was current when `SPI_connect` was called, which is precisely the right context for a value returned from your C function. Several of the other utility functions described in this section also return objects created in the upper executor context.

When `SPI_connect` is called, the private context of the C function, which is created by `SPI_connect`, is made the current context. All allocations made by `palloc`, `repalloc`, or SPI utility functions (except as described in this section) are made in this context. When a C function disconnects from the SPI manager (via `SPI_finish`) the current context is restored to the upper executor context, and all allocations made in the C function memory context are freed and cannot be used any more.

## SPI\_palloc

SPI\_palloc — allocate memory in the upper executor context

## Synopsis

```
void * SPI_palloc(Size size)
```

## Description

SPI\_palloc allocates memory in the upper executor context.

This function can only be used while connected to SPI. Otherwise, it throws an error.

## Arguments

Size *size*

size in bytes of storage to allocate

## Return Value

pointer to new storage space of the specified size



## SPI\_realloc

SPI\_realloc — reallocate memory in the upper executor context

### Synopsis

```
void * SPI_realloc(void * pointer, Size size)
```

### Description

SPI\_realloc changes the size of a memory segment previously allocated using SPI\_palloc.

This function is no longer different from plain realloc. It's kept just for backward compatibility of existing code.

### Arguments

```
void * pointer
```

pointer to existing storage to change

```
Size size
```

size in bytes of storage to allocate

### Return Value

pointer to new storage space of specified size with the contents copied from the existing area

## SPI\_pfree

SPI\_pfree — free memory in the upper executor context

## Synopsis

```
void SPI_pfree(void * pointer)
```

## Description

SPI\_pfree frees memory previously allocated using SPI\_palloc or SPI\_realloc.

This function is no longer different from plain `free`. It's kept just for backward compatibility of existing code.

## Arguments

```
void * pointer
```

pointer to existing storage to free

## SPI\_copytuple

SPI\_copytuple — make a copy of a row in the upper executor context

### Synopsis

```
HeapTuple SPI_copytuple(HeapTuple row)
```

### Description

SPI\_copytuple makes a copy of a row in the upper executor context. This is normally used to return a modified row from a trigger. In a function declared to return a composite type, use SPI\_returntuple instead.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets SPI\_result to SPI\_ERROR\_UNCONNECTED.

### Arguments

```
HeapTuple row
```

row to be copied

### Return Value

the copied row, or NULL on error (see SPI\_result for an error indication)

## SPI\_returntuple

SPI\_returntuple — prepare to return a tuple as a Datum

### Synopsis

```
HeapTupleHeader SPI_returntuple(HeapTuple row, TupleDesc rowdesc)
```

### Description

SPI\_returntuple makes a copy of a row in the upper executor context, returning it in the form of a row type Datum. The returned pointer need only be converted to Datum via `PointerGetDatum` before returning.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets `SPI_result` to `SPI_ERROR_UNCONNECTED`.

Note that this should be used for functions that are declared to return composite types. It is not used for triggers; use `SPI_copytuple` for returning a modified row in a trigger.

### Arguments

HeapTuple *row*

row to be copied

TupleDesc *rowdesc*

descriptor for row (pass the same descriptor each time for most effective caching)

### Return Value

HeapTupleHeader pointing to copied row, or NULL on error (see `SPI_result` for an error indication)

## SPI\_modifytuple

SPI\_modifytuple — create a row by replacing selected fields of a given row

### Synopsis

```
HeapTuple SPI_modifytuple(Relation rel, HeapTuple row, int ncols,
                          int * colnum, Datum * values, const char
                          * nulls)
```

### Description

SPI\_modifytuple creates a new row by substituting new values for selected columns, copying the original row's columns at other positions. The input row is not modified. The new row is returned in the upper executor context.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets SPI\_result to SPI\_ERROR\_UNCONNECTED.

### Arguments

Relation *rel*

Used only as the source of the row descriptor for the row. (Passing a relation rather than a row descriptor is a misfeature.)

HeapTuple *row*

row to be modified

int *ncols*

number of columns to be changed

int \* *colnum*

an array of length *ncols*, containing the numbers of the columns that are to be changed (column numbers start at 1)

Datum \* *values*

an array of length *ncols*, containing the new values for the specified columns

const char \* *nulls*

an array of length *ncols*, describing which new values are null

If *nulls* is NULL then SPI\_modifytuple assumes that no new values are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding new value is non-null, or 'n' if the corresponding new value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\\0' terminator.

### Return Value

new row with modifications, allocated in the upper executor context, or NULL on error (see SPI\_result for an error indication)

On error, `SPI_result` is set as follows:

`SPI_ERROR_ARGUMENT`

if `rel` is NULL, or if `row` is NULL, or if `ncols` is less than or equal to 0, or if `colnum` is NULL, or if `values` is NULL.

`SPI_ERROR_NOATTRIBUTE`

if `colnum` contains an invalid column number (less than or equal to 0 or greater than the number of columns in `row`)

`SPI_ERROR_UNCONNECTED`

if SPI is not active

## SPI\_freetuple

SPI\_freetuple — free a row allocated in the upper executor context

## Synopsis

```
void SPI_freetuple(HeapTuple row)
```

## Description

SPI\_freetuple frees a row previously allocated in the upper executor context.

This function is no longer different from plain heap\_freetuple. It's kept just for backward compatibility of existing code.

## Arguments

HeapTuple *row*

row to free

## SPI\_freetuptable

SPI\_freetuptable — free a row set created by SPI\_execute or a similar function

### Synopsis

```
void SPI_freetuptable(SPITupleTable * tuptable)
```

### Description

SPI\_freetuptable frees a row set created by a prior SPI command execution function, such as SPI\_execute. Therefore, this function is often called with the global variable SPI\_tuptable as argument.

This function is useful if an SPI-using C function needs to execute multiple commands and does not want to keep the results of earlier commands around until it ends. Note that any unfreed row sets will be freed anyway at SPI\_finish. Also, if a subtransaction is started and then aborted within execution of an SPI-using C function, SPI automatically frees any row sets created while the subtransaction was running.

SPI\_freetuptable contains guard logic to protect against duplicate deletion requests for the same row set.

### Arguments

```
SPITupleTable * tuptable
```

pointer to row set to free, or NULL to do nothing



## SPI\_freeplan

SPI\_freeplan — free a previously saved prepared statement

## Synopsis

```
int SPI_freeplan(SPIPlanPtr plan)
```

## Description

SPI\_freeplan releases a prepared statement previously returned by SPI\_prepare or saved by SPI\_keepplan or SPI\_saveplan.

## Arguments

SPIPlanPtr *plan*

pointer to statement to free

## Return Value

0 on success; SPI\_ERROR\_ARGUMENT if *plan* is NULL or invalid

# 43.4. Transaction Management

It is not possible to run transaction control commands such as COMMIT and ROLLBACK through SPI functions such as SPI\_execute. There are, however, separate interface functions that allow transaction control through SPI.

It is not generally safe and sensible to start and end transactions in arbitrary user-defined SQL-callable functions without taking into account the context in which they are called. For example, a transaction boundary in the middle of a function that is part of a complex SQL expression that is part of some SQL command will probably result in obscure internal errors or crashes. The interface functions presented here are primarily intended to be used by procedural language implementations to support transaction management in SQL-level procedures that are invoked by the CALL command, taking the context of the CALL invocation into account. SPI-using procedures implemented in C can implement the same logic, but the details of that are beyond the scope of this documentation.

## SPI\_commit

SPI\_commit, SPI\_commit\_and\_chain — commit the current transaction

## Synopsis

```
void SPI_commit(void)
```

```
void SPI_commit_and_chain(void)
```

## Description

SPI\_commit commits the current transaction. It is approximately equivalent to running the SQL command COMMIT. After the transaction is committed, a new transaction is automatically started using default transaction characteristics, so that the caller can continue using SPI facilities. If there is a failure during commit, the current transaction is instead rolled back and a new transaction is started, after which the error is thrown in the usual way.

SPI\_commit\_and\_chain is the same, but the new transaction is started with the same transaction characteristics as the just finished one, like with the SQL command COMMIT AND CHAIN.

These functions can only be executed if the SPI connection has been set as nonatomic in the call to SPI\_connect\_ext.

## SPI\_rollback

SPI\_rollback, SPI\_rollback\_and\_chain — abort the current transaction

## Synopsis

```
void SPI_rollback(void)
```

```
void SPI_rollback_and_chain(void)
```

## Description

SPI\_rollback rolls back the current transaction. It is approximately equivalent to running the SQL command ROLLBACK. After the transaction is rolled back, a new transaction is automatically started using default transaction characteristics, so that the caller can continue using SPI facilities.

SPI\_rollback\_and\_chain is the same, but the new transaction is started with the same transaction characteristics as the just finished one, like with the SQL command ROLLBACK AND CHAIN.

These functions can only be executed if the SPI connection has been set as nonatomic in the call to SPI\_connect\_ext.

## SPI\_start\_transaction

SPI\_start\_transaction — obsolete function

### Synopsis

```
void SPI_start_transaction(void)
```

### Description

SPI\_start\_transaction does nothing, and exists only for code compatibility with earlier LightDB releases. It used to be required after calling SPI\_commit or SPI\_rollback, but now those functions start a new transaction automatically.

## 43.5. Visibility of Data Changes

The following rules govern the visibility of data changes in functions that use SPI (or any other C function):

- During the execution of an SQL command, any data changes made by the command are invisible to the command itself. For example, in:

```
INSERT INTO a SELECT * FROM a;
```

the inserted rows are invisible to the SELECT part.

- Changes made by a command C are visible to all commands that are started after C, no matter whether they are started inside C (during the execution of C) or after C is done.
- Commands executed via SPI inside a function called by an SQL command (either an ordinary function or a trigger) follow one or the other of the above rules depending on the read/write flag passed to SPI. Commands executed in read-only mode follow the first rule: they cannot see changes of the calling command. Commands executed in read-write mode follow the second rule: they can see all changes made so far.
- All standard procedural languages set the SPI read-write mode depending on the volatility attribute of the function. Commands of STABLE and IMMUTABLE functions are done in read-only mode, while commands of VOLATILE functions are done in read-write mode. While authors of C functions are able to violate this convention, it's unlikely to be a good idea to do so.

The next section contains an example that illustrates the application of these rules.

## 43.6. Examples

This section contains a very simple example of SPI usage. The C function `execq` takes an SQL command as its first argument and a row count as its second, executes the command using `SPI_exec` and returns the number of rows that were processed by the command. You can find more complex examples for SPI in the source tree in `src/test/regress/regress.c` and in the `spi` module.

```
#include "postgres.h"

#include "executor/spi.h"
#include "utils/builtins.h"
```

```
PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(execq);

Datum
execq(PG_FUNCTION_ARGS)
{
    char *command;
    int cnt;
    int ret;
    uint64 proc;

    /* Convert given text object to a C string */
    command = text_to_cstring(PG_GETARG_TEXT_PP(0));
    cnt = PG_GETARG_INT32(1);

    SPI_connect();

    ret = SPI_exec(command, cnt);

    proc = SPI_processed;

    /*
     * If some rows were fetched, print them via elog(INFO).
     */
    if (ret > 0 && SPI_tuptable != NULL)
    {
        SPITupleTable *tuptable = SPI_tuptable;
        TupleDesc tupdesc = tuptable->tupdesc;
        char buf[8192];
        uint64 j;

        for (j = 0; j < tuptable->numvals; j++)
        {
            HeapTuple tuple = tuptable->vals[j];
            int i;

            for (i = 1, buf[0] = 0; i <= tupdesc->natts; i++)
                snprintf(buf + strlen(buf), sizeof(buf) -
strlen(buf), " %s%s",
                        SPI_getvalue(tuple, tupdesc, i),
                        (i == tupdesc->natts) ? " " : " |");
            elog(INFO, "EXECQ: %s", buf);
        }
    }

    SPI_finish();
    pfree(command);

    PG_RETURN_INT64(proc);
}
```

This is how you declare the function after having compiled it into a shared library (details are in Section 36.10.5.):

```
CREATE FUNCTION execq(text, integer) RETURNS int8
```

```
AS 'filename'
LANGUAGE C STRICT;
```

Here is a sample session:

```
=> SELECT execq('CREATE TABLE a (x integer)', 0);
execq
-----
      0
(1 row)

=> INSERT INTO a VALUES (execq('INSERT INTO a VALUES (0)', 0));
INSERT 0 1
=> SELECT execq('SELECT * FROM a', 0);
INFO: EXECQ: 0    -- inserted by execq
INFO: EXECQ: 1    -- returned by execq and inserted by upper
INSERT

execq
-----
      2
(1 row)

=> SELECT execq('INSERT INTO a SELECT x + 2 FROM a', 1);
execq
-----
      1
(1 row)

=> SELECT execq('SELECT * FROM a', 10);
INFO: EXECQ: 0
INFO: EXECQ: 1
INFO: EXECQ: 2    -- 0 + 2, only one row inserted - as specified

execq
-----
      3          -- 10 is the max value only, 3 is the real
number of rows
(1 row)

=> DELETE FROM a;
DELETE 3
=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INSERT 0 1
=> SELECT * FROM a;
x
---
      1          -- no rows in a (0) + 1
(1 row)

=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INFO: EXECQ: 1
INSERT 0 1
=> SELECT * FROM a;
x
---
      1
```

```

2                -- there was one row in a + 1
(2 rows)

-- This demonstrates the data changes visibility rule:

=> INSERT INTO a SELECT execq('SELECT * FROM a', 0) * x FROM a;
INFO:  EXECQ:  1
INFO:  EXECQ:  2
INFO:  EXECQ:  1
INFO:  EXECQ:  2
INFO:  EXECQ:  2
INSERT 0 2
=> SELECT * FROM a;
 x
---
 1
 2
 2                -- 2 rows * 1 (x in first row)
 6                -- 3 rows (2 + 1 just inserted) * 2 (x in
second row)
(4 rows)                ^^^^^^
                        rows visible to execq() in different
invocations

```

---

# Chapter 44. Background Worker Processes

LightDB can be extended to run user-supplied code in separate processes. Such processes are started, stopped and monitored by `lightdb`, which permits them to have a lifetime closely linked to the server's status. These processes have the option to attach to LightDB's shared memory area and to connect to databases internally; they can also run multiple transactions serially, just like a regular client-connected server process. Also, by linking to `libpq` they can connect to the server and behave like a regular client application.

## Warning

There are considerable robustness and security risks in using background worker processes because, being written in the C language, they have unrestricted access to data. Administrators wishing to enable modules that include background worker processes should exercise extreme caution. Only carefully audited modules should be permitted to run background worker processes.

Background workers can be initialized at the time that LightDB is started by including the module name in `shared_preload_libraries`. A module wishing to run a background worker can register it by calling `RegisterBackgroundWorker(BackgroundWorker *worker)` from its `_PG_init()` function. Background workers can also be started after the system is up and running by calling `RegisterDynamicBackgroundWorker(BackgroundWorker *worker, BackgroundWorkerHandle **handle)`. Unlike `RegisterBackgroundWorker`, which can only be called from within the postmaster process, `RegisterDynamicBackgroundWorker` must be called from a regular backend or another background worker.

The structure `BackgroundWorker` is defined thus:

```
typedef void (*bgworker_main_type)(Datum main_arg);
typedef struct BackgroundWorker
{
    char          bgw_name[BGW_MAXLEN];
    char          bgw_type[BGW_MAXLEN];
    int           bgw_flags;
    BgWorkerStartTime bgw_start_time;
    int           bgw_restart_time;          /* in seconds, or
BGW_NEVER_RESTART */
    char          bgw_library_name[BGW_MAXLEN];
    char          bgw_function_name[BGW_MAXLEN];
    Datum        bgw_main_arg;
    char          bgw_extra[BGW_EXTRALEN];
    int           bgw_notify_pid;
} BackgroundWorker;
```

`bgw_name` and `bgw_type` are strings to be used in log messages, process listings and similar contexts. `bgw_type` should be the same for all background workers of the same type, so that it is possible to group such workers in a process listing, for example. `bgw_name` on the other hand can contain additional information about the specific process. (Typically, the string for `bgw_name` will contain the type somehow, but that is not strictly required.)

`bgw_flags` is a bitwise-or'd bit mask indicating the capabilities that the module wants. Possible values are:



BGWORKER\_SHMEM\_ACCESS

Requests shared memory access. Workers without shared memory access cannot access any of LightDB's shared data structures, such as heavyweight or lightweight locks, shared buffers, or any custom data structures which the worker itself may wish to create and use.

BGWORKER\_BACKEND\_DATABASE\_CONNECTION

Requests the ability to establish a database connection through which it can later run transactions and queries. A background worker using `BGWORKER_BACKEND_DATABASE_CONNECTION` to connect to a database must also attach shared memory using `BGWORKER_SHMEM_ACCESS`, or worker start-up will fail.

`bgw_start_time` is the server state during which `lightdb` should start the process; it can be one of `BgWorkerStart_PostmasterStart` (start as soon as `lightdb` itself has finished its own initialization; processes requesting this are not eligible for database connections), `BgWorkerStart_ConsistentState` (start as soon as a consistent state has been reached in a hot standby, allowing processes to connect to databases and run read-only queries), and `BgWorkerStart_RecoveryFinished` (start as soon as the system has entered normal read-write state). Note the last two values are equivalent in a server that's not a hot standby. Note that this setting only indicates when the processes are to be started; they do not stop when a different state is reached.

`bgw_restart_time` is the interval, in seconds, that `lightdb` should wait before restarting the process in the event that it crashes. It can be any positive value, or `BGW_NEVER_RESTART`, indicating not to restart the process in case of a crash.

`bgw_library_name` is the name of a library in which the initial entry point for the background worker should be sought. The named library will be dynamically loaded by the worker process and `bgw_function_name` will be used to identify the function to be called. If loading a function from the core code, this must be set to "lightdb".

`bgw_function_name` is the name of a function in a dynamically loaded library which should be used as the initial entry point for a new background worker.

`bgw_main_arg` is the `Datum` argument to the background worker main function. This main function should take a single argument of type `Datum` and return `void`. `bgw_main_arg` will be passed as the argument. In addition, the global variable `MyBgworkerEntry` points to a copy of the `BackgroundWorker` structure passed at registration time; the worker may find it helpful to examine this structure.

On Windows (and anywhere else where `EXEC_BACKEND` is defined) or in dynamic background workers it is not safe to pass a `Datum` by reference, only by value. If an argument is required, it is safest to pass an `int32` or other small value and use that as an index into an array allocated in shared memory. If a value like a `cstring` or `text` is passed then the pointer won't be valid from the new background worker process.

`bgw_extra` can contain extra data to be passed to the background worker. Unlike `bgw_main_arg`, this data is not passed as an argument to the worker's main function, but it can be accessed via `MyBgworkerEntry`, as discussed above.

`bgw_notify_pid` is the PID of a LightDB backend process to which the postmaster should send `SIGUSR1` when the process is started or exits. It should be 0 for workers registered at postmaster startup time, or when the backend registering the worker does not wish to wait for the worker to start up. Otherwise, it should be initialized to `MyProcPid`.

Once running, the process can connect to a database by calling `BackgroundWorkerInitializeConnection(char *dbname, char *username, uint32 flags)` or `BackgroundWorkerInitializeConnectionByOid(Oid dboid, Oid useroid, uint32 flags)`. This allows the process to run transactions and queries

using the SPI interface. If `dbname` is `NULL` or `dboid` is `InvalidOid`, the session is not connected to any particular database, but shared catalogs can be accessed. If `username` is `NULL` or `userid` is `InvalidOid`, the process will run as the superuser created during `initdb`. If `BGWORKER_BYPASS_ALLOWCONN` is specified as `flags` it is possible to bypass the restriction to connect to databases not allowing user connections. A background worker can only call one of these two functions, and only once. It is not possible to switch databases.

Signals are initially blocked when control reaches the background worker's main function, and must be unblocked by it; this is to allow the process to customize its signal handlers, if necessary. Signals can be unblocked in the new process by calling `BackgroundWorkerUnblockSignals` and blocked by calling `BackgroundWorkerBlockSignals`.

If `bgw_restart_time` for a background worker is configured as `BGW_NEVER_RESTART`, or if it exits with an exit code of 0 or is terminated by `TerminateBackgroundWorker`, it will be automatically unregistered by the postmaster on exit. Otherwise, it will be restarted after the time period configured via `bgw_restart_time`, or immediately if the postmaster reinitializes the cluster due to a backend failure. Backends which need to suspend execution only temporarily should use an interruptible sleep rather than exiting; this can be achieved by calling `WaitLatch()`. Make sure the `WL_POSTMASTER_DEATH` flag is set when calling that function, and verify the return code for a prompt exit in the emergency case that `lightdb` itself has terminated.

When a background worker is registered using the `RegisterDynamicBackgroundWorker` function, it is possible for the backend performing the registration to obtain information regarding the status of the worker. Backends wishing to do this should pass the address of a `BackgroundWorkerHandle *` as the second argument to `RegisterDynamicBackgroundWorker`. If the worker is successfully registered, this pointer will be initialized with an opaque handle that can subsequently be passed to `GetBackgroundWorkerPid(BackgroundWorkerHandle *, pid_t *)` or `TerminateBackgroundWorker(BackgroundWorkerHandle *)`. `GetBackgroundWorkerPid` can be used to poll the status of the worker: a return value of `BGWH_NOT_YET_STARTED` indicates that the worker has not yet been started by the postmaster; `BGWH_STOPPED` indicates that it has been started but is no longer running; and `BGWH_STARTED` indicates that it is currently running. In this last case, the PID will also be returned via the second argument. `TerminateBackgroundWorker` causes the postmaster to send `SIGTERM` to the worker if it is running, and to unregister it as soon as it is not.

In some cases, a process which registers a background worker may wish to wait for the worker to start up. This can be accomplished by initializing `bgw_notify_pid` to `MyProcPid` and then passing the `BackgroundWorkerHandle *` obtained at registration time to `WaitForBackgroundWorkerStartup(BackgroundWorkerHandle *handle, pid_t *)` function. This function will block until the postmaster has attempted to start the background worker, or until the postmaster dies. If the background worker is running, the return value will be `BGWH_STARTED`, and the PID will be written to the provided address. Otherwise, the return value will be `BGWH_STOPPED` or `BGWH_POSTMASTER_DIED`.

A process can also wait for a background worker to shut down, by using the `WaitForBackgroundWorkerShutdown(BackgroundWorkerHandle *handle)` function and passing the `BackgroundWorkerHandle *` obtained at registration. This function will block until the background worker exits, or postmaster dies. When the background worker exits, the return value is `BGWH_STOPPED`, if postmaster dies it will return `BGWH_POSTMASTER_DIED`.

Background workers can send asynchronous notification messages, either by using the `NOTIFY` command via SPI, or directly via `Async_Notify()`. Such notifications will be sent at transaction commit. Background workers should not register to receive asynchronous notifications with the `LISTEN` command, as there is no infrastructure for a worker to consume such notifications.

The `src/test/modules/worker_spi` module contains a working example, which demonstrates some useful techniques.

The maximum number of registered background workers is limited by `max_worker_processes`.

---

# Chapter 45. Logical Decoding

LightDB provides infrastructure to stream the modifications performed via SQL to external consumers. This functionality can be used for a variety of purposes, including replication solutions and auditing.

Changes are sent out in streams identified by logical replication slots.

The format in which those changes are streamed is determined by the output plugin used. An example plugin is provided in the LightDB distribution. Additional plugins can be written to extend the choice of available formats without modifying any core code. Every output plugin has access to each individual new row produced by `INSERT` and the new row version created by `UPDATE`. Availability of old row versions for `UPDATE` and `DELETE` depends on the configured replica identity (see `REPLICA IDENTITY`).

Changes can be consumed either using the streaming replication protocol (see Section 49.4 and Section 45.3), or by calling functions via SQL (see Section 45.4). It is also possible to write additional methods of consuming the output of a replication slot without modifying core code (see Section 45.7).

## 45.1. Logical Decoding Examples

The following example demonstrates controlling logical decoding using the SQL interface.

Before you can use logical decoding, you must set `wal_level` to `logical` and `max_replication_slots` to at least 1. Then, you should connect to the target database (in the example below, `lightdb`) as a superuser.

```
lightdb@postgres=# -- Create a slot named 'regression_slot' using
the output plugin 'test_decoding'
```

```
lightdb@postgres=# SELECT * FROM
pg_create_logical_replication_slot('regression_slot',
'test_decoding');
```

slot_name	lsn
regression_slot	0/16B1970

(1 row)

```
lightdb@postgres=# SELECT slot_name, plugin, slot_type,
database, active, restart_lsn, confirmed_flush_lsn FROM
pg_replication_slots;
```

slot_name	plugin	slot_type	database	active	restart_lsn	confirmed_flush_lsn
regression_slot	test_decoding	logical	postgres	f	0/16A4408	0/16A4440

(1 row)

```
lightdb@postgres=# -- There are no changes to see yet
```

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
lsn | xid | data
```

lsn	xid	data
-----	-----	------

(0 rows)

```
lightdb@postgres=# CREATE TABLE data(id serial primary key, data
text);
```

CREATE TABLE

lightdb@postgres=# -- DDL isn't replicated, so all you'll see is the transaction

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn   |  xid  | data
-----+-----+-----
```

```
0/BA2DA58 | 10297 | BEGIN 10297
0/BA5A5A0 | 10297 | COMMIT 10297
(2 rows)
```

lightdb@postgres=# -- Once changes are read, they're consumed and not emitted

```
lightdb@postgres=# -- in a subsequent call:
lightdb@postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn |  xid | data
-----+-----+-----
```

(0 rows)

```
lightdb@postgres=# BEGIN;
lightdb@postgres=# INSERT INTO data(data) VALUES('1');
lightdb@postgres=# INSERT INTO data(data) VALUES('2');
lightdb@postgres=# COMMIT;
```

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn   |  xid  | data
```

```
-----+-----
+-----+-----+-----
0/BA5A688 | 10298 | BEGIN 10298
0/BA5A6F0 | 10298 | table public.data: INSERT: id[integer]:1
data[text]:'1'
0/BA5A7F8 | 10298 | table public.data: INSERT: id[integer]:2
data[text]:'2'
0/BA5A8A8 | 10298 | COMMIT 10298
(4 rows)
```

```
lightdb@postgres=# INSERT INTO data(data) VALUES('3');
```

lightdb@postgres=# -- You can also peek ahead in the change stream without consuming changes

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL);
   lsn   |  xid  | data
```

```
-----+-----
+-----+-----+-----
0/BA5A8E0 | 10299 | BEGIN 10299
0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
0/BA5A990 | 10299 | COMMIT 10299
(3 rows)
```

lightdb@postgres=# -- The next call to pg\_logical\_slot\_peek\_changes() returns the same changes again

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL);
   lsn   |   xid   | data
```

```
-----+-----
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
0/BA5A8E0 | 10299 | BEGIN 10299
0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
0/BA5A990 | 10299 | COMMIT 10299
(3 rows)
```

```
lightdb@postgres=# -- options can be passed to output plugin, to
influence the formatting
```

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL,
'include-timestamp', 'on');
   lsn   |   xid   | data
```

```
-----+-----
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
0/BA5A8E0 | 10299 | BEGIN 10299
0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
0/BA5A990 | 10299 | COMMIT 10299 (at 2017-05-10
12:07:21.272494-04)
(3 rows)
```

```
lightdb@postgres=# -- Remember to destroy a slot you no longer need
to stop it consuming
```

```
lightdb@postgres=# -- server resources:
lightdb@postgres=# SELECT
pg_drop_replication_slot('regression_slot');
pg_drop_replication_slot
```

```
-----
(1 row)
```

The following example shows how logical decoding is controlled over the streaming replication protocol, using the program `lt_recvlogical` included in the LightDB distribution. This requires that client authentication is set up to allow replication connections (see Section 24.2.5.1) and that `max_wal_senders` is set sufficiently high to allow an additional connection.

```
$ lt_recvlogical -d postgres --slot=test --create-slot
$ lt_recvlogical -d postgres --slot=test --start -f -
Control+Z
$ ltsql -d postgres -c "INSERT INTO data(data) VALUES('4');"
$ fg
BEGIN 693
table public.data: INSERT: id[integer]:4 data[text]:'4'
COMMIT 693
Control+C
$ lt_recvlogical -d postgres --slot=test --drop-slot
```

## 45.2. Logical Decoding Concepts

### 45.2.1. Logical Decoding

Logical decoding is the process of extracting all persistent changes to a database's tables into a coherent, easy to understand format which can be interpreted without detailed knowledge of the database's internal state.

In LightDB, logical decoding is implemented by decoding the contents of the write-ahead log, which describe changes on a storage level, into an application-specific form such as a stream of tuples or SQL statements.

### 45.2.2. Replication Slots

In the context of logical replication, a slot represents a stream of changes that can be replayed to a client in the order they were made on the origin server. Each slot streams a sequence of changes from a single database.

#### Note

LightDB also has streaming replication slots (see Section 24.2.5), but they are used somewhat differently there.

A replication slot has an identifier that is unique across all databases in a LightDB cluster. Slots persist independently of the connection using them and are crash-safe.

A logical slot will emit each change just once in normal operation. The current position of each slot is persisted only at checkpoint, so in the case of a crash the slot may return to an earlier LSN, which will then cause recent changes to be sent again when the server restarts. Logical decoding clients are responsible for avoiding ill effects from handling the same message more than once. Clients may wish to record the last LSN they saw when decoding and skip over any repeated data or (when using the replication protocol) request that decoding start from that LSN rather than letting the server determine the start point. The Replication Progress Tracking feature is designed for this purpose, refer to replication origins.

Multiple independent slots may exist for a single database. Each slot has its own state, allowing different consumers to receive changes from different points in the database change stream. For most applications, a separate slot will be required for each consumer.

A logical replication slot knows nothing about the state of the receiver(s). It's even possible to have multiple different receivers using the same slot at different times; they'll just get the changes following on from when the last receiver stopped consuming them. Only one receiver may consume changes from a slot at any given time.

#### Caution

Replication slots persist across crashes and know nothing about the state of their consumer(s). They will prevent removal of required resources even when there is no connection using them. This consumes storage because neither required WAL nor required rows from the system catalogs can be removed by VACUUM as long as they are required by a replication slot. In extreme cases this could cause the database to shut down to prevent transaction ID wraparound (see Section 22.1.5). So if a slot is no longer required it should be dropped.

### 45.2.3. Output Plugins

Output plugins transform the data from the write-ahead log's internal representation into the format the consumer of a replication slot desires.

### 45.2.4. Exported Snapshots

When a new replication slot is created using the streaming replication interface (see `CREATE_REPLICATION_SLOT`), a snapshot is exported (see Section 9.27.5), which will show exactly the state of the database after which all changes will be included in the change stream. This can be used to create a new replica by using `SET TRANSACTION SNAPSHOT` to read the state of the database at the moment the slot was created. This transaction can then be used to dump the database's state at that point in time, which afterwards can be updated using the slot's contents without losing any changes.

Creation of a snapshot is not always possible. In particular, it will fail when connected to a hot standby. Applications that do not require snapshot export may suppress it with the `NOEXPORT_SNAPSHOT` option.

## 45.3. Streaming Replication Protocol Interface

The commands

- `CREATE_REPLICATION_SLOT slot_name LOGICAL output_plugin`
- `DROP_REPLICATION_SLOT slot_name [ WAIT ]`
- `START_REPLICATION SLOT slot_name LOGICAL ...`

are used to create, drop, and stream changes from a replication slot, respectively. These commands are only available over a replication connection; they cannot be used via SQL. See Section 49.4 for details on these commands.

The command `lt_recvlogical` can be used to control logical decoding over a streaming replication connection. (It uses these commands internally.)

## 45.4. Logical Decoding SQL Interface

See Section 9.27.6 for detailed documentation on the SQL-level API for interacting with logical decoding.

Synchronous replication (see Section 24.2.8) is only supported on replication slots used over the streaming replication interface. The function interface and additional, non-core interfaces do not support synchronous replication.

## 45.5. System Catalogs Related to Logical Decoding

The `pg_replication_slots` view and the `pg_stat_replication` view provide information about the current state of replication slots and streaming replication connections respectively. These views apply to both physical and logical replication.

## 45.6. Logical Decoding Output Plugins

An example output plugin can be found in the `contrib/test_decoding` subdirectory of the LightDB source tree.

### 45.6.1. Initialization Function

An output plugin is loaded by dynamically loading a shared library with the output plugin's name as the library base name. The normal library search path is used to locate the library. To provide the required output plugin callbacks and to indicate that the library is actually an output plugin it needs to provide a function named `_PG_output_plugin_init`. This function is passed a struct that needs to be filled with the callback function pointers for individual actions.

```
typedef struct OutputPluginCallbacks
{
    LogicalDecodeStartupCB startup_cb;
    LogicalDecodeBeginCB begin_cb;
    LogicalDecodeChangeCB change_cb;
    LogicalDecodeTruncateCB truncate_cb;
    LogicalDecodeCommitCB commit_cb;
    LogicalDecodeMessageCB message_cb;
    LogicalDecodeFilterByOriginCB filter_by_origin_cb;
    LogicalDecodeShutdownCB shutdown_cb;
} OutputPluginCallbacks;

typedef void (*LogicalOutputPluginInit) (struct
    OutputPluginCallbacks *cb);
```

The `begin_cb`, `change_cb` and `commit_cb` callbacks are required, while `startup_cb`, `filter_by_origin_cb`, `truncate_cb`, and `shutdown_cb` are optional. If `truncate_cb` is not set but a `TRUNCATE` is to be decoded, the action will be ignored.

### 45.6.2. Capabilities

To decode, format and output changes, output plugins can use most of the backend's normal infrastructure, including calling output functions. Read only access to relations is permitted as long as only relations are accessed that either have been created by `initdb` in the `pg_catalog` schema, or have been marked as user provided catalog tables using

```
ALTER TABLE user_catalog_table SET (user_catalog_table = true);
CREATE TABLE another_catalog_table(data text) WITH
    (user_catalog_table = true);
```

Any actions leading to transaction ID assignment are prohibited. That, among others, includes writing to tables, performing DDL changes, and calling `pg_current_xact_id()`.

### 45.6.3. Output Modes

Output plugin callbacks can pass data to the consumer in nearly arbitrary formats. For some use cases, like viewing the changes via SQL, returning data in a data type that can contain arbitrary data (e.g., `bytea`) is cumbersome. If the output plugin only outputs textual data in the server's encoding, it can declare that by setting `OutputPluginOptions.output_type` to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` instead of `OUTPUT_PLUGIN_BINARY_OUTPUT` in the startup callback. In that case, all the data has to be in the server's encoding so that a `text` datum can contain it. This is checked in assertion-enabled builds.



## 45.6.4. Output Plugin Callbacks

An output plugin gets notified about changes that are happening via various callbacks it needs to provide.

Concurrent transactions are decoded in commit order, and only changes belonging to a specific transaction are decoded between the `begin` and `commit` callbacks. Transactions that were rolled back explicitly or implicitly never get decoded. Successful savepoints are folded into the transaction containing them in the order they were executed within that transaction.

### Note

Only transactions that have already safely been flushed to disk will be decoded. That can lead to a `COMMIT` not immediately being decoded in a directly following `pg_logical_slot_get_changes()` when `synchronous_commit` is set to `off`.

### 45.6.4.1. Startup Callback

The optional `startup_cb` callback is called whenever a replication slot is created or asked to stream changes, independent of the number of changes that are ready to be put out.

```
typedef void (*LogicalDecodeStartupCB) (struct
    LogicalDecodingContext *ctx,
                                        OutputPluginOptions
    *options,
                                        bool is_init);
```

The `is_init` parameter will be true when the replication slot is being created and false otherwise. `options` points to a struct of options that output plugins can set:

```
typedef struct OutputPluginOptions
{
    OutputPluginOutputType output_type;
    bool receive_rewrites;
} OutputPluginOptions;
```

`output_type` has to either be set to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` or `OUTPUT_PLUGIN_BINARY_OUTPUT`. See also Section 45.6.3. If `receive_rewrites` is true, the output plugin will also be called for changes made by heap rewrites during certain DDL operations. These are of interest to plugins that handle DDL replication, but they require special handling.

The startup callback should validate the options present in `ctx->output_plugin_options`. If the output plugin needs to have a state, it can use `ctx->output_plugin_private` to store it.

### 45.6.4.2. Shutdown Callback

The optional `shutdown_cb` callback is called whenever a formerly active replication slot is not used anymore and can be used to deallocate resources private to the output plugin. The slot isn't necessarily being dropped, streaming is just being stopped.

```
typedef void (*LogicalDecodeShutdownCB) (struct
    LogicalDecodingContext *ctx);
```

### 45.6.4.3. Transaction Begin Callback

The required `begin_cb` callback is called whenever a start of a committed transaction has been decoded. Aborted transactions and their contents never get decoded.

```
typedef void (*LogicalDecodeBeginCB) (struct LogicalDecodingContext
    *ctx,
                                     ReorderBufferTXN *txn);
```

The `txn` parameter contains meta information about the transaction, like the time stamp at which it has been committed and its XID.

### 45.6.4.4. Transaction End Callback

The required `commit_cb` callback is called whenever a transaction commit has been decoded. The `change_cb` callbacks for all modified rows will have been called before this, if there have been any modified rows.

```
typedef void (*LogicalDecodeCommitCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     XLogRecPtr commit_lsn);
```

### 45.6.4.5. Change Callback

The required `change_cb` callback is called for every individual row modification inside a transaction, may it be an INSERT, UPDATE, or DELETE. Even if the original command modified several rows at once the callback will be called individually for each row.

```
typedef void (*LogicalDecodeChangeCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     Relation relation,
                                     ReorderBufferChange
    *change);
```

The `ctx` and `txn` parameters have the same contents as for the `begin_cb` and `commit_cb` callbacks, but additionally the relation descriptor `relation` points to the relation the row belongs to and a struct `change` describing the row modification are passed in.

#### Note

Only changes in user defined tables that are not unlogged (see UNLOGGED) and not temporary (see TEMPORARY or TEMP) can be extracted using logical decoding.

### 45.6.4.6. Truncate Callback

The `truncate_cb` callback is called for a TRUNCATE command.

```
typedef void (*LogicalDecodeTruncateCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
```

```

        int nrelations,
        Relation relations[],
        ReorderBufferChange
    *change);

```

The parameters are analogous to the `change_cb` callback. However, because `TRUNCATE` actions on tables connected by foreign keys need to be executed together, this callback receives an array of relations instead of just a single one. See the description of the `TRUNCATE` statement for details.

#### 45.6.4.7. Origin Filter Callback

The optional `filter_by_origin_cb` callback is called to determine whether data that has been replayed from `origin_id` is of interest to the output plugin.

```

typedef bool (*LogicalDecodeFilterByOriginCB) (struct
    LogicalDecodingContext *ctx,
                                                RepOriginId
    origin_id);

```

The `ctx` parameter has the same contents as for the other callbacks. No information but the origin is available. To signal that changes originating on the passed in node are irrelevant, return true, causing them to be filtered away; false otherwise. The other callbacks will not be called for transactions and changes that have been filtered away.

This is useful when implementing cascading or multidirectional replication solutions. Filtering by the origin allows to prevent replicating the same changes back and forth in such setups. While transactions and changes also carry information about the origin, filtering via this callback is noticeably more efficient.

#### 45.6.4.8. Generic Message Callback

The optional `message_cb` callback is called whenever a logical decoding message has been decoded.

```

typedef void (*LogicalDecodeMessageCB) (struct
    LogicalDecodingContext *ctx,
                                                ReorderBufferTXN *txn,
                                                XLogRecPtr message_lsn,
                                                bool transactional,
                                                const char *prefix,
                                                Size message_size,
                                                const char *message);

```

The `txn` parameter contains meta information about the transaction, like the time stamp at which it has been committed and its `XID`. Note however that it can be `NULL` when the message is non-transactional and the `XID` was not assigned yet in the transaction which logged the message. The `lsn` has WAL location of the message. The `transactional` says if the message was sent as transactional or not. The `prefix` is arbitrary null-terminated prefix which can be used for identifying interesting messages for the current plugin. And finally the `message` parameter holds the actual message of `message_size` size.

Extra care should be taken to ensure that the prefix the output plugin considers interesting is unique. Using name of the extension or the output plugin itself is often a good choice.

### 45.6.5. Functions for Producing Output

To actually produce output, output plugins can write data to the `StringInfo` output buffer in `ctx->out` when inside the `begin_cb`, `commit_cb`, or `change_cb` callbacks. Before writing to the

output buffer, `OutputPluginPrepareWrite(ctx, last_write)` has to be called, and after finishing writing to the buffer, `OutputPluginWrite(ctx, last_write)` has to be called to perform the write. The `last_write` indicates whether a particular write was the callback's last write.

The following example shows how to output data to the consumer of an output plugin:

```
OutputPluginPrepareWrite(ctx, true);
appendStringInfo(ctx->out, "BEGIN %u", txn->xid);
OutputPluginWrite(ctx, true);
```

## 45.7. Logical Decoding Output Writers

It is possible to add more output methods for logical decoding. For details, see `src/backend/replication/logical/logicalfuncs.c`. Essentially, three functions need to be provided: one to read WAL, one to prepare writing output, and one to write the output (see Section 45.6.5).

## 45.8. Synchronous Replication Support for Logical Decoding

### 45.8.1. Overview

Logical decoding can be used to build synchronous replication solutions with the same user interface as synchronous replication for streaming replication. To do this, the streaming replication interface (see Section 45.3) must be used to stream out data. Clients have to send `Standby status update (F)` (see Section 49.4) messages, just like streaming replication clients do.

#### Note

A synchronous replica receiving changes via logical decoding will work in the scope of a single database. Since, in contrast to that, `synchronous_standby_names` currently is server wide, this means this technique will not work properly if more than one database is actively used.

### 45.8.2. Caveats

In synchronous replication setup, a deadlock can happen, if the transaction has locked [user] catalog tables exclusively. See Section 45.6.2 for information on user catalog tables. This is because logical decoding of transactions can lock catalog tables to access them. To avoid this users must refrain from taking an exclusive lock on [user] catalog tables. This can happen in the following ways:

- Issuing an explicit `LOCK` on `pg_class` in a transaction.
- Perform `CLUSTER` on `pg_class` in a transaction.
- Executing `TRUNCATE` on [user] catalog table in a transaction.

Note that these commands that can cause deadlock apply to not only explicitly indicated system catalog tables above but also to any other [user] catalog table.

---

# Chapter 46. Replication Progress Tracking

Replication origins are intended to make it easier to implement logical replication solutions on top of logical decoding. They provide a solution to two common problems:

- How to safely keep track of replication progress
- How to change replication behavior based on the origin of a row; for example, to prevent loops in bi-directional replication setups

Replication origins have just two properties, a name and an OID. The name, which is what should be used to refer to the origin across systems, is free-form text. It should be used in a way that makes conflicts between replication origins created by different replication solutions unlikely; e.g., by prefixing the replication solution's name to it. The OID is used only to avoid having to store the long version in situations where space efficiency is important. It should never be shared across systems.

Replication origins can be created using the function `pg_replication_origin_create()`; dropped using `pg_replication_origin_drop()`; and seen in the `pg_replication_origin` system catalog.

One nontrivial part of building a replication solution is to keep track of replay progress in a safe manner. When the applying process, or the whole cluster, dies, it needs to be possible to find out up to where data has successfully been replicated. Naive solutions to this, such as updating a row in a table for every replayed transaction, have problems like run-time overhead and database bloat.

Using the replication origin infrastructure a session can be marked as replaying from a remote node (using the `pg_replication_origin_session_setup()` function). Additionally the LSN and commit time stamp of every source transaction can be configured on a per transaction basis using `pg_replication_origin_xact_setup()`. If that's done replication progress will persist in a crash safe manner. Replay progress for all replication origins can be seen in the `pg_replication_origin_status` view. An individual origin's progress, e.g., when resuming replication, can be acquired using `pg_replication_origin_progress()` for any origin or `pg_replication_origin_session_progress()` for the origin configured in the current session.

In replication topologies more complex than replication from exactly one system to one other system, another problem can be that it is hard to avoid replicating replayed rows again. That can lead both to cycles in the replication and inefficiencies. Replication origins provide an optional mechanism to recognize and prevent that. When configured using the functions referenced in the previous paragraph, every change and transaction passed to output plugin callbacks (see Section 45.6) generated by the session is tagged with the replication origin of the generating session. This allows treating them differently in the output plugin, e.g., ignoring all but locally-originating rows. Additionally the `filter_by_origin_cb` callback can be used to filter the logical decoding change stream based on the source. While less flexible, filtering via that callback is considerably more efficient than doing it in the output plugin.

---

# Part VI. Reference

The entries in this Reference are meant to provide in reasonable length an authoritative, complete, and formal summary about their respective subjects. More information about the use of LightDB, in narrative, tutorial, or example form, can be found in other parts of this book. See the cross-references listed on each reference page.

The reference entries are also available as traditional “man” pages.

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---

# SQL Commands

This part contains reference information for the SQL commands supported by LightDB. By “SQL” the language in general is meant; information about the standards conformance and compatibility of each command can be found on the respective reference page.

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---

# ABORT

ABORT — abort the current transaction

## Synopsis

```
ABORT [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

## Description

ABORT rolls back the current transaction and causes all the updates made by the transaction to be discarded. This command is identical in behavior to the standard SQL command ROLLBACK, and is present only for historical reasons.

## Parameters

WORK  
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

## Notes

Use COMMIT to successfully terminate a transaction.

Issuing ABORT outside of a transaction block emits a warning and otherwise has no effect.

## Examples

To abort all changes:

```
ABORT ;
```

## Compatibility

This command is a LightDB extension present for historical reasons. ROLLBACK is the equivalent standard SQL command.

## See Also

BEGIN, COMMIT, ROLLBACK



---

# ALTER AGGREGATE

ALTER AGGREGATE — change the definition of an aggregate function

## Synopsis

```
ALTER AGGREGATE name ( aggregate_signature ) RENAME TO new_name
ALTER AGGREGATE name ( aggregate_signature )
    OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER AGGREGATE name ( aggregate_signature ) SET SCHEMA new_schema
```

where *aggregate\_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

## Description

ALTER AGGREGATE changes the definition of an aggregate function.

You must own the aggregate function to use ALTER AGGREGATE. To change the schema of an aggregate function, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the aggregate function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the aggregate function. However, a superuser can alter ownership of any aggregate function anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing aggregate function.

*argmode*

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

*argname*

The name of an argument. Note that ALTER AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

*argtype*

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write \* in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

*new\_name*

The new name of the aggregate function.

*new\_owner*

The new owner of the aggregate function.

*new\_schema*

The new schema for the aggregate function.

## Notes

The recommended syntax for referencing an ordered-set aggregate is to write `ORDER BY` between the direct and aggregated argument specifications, in the same style as in `CREATE AGGREGATE`. However, it will also work to omit `ORDER BY` and just run the direct and aggregated argument specifications into a single list. In this abbreviated form, if `VARIADIC "any"` was used in both the direct and aggregated argument lists, write `VARIADIC "any"` only once.

## Examples

To rename the aggregate function `myavg` for type `integer` to `my_average`:

```
ALTER AGGREGATE myavg(integer) RENAME TO my_average;
```

To change the owner of the aggregate function `myavg` for type `integer` to `joe`:

```
ALTER AGGREGATE myavg(integer) OWNER TO joe;
```

To move the ordered-set aggregate `mypercentile` with direct argument of type `float8` and aggregated argument of type `integer` into schema `myschema`:

```
ALTER AGGREGATE mypercentile(float8 ORDER BY integer) SET SCHEMA
myschema;
```

This will work too:

```
ALTER AGGREGATE mypercentile(float8, integer) SET SCHEMA myschema;
```

## Compatibility

There is no `ALTER AGGREGATE` statement in the SQL standard.

## See Also

`CREATE AGGREGATE`, `DROP AGGREGATE`

---

# ALTER COLLATION

ALTER COLLATION — change the definition of a collation

## Synopsis

```
ALTER COLLATION name REFRESH VERSION
```

```
ALTER COLLATION name RENAME TO new_name
```

```
ALTER COLLATION name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }
```

```
ALTER COLLATION name SET SCHEMA new_schema
```

## Description

ALTER COLLATION changes the definition of a collation.

You must own the collation to use ALTER COLLATION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the collation's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the collation. However, a superuser can alter ownership of any collation anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing collation.

*new\_name*

The new name of the collation.

*new\_owner*

The new owner of the collation.

*new\_schema*

The new schema for the collation.

REFRESH VERSION

Update the collation's version. See Notes below.

## Notes

When using collations provided by the ICU library, the ICU-specific version of the collator is recorded in the system catalog when the collation object is created. When the collation is used, the current version is checked against the recorded version, and a warning is issued when there is a mismatch, for example:

```
WARNING: collation "xx-x-icu" has version mismatch  
DETAIL: The collation in the database was created using version  
1.2.3.4, but the operating system provides version 2.3.4.5.
```

**HINT:** Rebuild all objects affected by this collation and run `ALTER COLLATION pg_catalog."xx-x-icu" REFRESH VERSION`, or build LightDB with the right library version.

A change in collation definitions can lead to corrupt indexes and other problems because the database system relies on stored objects having a certain sort order. Generally, this should be avoided, but it can happen in legitimate circumstances, such as when using `lt_upgrade` to upgrade to server binaries linked with a newer version of ICU. When this happens, all objects depending on the collation should be rebuilt, for example, using `REINDEX`. When that is done, the collation version can be refreshed using the command `ALTER COLLATION ... REFRESH VERSION`. This will update the system catalog to record the current collator version and will make the warning go away. Note that this does not actually check whether all affected objects have been rebuilt correctly.

When using collations provided by `libc` and LightDB was built with the GNU C library, the C library's version is used as a collation version. Since collation definitions typically change only with GNU C library releases, this provides some defense against corruption, but it is not completely reliable.

Currently, there is no version tracking for the database default collation.

The following query can be used to identify all collations in the current database that need to be refreshed and the objects that depend on them:

```
SELECT pg_describe_object(refclassid, refobjid, refobjsubid) AS
    "Collation",
       pg_describe_object(classid, objid, objsubid) AS "Object"
FROM pg_depend d JOIN pg_collation c
    ON refclassid = 'pg_collation'::regclass AND refobjid =
    c.oid
WHERE c.collversion <> pg_collation_actual_version(c.oid)
ORDER BY 1, 2;
```

## Examples

To rename the collation `de_DE` to `german`:

```
ALTER COLLATION "de_DE" RENAME TO german;
```

To change the owner of the collation `en_US` to `joe`:

```
ALTER COLLATION "en_US" OWNER TO joe;
```

## Compatibility

There is no `ALTER COLLATION` statement in the SQL standard.

## See Also

`CREATE COLLATION`, `DROP COLLATION`

---

# ALTER CONVERSION

ALTER CONVERSION — change the definition of a conversion

## Synopsis

```
ALTER CONVERSION name RENAME TO new_name
ALTER CONVERSION name OWNER TO { new_owner | CURRENT_USER |
  SESSION_USER }
ALTER CONVERSION name SET SCHEMA new_schema
```

## Description

ALTER CONVERSION changes the definition of a conversion.

You must own the conversion to use ALTER CONVERSION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the conversion's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the conversion. However, a superuser can alter ownership of any conversion anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing conversion.

*new\_name*

The new name of the conversion.

*new\_owner*

The new owner of the conversion.

*new\_schema*

The new schema for the conversion.

## Examples

To rename the conversion `iso_8859_1_to_utf8` to `latin1_to_unicode`:

```
ALTER CONVERSION iso_8859_1_to_utf8 RENAME TO latin1_to_unicode;
```

To change the owner of the conversion `iso_8859_1_to_utf8` to `joe`:

```
ALTER CONVERSION iso_8859_1_to_utf8 OWNER TO joe;
```

## Compatibility

There is no ALTER CONVERSION statement in the SQL standard.

## **See Also**

CREATE CONVERSION, DROP CONVERSION

---

# ALTER DATABASE

ALTER DATABASE — change a database

## Synopsis

```
ALTER DATABASE name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
ALLOW_CONNECTIONS allowconn  
CONNECTION LIMIT connlimit  
IS_TEMPLATE istemplate
```

```
ALTER DATABASE name RENAME TO new_name
```

```
ALTER DATABASE name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }
```

```
ALTER DATABASE name SET TABLESPACE new_tablespace
```

```
ALTER DATABASE name SET configuration_parameter { TO | = } { value  
| DEFAULT }
```

```
ALTER DATABASE name SET configuration_parameter FROM CURRENT
```

```
ALTER DATABASE name RESET configuration_parameter
```

```
ALTER DATABASE name RESET ALL
```

## Description

ALTER DATABASE changes the attributes of a database.

The first form changes certain per-database settings. (See below for details.) Only the database owner or a superuser can change these settings.

The second form changes the name of the database. Only the database owner or a superuser can rename a database; non-superuser owners must also have the CREATEDB privilege. The current database cannot be renamed. (Connect to a different database if you need to do that.)

The third form changes the owner of the database. To alter the owner, you must own the database and also be a direct or indirect member of the new owning role, and you must have the CREATEDB privilege. (Note that superusers have all these privileges automatically.)

The fourth form changes the default tablespace of the database. Only the database owner or a superuser can do this; you must also have create privilege for the new tablespace. This command physically moves any tables or indexes in the database's old default tablespace to the new tablespace. The new default tablespace must be empty for this database, and no one can be connected to the database. Tables and indexes in non-default tablespaces are unaffected.

The remaining forms change the session default for a run-time configuration variable for a LightDB database. Whenever a new session is subsequently started in that database, the specified value becomes the session default value. The database-specific default overrides whatever setting is present in `lightdb.conf` or has been received from the `lightdb` command line. Only the database owner or a superuser can change the session defaults for a database. Certain variables cannot be set this way, or can only be set by a superuser.

## Parameters

*name*

The name of the database whose attributes are to be altered.

*allowconn*

If false then no one can connect to this database.

*connlimit*

How many concurrent connections can be made to this database. -1 means no limit.

*istemplate*

If true, then this database can be cloned by any user with CREATEDB privileges; if false, then only superusers or the owner of the database can clone it.

*new\_name*

The new name of the database.

*new\_owner*

The new owner of the database.

*new\_tablespace*

The new default tablespace of the database.

This form of the command cannot be executed inside a transaction block.

*configuration\_parameter*

*value*

Set this database's session default for the specified configuration parameter to the given value. If *value* is DEFAULT or, equivalently, RESET is used, the database-specific setting is removed, so the system-wide default setting will be inherited in new sessions. Use RESET ALL to clear all database-specific settings. SET FROM CURRENT saves the session's current value of the parameter as the database-specific value.

See SET and Chapter 17 for more information about allowed parameter names and values.

## Notes

It is also possible to tie a session default to a specific role rather than to a database; see ALTER ROLE. Role-specific settings override database-specific ones if there is a conflict.

## Examples

To disable index scans by default in the database test:

```
ALTER DATABASE test SET enable_indexscan TO off;
```

## Compatibility

The ALTER DATABASE statement is a LightDB extension.



## **See Also**

CREATE DATABASE, DROP DATABASE, SET, CREATE TABLESPACE

---

# ALTER DEFAULT PRIVILEGES

ALTER DEFAULT PRIVILEGES — define default access privileges

## Synopsis

```
ALTER DEFAULT PRIVILEGES
  [ FOR { ROLE | USER } target_role [, ...] ]
  [ IN SCHEMA schema_name [, ...] ]
  abbreviated_grant_or_revoke
```

where *abbreviated\_grant\_or\_revoke* is one of:

```
GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES
  | TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON TABLES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON SEQUENCES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { EXECUTE | ALL [ PRIVILEGES ] }
  ON { FUNCTIONS | ROUTINES }
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON TYPES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { USAGE | CREATE | ALL [ PRIVILEGES ] }
  ON SCHEMAS
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
REVOKE [ GRANT OPTION FOR ]
  { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES |
  TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON TABLES
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
  [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
  { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON SEQUENCES
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
```

```
[ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { EXECUTE | ALL [ PRIVILEGES ] }
ON { FUNCTIONS | ROUTINES }
FROM { [ GROUP ] role_name | PUBLIC } [, ...]
[ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { USAGE | ALL [ PRIVILEGES ] }
ON TYPES
FROM { [ GROUP ] role_name | PUBLIC } [, ...]
[ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { USAGE | CREATE | ALL [ PRIVILEGES ] }
ON SCHEMAS
FROM { [ GROUP ] role_name | PUBLIC } [, ...]
[ CASCADE | RESTRICT ]
```

## Description

ALTER DEFAULT PRIVILEGES allows you to set the privileges that will be applied to objects created in the future. (It does not affect privileges assigned to already-existing objects.) Currently, only the privileges for schemas, tables (including views and foreign tables), sequences, functions, and types (including domains) can be altered. For this command, functions include aggregates and procedures. The words FUNCTIONS and ROUTINES are equivalent in this command. (ROUTINES is preferred going forward as the standard term for functions and procedures taken together. In earlier LightDB releases, only the word FUNCTIONS was allowed. It is not possible to set default privileges for functions and procedures separately.)

You can change default privileges only for objects that will be created by yourself or by roles that you are a member of. The privileges can be set globally (i.e., for all objects created in the current database), or just for objects created in specified schemas.

As explained in Section 5.7, the default privileges for any object type normally grant all grantable permissions to the object owner, and may grant some privileges to PUBLIC as well. However, this behavior can be changed by altering the global default privileges with ALTER DEFAULT PRIVILEGES.

Default privileges that are specified per-schema are added to whatever the global default privileges are for the particular object type. This means you cannot revoke privileges per-schema if they are granted globally (either by default, or according to a previous ALTER DEFAULT PRIVILEGES command that did not specify a schema). Per-schema REVOKE is only useful to reverse the effects of a previous per-schema GRANT.

## Parameters

*target\_role*

The name of an existing role of which the current role is a member. If FOR ROLE is omitted, the current role is assumed.

*schema\_name*

The name of an existing schema. If specified, the default privileges are altered for objects later created in that schema. If IN SCHEMA is omitted, the global default privileges are altered. IN SCHEMA is not allowed when setting privileges for schemas, since schemas can't be nested.

*role\_name*

The name of an existing role to grant or revoke privileges for. This parameter, and all the other parameters in *abbreviated\_grant\_or\_revoke*, act as described under GRANT or REVOKE, except that one is setting permissions for a whole class of objects rather than specific named objects.

## Notes

Use `lsql's \ddp` command to obtain information about existing assignments of default privileges. The meaning of the privilege display is the same as explained for `\dp` in Section 5.7.

If you wish to drop a role for which the default privileges have been altered, it is necessary to reverse the changes in its default privileges or use `DROP OWNED BY` to get rid of the default privileges entry for the role.

## Examples

Grant SELECT privilege to everyone for all tables (and views) you subsequently create in schema `myschema`, and allow role `webuser` to INSERT into them too:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT SELECT ON TABLES
  TO PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT INSERT ON TABLES
  TO webuser;
```

Undo the above, so that subsequently-created tables won't have any more permissions than normal:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE SELECT ON TABLES
  FROM PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE INSERT ON TABLES
  FROM webuser;
```

Remove the public EXECUTE permission that is normally granted on functions, for all functions subsequently created by role `admin`:

```
ALTER DEFAULT PRIVILEGES FOR ROLE admin REVOKE EXECUTE ON FUNCTIONS
  FROM PUBLIC;
```

Note however that you *cannot* accomplish that effect with a command limited to a single schema. This command has no effect, unless it is undoing a matching GRANT:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA public REVOKE EXECUTE ON
  FUNCTIONS FROM PUBLIC;
```

That's because per-schema default privileges can only add privileges to the global setting, not remove privileges granted by it.

## Compatibility

There is no ALTER DEFAULT PRIVILEGES statement in the SQL standard.

## See Also

GRANT, REVOKE

---

# ALTER DOMAIN

ALTER DOMAIN — change the definition of a domain

## Synopsis

```
ALTER DOMAIN name
    { SET DEFAULT expression | DROP DEFAULT }
ALTER DOMAIN name
    { SET | DROP } NOT NULL
ALTER DOMAIN name
    ADD domain_constraint [ NOT VALID ]
ALTER DOMAIN name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
    CASCADE ]
ALTER DOMAIN name
    RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER DOMAIN name
    VALIDATE CONSTRAINT constraint_name
ALTER DOMAIN name
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER DOMAIN name
    RENAME TO new_name
ALTER DOMAIN name
    SET SCHEMA new_schema
```

## Description

ALTER DOMAIN changes the definition of an existing domain. There are several sub-forms:

SET/DROP DEFAULT

These forms set or remove the default value for a domain. Note that defaults only apply to subsequent INSERT commands; they do not affect rows already in a table using the domain.

SET/DROP NOT NULL

These forms change whether a domain is marked to allow NULL values or to reject NULL values. You can only SET NOT NULL when the columns using the domain contain no null values.

ADD *domain\_constraint* [ NOT VALID ]

This form adds a new constraint to a domain using the same syntax as CREATE DOMAIN. When a new constraint is added to a domain, all columns using that domain will be checked against the newly added constraint. These checks can be suppressed by adding the new constraint using the NOT VALID option; the constraint can later be made valid using ALTER DOMAIN ... VALIDATE CONSTRAINT. Newly inserted or updated rows are always checked against all constraints, even those marked NOT VALID. NOT VALID is only accepted for CHECK constraints.

DROP CONSTRAINT [ IF EXISTS ]

This form drops constraints on a domain. If IF EXISTS is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

RENAME CONSTRAINT

This form changes the name of a constraint on a domain.

VALIDATE CONSTRAINT

This form validates a constraint previously added as NOT VALID, that is, it verifies that all values in table columns of the domain type satisfy the specified constraint.

OWNER

This form changes the owner of the domain to the specified user.

RENAME

This form changes the name of the domain.

SET SCHEMA

This form changes the schema of the domain. Any constraints associated with the domain are moved into the new schema as well.

You must own the domain to use ALTER DOMAIN. To change the schema of a domain, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the domain's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the domain. However, a superuser can alter ownership of any domain anyway.)

## Parameters

*name*

The name (possibly schema-qualified) of an existing domain to alter.

*domain\_constraint*

New domain constraint for the domain.

*constraint\_name*

Name of an existing constraint to drop or rename.

NOT VALID

Do not verify existing stored data for constraint validity.

CASCADE

Automatically drop objects that depend on the constraint, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the constraint if there are any dependent objects. This is the default behavior.

*new\_name*

The new name for the domain.

*new\_constraint\_name*

The new name for the constraint.

*new\_owner*

The user name of the new owner of the domain.

*new\_schema*

The new schema for the domain.

## Notes

Although `ALTER DOMAIN ADD CONSTRAINT` attempts to verify that existing stored data satisfies the new constraint, this check is not bulletproof, because the command cannot “see” table rows that are newly inserted or updated and not yet committed. If there is a hazard that concurrent operations might insert bad data, the way to proceed is to add the constraint using the `NOT VALID` option, commit that command, wait until all transactions started before that commit have finished, and then issue `ALTER DOMAIN VALIDATE CONSTRAINT` to search for data violating the constraint. This method is reliable because once the constraint is committed, all new transactions are guaranteed to enforce it against new values of the domain type.

Currently, `ALTER DOMAIN ADD CONSTRAINT`, `ALTER DOMAIN VALIDATE CONSTRAINT`, and `ALTER DOMAIN SET NOT NULL` will fail if the named domain or any derived domain is used within a container-type column (a composite, array, or range column) in any table in the database. They should eventually be improved to be able to verify the new constraint for such nested values.

## Examples

To add a `NOT NULL` constraint to a domain:

```
ALTER DOMAIN zipcode SET NOT NULL;
```

To remove a `NOT NULL` constraint from a domain:

```
ALTER DOMAIN zipcode DROP NOT NULL;
```

To add a check constraint to a domain:

```
ALTER DOMAIN zipcode ADD CONSTRAINT zipchk CHECK  
(char_length(VALUE) = 5);
```

To remove a check constraint from a domain:

```
ALTER DOMAIN zipcode DROP CONSTRAINT zipchk;
```

To rename a check constraint on a domain:

```
ALTER DOMAIN zipcode RENAME CONSTRAINT zipchk TO zip_check;
```

To move the domain into a different schema:

```
ALTER DOMAIN zipcode SET SCHEMA customers;
```

## Compatibility

`ALTER DOMAIN` conforms to the SQL standard, except for the `OWNER`, `RENAME`, `SET SCHEMA`, and `VALIDATE CONSTRAINT` variants, which are LightDB extensions. The `NOT VALID` clause of the `ADD CONSTRAINT` variant is also a LightDB extension.

## See Also

CREATE DOMAIN, DROP DOMAIN



---

# ALTER EVENT TRIGGER

ALTER EVENT TRIGGER — change the definition of an event trigger

## Synopsis

```
ALTER EVENT TRIGGER name DISABLE
ALTER EVENT TRIGGER name ENABLE [ REPLICa | ALWAYS ]
ALTER EVENT TRIGGER name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER EVENT TRIGGER name RENAME TO new_name
```

## Description

ALTER EVENT TRIGGER changes properties of an existing event trigger.

You must be superuser to alter an event trigger.

## Parameters

*name*

The name of an existing trigger to alter.

*new\_owner*

The user name of the new owner of the event trigger.

*new\_name*

The new name of the event trigger.

DISABLE/ENABLE [ REPLICa | ALWAYS ] TRIGGER

These forms configure the firing of event triggers. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. See also `session_replication_role`.

## Compatibility

There is no ALTER EVENT TRIGGER statement in the SQL standard.

## See Also

CREATE EVENT TRIGGER, DROP EVENT TRIGGER

---

# ALTER EXTENSION

ALTER EXTENSION — change the definition of an extension

## Synopsis

```
ALTER EXTENSION name UPDATE [ TO new_version ]
ALTER EXTENSION name SET SCHEMA new_schema
ALTER EXTENSION name ADD member_object
ALTER EXTENSION name DROP member_object
```

where *member\_object* is:

```
ACCESS METHOD object_name |
AGGREGATE aggregate_name ( aggregate_signature ) |
CAST ( source_type AS target_type ) |
COLLATION object_name |
CONVERSION object_name |
DOMAIN object_name |
EVENT TRIGGER object_name |
FOREIGN DATA WRAPPER object_name |
FOREIGN TABLE object_name |
FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
MATERIALIZED VIEW object_name |
OPERATOR operator_name ( left_type , right_type ) |
OPERATOR CLASS object_name USING index_method |
OPERATOR FAMILY object_name USING index_method |
[ PROCEDURAL ] LANGUAGE object_name |
PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
SCHEMA object_name |
SEQUENCE object_name |
SERVER object_name |
TABLE object_name |
TEXT SEARCH CONFIGURATION object_name |
TEXT SEARCH DICTIONARY object_name |
TEXT SEARCH PARSER object_name |
TEXT SEARCH TEMPLATE object_name |
TRANSFORM FOR type_name LANGUAGE lang_name |
TYPE object_name |
VIEW object_name
```

and *aggregate\_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

## Description

ALTER EXTENSION changes the definition of an installed extension. There are several subforms:

### UPDATE

This form updates the extension to a newer version. The extension must supply a suitable update script (or series of scripts) that can modify the currently-installed version into the requested version.

### SET SCHEMA

This form moves the extension's objects into another schema. The extension has to be *relocatable* for this command to succeed.

### ADD *member\_object*

This form adds an existing object to the extension. This is mainly useful in extension update scripts. The object will subsequently be treated as a member of the extension; notably, it can only be dropped by dropping the extension.

### DROP *member\_object*

This form removes a member object from the extension. This is mainly useful in extension update scripts. The object is not dropped, only disassociated from the extension.

See Section 36.17 for more information about these operations.

You must own the extension to use ALTER EXTENSION. The ADD/DROP forms require ownership of the added/dropped object as well.

## Parameters

### *name*

The name of an installed extension.

### *new\_version*

The desired new version of the extension. This can be written as either an identifier or a string literal. If not specified, ALTER EXTENSION UPDATE attempts to update to whatever is shown as the default version in the extension's control file.

### *new\_schema*

The new schema for the extension.

### *object\_name*

### *aggregate\_name*

### *function\_name*

### *operator\_name*

### *procedure\_name*

### *routine\_name*

The name of an object to be added to or removed from the extension. Names of tables, aggregates, domains, foreign tables, functions, operators, operator classes, operator families, procedures, routines, sequences, text search objects, types, and views can be schema-qualified.

### *source\_type*

The name of the source data type of the cast.

*target\_type*

The name of the target data type of the cast.

*argmode*

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER EXTENSION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

*argname*

The name of a function, procedure, or aggregate argument. Note that ALTER EXTENSION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

*argtype*

The data type of a function, procedure, or aggregate argument.

*left\_type*

*right\_type*

The data type(s) of the operator's arguments (optionally schema-qualified). Write NONE for the missing argument of a prefix or postfix operator.

PROCEDURAL

This is a noise word.

*type\_name*

The name of the data type of the transform.

*lang\_name*

The name of the language of the transform.

## Examples

To update the hstore extension to version 2.0:

```
ALTER EXTENSION hstore UPDATE TO '2.0';
```

To change the schema of the hstore extension to utils:

```
ALTER EXTENSION hstore SET SCHEMA utils;
```

To add an existing function to the hstore extension:

```
ALTER EXTENSION hstore ADD FUNCTION populate_record(anyelement,  
hstore);
```

## Compatibility

ALTER EXTENSION is a LightDB extension.

## **See Also**

CREATE EXTENSION, DROP EXTENSION

---

# ALTER FOREIGN DATA WRAPPER

ALTER FOREIGN DATA WRAPPER — change the definition of a foreign-data wrapper

## Synopsis

```
ALTER FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] ) ]
ALTER FOREIGN DATA WRAPPER name OWNER TO { new_owner | CURRENT_USER
| SESSION_USER }
ALTER FOREIGN DATA WRAPPER name RENAME TO new_name
```

## Description

ALTER FOREIGN DATA WRAPPER changes the definition of a foreign-data wrapper. The first form of the command changes the support functions or the generic options of the foreign-data wrapper (at least one clause is required). The second form changes the owner of the foreign-data wrapper.

Only superusers can alter foreign-data wrappers. Additionally, only superusers can own foreign-data wrappers.

## Parameters

*name*

The name of an existing foreign-data wrapper.

HANDLER *handler\_function*

Specifies a new handler function for the foreign-data wrapper.

NO HANDLER

This is used to specify that the foreign-data wrapper should no longer have a handler function.

Note that foreign tables that use a foreign-data wrapper with no handler cannot be accessed.

VALIDATOR *validator\_function*

Specifies a new validator function for the foreign-data wrapper.

Note that it is possible that pre-existing options of the foreign-data wrapper, or of dependent servers, user mappings, or foreign tables, are invalid according to the new validator. LightDB does not check for this. It is up to the user to make sure that these options are correct before using the modified foreign-data wrapper. However, any options specified in this ALTER FOREIGN DATA WRAPPER command will be checked using the new validator.

NO VALIDATOR

This is used to specify that the foreign-data wrapper should no longer have a validator function.

OPTIONS ( [ ADD | SET | DROP ] *option* ['*value*'] [, ... ] )

Change options for the foreign-data wrapper. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the foreign data wrapper's validator function, if any.

*new\_owner*

The user name of the new owner of the foreign-data wrapper.

*new\_name*

The new name for the foreign-data wrapper.

## Examples

Change a foreign-data wrapper `dbi`, add option `foo`, drop `bar`:

```
ALTER FOREIGN DATA WRAPPER dbi OPTIONS (ADD foo '1', DROP 'bar');
```

Change the foreign-data wrapper `dbi` validator to `bob.myvalidator`:

```
ALTER FOREIGN DATA WRAPPER dbi VALIDATOR bob.myvalidator;
```

## Compatibility

`ALTER FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), except that the `HANDLER`, `VALIDATOR`, `OWNER TO`, and `RENAME` clauses are extensions.

## See Also

`CREATE FOREIGN DATA WRAPPER`, `DROP FOREIGN DATA WRAPPER`

---

# ALTER FOREIGN TABLE

ALTER FOREIGN TABLE — change the definition of a foreign table

## Synopsis

```
ALTER FOREIGN TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    action [, ... ]
ALTER FOREIGN TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
```

where *action* is one of:

```
    ADD [ COLUMN ] column_name data_type [ COLLATE collation ]
    [ column_constraint [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT |
CASCADE ]
    ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type
    [ COLLATE collation ]
    ALTER [ COLUMN ] column_name SET DEFAULT expression
    ALTER [ COLUMN ] column_name DROP DEFAULT
    ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value
[, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option
[, ... ] )
    ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
EXTENDED | MAIN }
    ALTER [ COLUMN ] column_name OPTIONS ( [ ADD | SET |
DROP ] option ['value'] [, ... ] )
    ADD table_constraint [ NOT VALID ]
    VALIDATE CONSTRAINT constraint_name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
CASCADE ]
    DISABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE REPLICA TRIGGER trigger_name
    ENABLE ALWAYS TRIGGER trigger_name
    SET WITHOUT OIDS
    INHERIT parent_table
    NO INHERIT parent_table
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
    OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

## Description

ALTER FOREIGN TABLE changes the definition of an existing foreign table. There are several subforms:



## ADD COLUMN

This form adds a new column to the foreign table, using the same syntax as CREATE FOREIGN TABLE. Unlike the case when adding a column to a regular table, nothing happens to the underlying storage: this action simply declares that some new column is now accessible through the foreign table.

## DROP COLUMN [ IF EXISTS ]

This form drops a column from a foreign table. You will need to say CASCADE if anything outside the table depends on the column; for example, views. If IF EXISTS is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

## SET DATA TYPE

This form changes the type of a column of a foreign table. Again, this has no effect on any underlying storage: this action simply changes the type that LightDB believes the column to have.

## SET/DROP DEFAULT

These forms set or remove the default value for a column. Default values only apply in subsequent INSERT or UPDATE commands; they do not cause rows already in the table to change.

## SET/DROP NOT NULL

Mark a column as allowing, or not allowing, null values.

## SET STATISTICS

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations. See the similar form of ALTER TABLE for more details.

SET ( *attribute\_option* = *value* [, ... ] )  
RESET ( *attribute\_option* [, ... ] )

This form sets or resets per-attribute options. See the similar form of ALTER TABLE for more details.

## SET STORAGE

This form sets the storage mode for a column. See the similar form of ALTER TABLE for more details. Note that the storage mode has no effect unless the table's foreign-data wrapper chooses to pay attention to it.

ADD *table\_constraint* [ NOT VALID ]

This form adds a new constraint to a foreign table, using the same syntax as CREATE FOREIGN TABLE. Currently only CHECK constraints are supported.

Unlike the case when adding a constraint to a regular table, nothing is done to verify the constraint is correct; rather, this action simply declares that some new condition should be assumed to hold for all rows in the foreign table. (See the discussion in CREATE FOREIGN TABLE.) If the constraint is marked NOT VALID, then it isn't assumed to hold, but is only recorded for possible future use.

## VALIDATE CONSTRAINT

This form marks as valid a constraint that was previously marked as NOT VALID. No action is taken to verify the constraint, but future queries will assume that it holds.

## DROP CONSTRAINT [ IF EXISTS ]

This form drops the specified constraint on a foreign table. If IF EXISTS is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

DISABLE/ENABLE [ REPLICA | ALWAYS ] TRIGGER

These forms configure the firing of trigger(s) belonging to the foreign table. See the similar form of ALTER TABLE for more details.

SET WITHOUT OIDS

Backward compatibility syntax for removing the `oid` system column. As `oid` system columns cannot be added anymore, this never has an effect.

INHERIT *parent\_table*

This form adds the target foreign table as a new child of the specified parent table. See the similar form of ALTER TABLE for more details.

NO INHERIT *parent\_table*

This form removes the target foreign table from the list of children of the specified parent table.

OWNER

This form changes the owner of the foreign table to the specified user.

OPTIONS ( [ ADD | SET | DROP ] *option* ['*value*'] [, ... ] )

Change options for the foreign table or one of its columns. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name). Option names and values are also validated using the foreign data wrapper library.

RENAME

The RENAME forms change the name of a foreign table or the name of an individual column in a foreign table.

SET SCHEMA

This form moves the foreign table into another schema.

All the actions except RENAME and SET SCHEMA can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several columns and/or alter the type of several columns in a single command.

If the command is written as ALTER FOREIGN TABLE IF EXISTS . . . and the foreign table does not exist, no error is thrown. A notice is issued in this case.

You must own the table to use ALTER FOREIGN TABLE. To change the schema of a foreign table, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type, you must also have USAGE privilege on the data type.

## Parameters

*name*

The name (possibly schema-qualified) of an existing foreign table to alter. If ONLY is specified before the table name, only that table is altered. If ONLY is not specified, the table and all its descendant tables (if any) are altered. Optionally, \* can be specified after the table name to explicitly indicate that descendant tables are included.

*column\_name*

Name of a new or existing column.

*new\_column\_name*

New name for an existing column.

*new\_name*

New name for the table.

*data\_type*

Data type of the new column, or new data type for an existing column.

*table\_constraint*

New table constraint for the foreign table.

*constraint\_name*

Name of an existing constraint to drop.

CASCADE

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

*trigger\_name*

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the foreign table. (This requires superuser privilege if any of the triggers are internally generated triggers. The core system does not add such triggers to foreign tables, but add-on code could do so.)

USER

Disable or enable all triggers belonging to the foreign table except for internally generated triggers.

*parent\_table*

A parent table to associate or de-associate with this foreign table.

*new\_owner*

The user name of the new owner of the table.

*new\_schema*

The name of the schema to which the table will be moved.

## Notes

The key word COLUMN is noise and can be omitted.

Consistency with the foreign server is not checked when a column is added or removed with `ADD COLUMN` or `DROP COLUMN`, a `NOT NULL` or `CHECK` constraint is added, or a column type is changed with `SET DATA TYPE`. It is the user's responsibility to ensure that the table definition matches the remote side.

Refer to `CREATE FOREIGN TABLE` for a further description of valid parameters.

## Examples

To mark a column as not-null:

```
ALTER FOREIGN TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To change options of a foreign table:

```
ALTER FOREIGN TABLE myschema.distributors OPTIONS (ADD opt1
'value', SET opt2 'value2', DROP opt3 'value3');
```

## Compatibility

The forms `ADD`, `DROP`, and `SET DATA TYPE` conform with the SQL standard. The other forms are LightDB extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER FOREIGN TABLE` command is an extension.

`ALTER FOREIGN TABLE DROP COLUMN` can be used to drop the only column of a foreign table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column foreign tables.

## See Also

`CREATE FOREIGN TABLE`, `DROP FOREIGN TABLE`

---

# ALTER FUNCTION

ALTER FUNCTION — change the definition of a function

## Synopsis

```
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    action [ ... ] [ RESTRICT ]
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    RENAME TO new_name
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    SET SCHEMA new_schema
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    [ NO ] DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
    CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
    IMMUTABLE | STABLE | VOLATILE
    [ NOT ] LEAKPROOF
    [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
    PARALLEL { UNSAFE | RESTRICTED | SAFE }
    COST execution_cost
    ROWS result_rows
    SUPPORT support_function
    SET configuration_parameter { TO | = } { value | DEFAULT }
    SET configuration_parameter FROM CURRENT
    RESET configuration_parameter
    RESET ALL
```

## Description

ALTER FUNCTION changes the definition of a function.

You must own the function to use ALTER FUNCTION. To change a function's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the function. However, a superuser can alter ownership of any function anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing function. If no argument list is specified, the name must be unique in its schema.

*argmode*

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

*argname*

The name of an argument. Note that ALTER FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

*argtype*

The data type(s) of the function's arguments (optionally schema-qualified), if any.

*new\_name*

The new name of the function.

*new\_owner*

The new owner of the function. Note that if the function is marked SECURITY DEFINER, it will subsequently execute as the new owner.

*new\_schema*

The new schema for the function.

DEPENDS ON EXTENSION *extension\_name*

NO DEPENDS ON EXTENSION *extension\_name*

This form marks the function as dependent on the extension, or no longer dependent on that extension if NO is specified. A function that's marked as dependent on an extension is dropped when the extension is dropped, even if CASCADE is not specified. A function can depend upon multiple extensions, and will be dropped when any one of those extensions is dropped.

CALLED ON NULL INPUT

RETURNS NULL ON NULL INPUT

STRICT

CALLED ON NULL INPUT changes the function so that it will be invoked when some or all of its arguments are null. RETURNS NULL ON NULL INPUT or STRICT changes the function so that it is not invoked if any of its arguments are null; instead, a null result is assumed automatically. See CREATE FUNCTION for more information.

IMMUTABLE

STABLE

VOLATILE

Change the volatility of the function to the specified setting. See CREATE FUNCTION for details.

[ EXTERNAL ] SECURITY INVOKER

[ EXTERNAL ] SECURITY DEFINER

Change whether the function is a security definer or not. The key word EXTERNAL is ignored for SQL conformance. See CREATE FUNCTION for more information about this capability.

PARALLEL

Change whether the function is deemed safe for parallelism. See CREATE FUNCTION for details.

**LEAKPROOF**

Change whether the function is considered leakproof or not. See `CREATE FUNCTION` for more information about this capability.

**COST** *execution\_cost*

Change the estimated execution cost of the function. See `CREATE FUNCTION` for more information.

**ROWS** *result\_rows*

Change the estimated number of rows returned by a set-returning function. See `CREATE FUNCTION` for more information.

**SUPPORT** *support\_function*

Set or change the planner support function to use for this function. See Section 36.11 for details. You must be superuser to use this option.

This option cannot be used to remove the support function altogether, since it must name a new support function. Use `CREATE OR REPLACE FUNCTION` if you need to do that.

*configuration\_parameter  
value*

Add or change the assignment to be made to a configuration parameter when the function is called. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the function-local setting is removed, so that the function executes with the value present in its environment. Use `RESET ALL` to clear all function-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER FUNCTION` is executed as the value to be applied when the function is entered.

See `SET` and Chapter 17 for more information about allowed parameter names and values.

**RESTRICT**

Ignored for conformance with the SQL standard.

## Examples

To rename the function `sqrt` for type `integer` to `square_root`:

```
ALTER FUNCTION sqrt(integer) RENAME TO square_root;
```

To change the owner of the function `sqrt` for type `integer` to `joe`:

```
ALTER FUNCTION sqrt(integer) OWNER TO joe;
```

To change the schema of the function `sqrt` for type `integer` to `maths`:

```
ALTER FUNCTION sqrt(integer) SET SCHEMA maths;
```

To mark the function `sqrt` for type `integer` as being dependent on the extension `mathlib`:

```
ALTER FUNCTION sqrt(integer) DEPENDS ON EXTENSION mathlib;
```

To adjust the search path that is automatically set for a function:

```
ALTER FUNCTION check_password(text) SET search_path = admin,  
pg_temp;
```

To disable automatic setting of `search_path` for a function:

```
ALTER FUNCTION check_password(text) RESET search_path;
```

The function will now execute with whatever search path is used by its caller.

## Compatibility

This statement is partially compatible with the `ALTER FUNCTION` statement in the SQL standard. The standard allows more properties of a function to be modified, but does not provide the ability to rename a function, make a function a security definer, attach configuration parameter values to a function, or change the owner, schema, or volatility of a function. The standard also requires the `RESTRICT` key word, which is optional in LightDB.

## See Also

`CREATE FUNCTION`, `DROP FUNCTION`, `ALTER PROCEDURE`, `ALTER ROUTINE`



---

# ALTER GROUP

ALTER GROUP — change role name or membership

## Synopsis

```
ALTER GROUP role_specification ADD USER user_name [, ... ]
ALTER GROUP role_specification DROP USER user_name [, ... ]
```

where *role\_specification* can be:

```
    role_name
  | CURRENT_USER
  | SESSION_USER
```

```
ALTER GROUP group_name RENAME TO new_name
```

## Description

ALTER GROUP changes the attributes of a user group. This is an obsolete command, though still accepted for backwards compatibility, because groups (and users too) have been superseded by the more general concept of roles.

The first two variants add users to a group or remove them from a group. (Any role can play the part of either a “user” or a “group” for this purpose.) These variants are effectively equivalent to granting or revoking membership in the role named as the “group”; so the preferred way to do this is to use GRANT or REVOKE.

The third variant changes the name of the group. This is exactly equivalent to renaming the role with ALTER ROLE.

## Parameters

*group\_name*

The name of the group (role) to modify.

*user\_name*

Users (roles) that are to be added to or removed from the group. The users must already exist; ALTER GROUP does not create or drop users.

*new\_name*

The new name of the group.

## Examples

Add users to a group:

```
ALTER GROUP staff ADD USER karl, john;
```

Remove a user from a group:

```
ALTER GROUP workers DROP USER beth;
```

## Compatibility

There is no `ALTER GROUP` statement in the SQL standard.

## See Also

GRANT, REVOKE, ALTER ROLE

---

# ALTER INDEX

ALTER INDEX — change the definition of an index

## Synopsis

```
ALTER INDEX [ IF EXISTS ] name RENAME TO [ schema_name. ] new_name
ALTER INDEX [ IF EXISTS ] name SET TABLESPACE tablespace_name
ALTER INDEX name ATTACH PARTITION index_name
ALTER INDEX name [ NO ] DEPENDS ON EXTENSION extension_name
ALTER INDEX [ IF EXISTS ] name SET ( storage_parameter [= value]
    [ , ... ] )
ALTER INDEX [ IF EXISTS ] name RESET ( storage_parameter [ , ... ] )
ALTER INDEX [ IF EXISTS ] name ALTER [ COLUMN ] column_number
    SET STATISTICS integer
ALTER INDEX ALL IN TABLESPACE name [ OWNED BY role_name [ , ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
ALTER INDEX [ IF EXISTS ] index_name REBUILD
```

## Description

ALTER INDEX changes the definition of an existing index. There are several subforms described below. Note that the lock level required may differ for each subform. An ACCESS EXCLUSIVE lock is held unless explicitly noted. When multiple subcommands are listed, the lock held will be the strictest one required from any subcommand. ALTER INDEX *index\_name* REBUILD is analogous to REINDEX *index name*, this syntax feature is included since LightDB 23.2 for oracle compatibility.

### RENAME

The RENAME form changes the name of the index. If the index is associated with a table constraint (either UNIQUE, PRIMARY KEY, or EXCLUDE), the constraint is renamed as well. There is no effect on the stored data.

Renaming an index acquires a SHARE UPDATE EXCLUSIVE lock.

### SET TABLESPACE

This form changes the index's tablespace to the specified tablespace and moves the data file(s) associated with the index to the new tablespace. To change the tablespace of an index, you must own the index and have CREATE privilege on the new tablespace. All indexes in the current database in a tablespace can be moved by using the ALL IN TABLESPACE form, which will lock all indexes to be moved and then move each one. This form also supports OWNED BY, which will only move indexes owned by the roles specified. If the NOWAIT option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs will not be moved by this command, use ALTER DATABASE or explicit ALTER INDEX invocations instead if desired. See also CREATE TABLESPACE.

### ATTACH PARTITION

Causes the named index to become attached to the altered index. The named index must be on a partition of the table containing the index being altered, and have an equivalent definition. An attached index cannot be dropped by itself, and will automatically be dropped if its parent index is dropped.

DEPENDS ON EXTENSION *extension\_name*  
NO DEPENDS ON EXTENSION *extension\_name*

This form marks the index as dependent on the extension, or no longer dependent on that extension if NO is specified. An index that's marked as dependent on an extension is automatically dropped when the extension is dropped.

SET ( *storage\_parameter* [= *value*] [, ... ] )

This form changes one or more index-method-specific storage parameters for the index. See CREATE INDEX for details on the available parameters. Note that the index contents will not be modified immediately by this command; depending on the parameter you might need to rebuild the index with REINDEX to get the desired effects.

RESET ( *storage\_parameter* [, ... ] )

This form resets one or more index-method-specific storage parameters to their defaults. As with SET, a REINDEX might be needed to update the index entirely.

ALTER [ COLUMN ] *column\_number* SET STATISTICS *integer*

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations, though can be used only on index columns that are defined as an expression. Since expressions lack a unique name, we refer to them using the ordinal number of the index column. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the system default statistics target (*default\_statistics\_target*). For more information on the use of statistics by the LightDB query planner, refer to Section 14.2.

REBUILD

The REBUILD rebuilds an index using the data stored in the index's table .

## Parameters

IF EXISTS

Do not throw an error if the index does not exist. A notice is issued in this case.

*column\_number*

The ordinal number refers to the ordinal (left-to-right) position of the index column.

*name*

The name (possibly schema-qualified) of an existing index to alter.

*new\_name*

The new name for the index.

*schema\_name*

Starting from LightDB 23.2, the new index name of the ALTER INDEX RENAME TO statement supports specifying the schema name to be compatible with Oracle database syntax. This function is just a syntactic sugar, there is no specific function implementation.

*tablespace\_name*

The tablespace to which the index will be moved.

*extension\_name*

The name of the extension that the index is to depend on.

*storage\_parameter*

The name of an index-method-specific storage parameter.

*value*

The new value for an index-method-specific storage parameter. This might be a number or a word depending on the parameter.

*index\_name*

The name of the index to REBUILD.

## Notes

These operations are also possible using ALTER TABLE. ALTER INDEX is in fact just an alias for the forms of ALTER TABLE that apply to indexes.

There was formerly an ALTER INDEX OWNER variant, but this is now ignored (with a warning). An index cannot have an owner different from its table's owner. Changing the table's owner automatically changes the index as well.

Changing any part of a system catalog index is not permitted.

## Examples

To rename an existing index:

```
ALTER INDEX distributors RENAME TO suppliers;
```

To move an index to a different tablespace:

```
ALTER INDEX distributors SET TABLESPACE fasttablespace;
```

To change an index's fill factor (assuming that the index method supports it):

```
ALTER INDEX distributors SET (fillfactor = 75);  
REINDEX INDEX distributors;
```

Set the statistics-gathering target for an expression index:

```
CREATE INDEX coord_idx ON measured (x, y, (z + t));  
ALTER INDEX coord_idx ALTER COLUMN 3 SET STATISTICS 1000;
```

Index is renamed to a new name, which uses the schema prefix.

```
create table t1(id int);  
create index hahaha.index_t1_id on t1(id);  
alter index index_t1_id rename to xxww.index_t1_id_1;
```

Rebuilds an index:

```
create table t1(id int);  
create index idx_t1_id on t1(id);
```

```
ALTER INDEX idx_t1_id REBUILD;
```

## Compatibility

ALTER INDEX is a LightDB extension.

## See Also

CREATE INDEX, REINDEX

---

# ALTER LANGUAGE

ALTER LANGUAGE — change the definition of a procedural language

## Synopsis

```
ALTER [ PROCEDURAL ] LANGUAGE name RENAME TO new_name
ALTER [ PROCEDURAL ] LANGUAGE name OWNER TO { new_owner |
CURRENT_USER | SESSION_USER }
```

## Description

ALTER LANGUAGE changes the definition of a procedural language. The only functionality is to rename the language or assign a new owner. You must be superuser or owner of the language to use ALTER LANGUAGE.

## Parameters

*name*

Name of a language

*new\_name*

The new name of the language

*new\_owner*

The new owner of the language

## Compatibility

There is no ALTER LANGUAGE statement in the SQL standard.

## See Also

CREATE LANGUAGE, DROP LANGUAGE

---

# ALTER LARGE OBJECT

ALTER LARGE OBJECT — change the definition of a large object

## Synopsis

```
ALTER LARGE OBJECT large_object_oid OWNER TO { new_owner |  
CURRENT_USER | SESSION_USER }
```

## Description

ALTER LARGE OBJECT changes the definition of a large object.

You must own the large object to use ALTER LARGE OBJECT. To alter the owner, you must also be a direct or indirect member of the new owning role. (However, a superuser can alter any large object anyway.) Currently, the only functionality is to assign a new owner, so both restrictions always apply.

## Parameters

*large\_object\_oid*

OID of the large object to be altered

*new\_owner*

The new owner of the large object

## Compatibility

There is no ALTER LARGE OBJECT statement in the SQL standard.

## See Also

Chapter 33



---

# ALTER MATERIALIZED VIEW

ALTER MATERIALIZED VIEW — change the definition of a materialized view

## Synopsis

```
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    action [, ... ]
ALTER MATERIALIZED VIEW name
    [ NO ] DEPENDS ON EXTENSION extension_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME TO new_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER MATERIALIZED VIEW ALL IN TABLESPACE name [ OWNED BY role_name
    [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
```

where *action* is one of:

```
ALTER [ COLUMN ] column_name SET STATISTICS integer
ALTER [ COLUMN ] column_name SET ( attribute_option = value
    [, ... ] )
ALTER [ COLUMN ] column_name RESET ( attribute_option
    [, ... ] )
ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
EXTENDED | MAIN }
CLUSTER ON index_name
SET WITHOUT CLUSTER
SET TABLESPACE new_tablespace
SET ( storage_parameter [= value] [, ... ] )
RESET ( storage_parameter [, ... ] )
OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

## Description

ALTER MATERIALIZED VIEW changes various auxiliary properties of an existing materialized view.

You must own the materialized view to use ALTER MATERIALIZED VIEW. To change a materialized view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the materialized view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the materialized view. However, a superuser can alter ownership of any view anyway.)

The statement subforms and actions available for ALTER MATERIALIZED VIEW are a subset of those available for ALTER TABLE, and have the same meaning when used for materialized views. See the descriptions for ALTER TABLE for details.

## Parameters

*name*

The name (optionally schema-qualified) of an existing materialized view.

*column\_name*

Name of a new or existing column.

*extension\_name*

The name of the extension that the materialized view is to depend on (or no longer dependent on, if NO is specified). A materialized view that's marked as dependent on an extension is automatically dropped when the extension is dropped.

*new\_column\_name*

New name for an existing column.

*new\_owner*

The user name of the new owner of the materialized view.

*new\_name*

The new name for the materialized view.

*new\_schema*

The new schema for the materialized view.

## Examples

To rename the materialized view `foo` to `bar`:

```
ALTER MATERIALIZED VIEW foo RENAME TO bar;
```

## Compatibility

ALTER MATERIALIZED VIEW is a LightDB extension.

## See Also

CREATE MATERIALIZED VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

---

# ALTER OPERATOR

ALTER OPERATOR — change the definition of an operator

## Synopsis

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    SET SCHEMA new_schema
```

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    SET ( { RESTRICT = { res_proc | NONE }  
          | JOIN = { join_proc | NONE }  
          } [ , ... ] )
```

## Description

ALTER OPERATOR changes the definition of an operator.

You must own the operator to use ALTER OPERATOR. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator. However, a superuser can alter ownership of any operator anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing operator.

*left\_type*

The data type of the operator's left operand; write NONE if the operator has no left operand.

*right\_type*

The data type of the operator's right operand; write NONE if the operator has no right operand.

*new\_owner*

The new owner of the operator.

*new\_schema*

The new schema for the operator.

*res\_proc*

The restriction selectivity estimator function for this operator; write NONE to remove existing selectivity estimator.

*join\_proc*

The join selectivity estimator function for this operator; write NONE to remove existing selectivity estimator.

## Examples

Change the owner of a custom operator a @@ b for type text:

```
ALTER OPERATOR @@ (text, text) OWNER TO joe;
```

Change the restriction and join selectivity estimator functions of a custom operator a && b for type int[]:

```
ALTER OPERATOR && (_int4, _int4) SET (RESTRICT = _int_contsel, JOIN  
= _int_contjoinssel);
```

## Compatibility

There is no ALTER OPERATOR statement in the SQL standard.

## See Also

CREATE OPERATOR, DROP OPERATOR

---

# ALTER OPERATOR CLASS

ALTER OPERATOR CLASS — change the definition of an operator class

## Synopsis

```
ALTER OPERATOR CLASS name USING index_method
    RENAME TO new_name
```

```
ALTER OPERATOR CLASS name USING index_method
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

```
ALTER OPERATOR CLASS name USING index_method
    SET SCHEMA new_schema
```

## Description

ALTER OPERATOR CLASS changes the definition of an operator class.

You must own the operator class to use ALTER OPERATOR CLASS. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator class's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator class. However, a superuser can alter ownership of any operator class anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing operator class.

*index\_method*

The name of the index method this operator class is for.

*new\_name*

The new name of the operator class.

*new\_owner*

The new owner of the operator class.

*new\_schema*

The new schema for the operator class.

## Compatibility

There is no ALTER OPERATOR CLASS statement in the SQL standard.

## See Also

CREATE OPERATOR CLASS, DROP OPERATOR CLASS, ALTER OPERATOR FAMILY

---

# ALTER OPERATOR FAMILY

ALTER OPERATOR FAMILY — change the definition of an operator family

## Synopsis

```
ALTER OPERATOR FAMILY name USING index_method ADD
{ OPERATOR strategy_number operator_name ( op_type, op_type )
  [ FOR SEARCH | FOR ORDER BY sort_family_name ]
| FUNCTION support_number [ ( op_type [ , op_type ] ) ]
  function_name [ ( argument_type [ , ... ] ) ]
} [, ... ]

ALTER OPERATOR FAMILY name USING index_method DROP
{ OPERATOR strategy_number ( op_type [ , op_type ] )
| FUNCTION support_number ( op_type [ , op_type ] )
} [, ... ]

ALTER OPERATOR FAMILY name USING index_method
  RENAME TO new_name

ALTER OPERATOR FAMILY name USING index_method
  OWNER TO { new_owner | CURRENT_USER | SESSION_USER }

ALTER OPERATOR FAMILY name USING index_method
  SET SCHEMA new_schema
```

## Description

ALTER OPERATOR FAMILY changes the definition of an operator family. You can add operators and support functions to the family, remove them from the family, or change the family's name or owner.

When operators and support functions are added to a family with ALTER OPERATOR FAMILY, they are not part of any specific operator class within the family, but are just “loose” within the family. This indicates that these operators and functions are compatible with the family's semantics, but are not required for correct functioning of any specific index. (Operators and functions that are so required should be declared as part of an operator class, instead; see CREATE OPERATOR CLASS.) LightDB will allow loose members of a family to be dropped from the family at any time, but members of an operator class cannot be dropped without dropping the whole class and any indexes that depend on it. Typically, single-data-type operators and functions are part of operator classes because they are needed to support an index on that specific data type, while cross-data-type operators and functions are made loose members of the family.

You must be a superuser to use ALTER OPERATOR FAMILY. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

ALTER OPERATOR FAMILY does not presently check whether the operator family definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator family.

Refer to Section 36.16 for further information.

## Parameters

*name*

The name (optionally schema-qualified) of an existing operator family.

*index\_method*

The name of the index method this operator family is for.

*strategy\_number*

The index method's strategy number for an operator associated with the operator family.

*operator\_name*

The name (optionally schema-qualified) of an operator associated with the operator family.

*op\_type*

In an `OPERATOR` clause, the operand data type(s) of the operator, or `NONE` to signify a left-unary or right-unary operator. Unlike the comparable syntax in `CREATE OPERATOR CLASS`, the operand data types must always be specified.

In an `ADD FUNCTION` clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function. For B-tree comparison functions and hash functions it is not necessary to specify *op\_type* since the function's input data type(s) are always the correct ones to use. For B-tree sort support functions, B-Tree equal image functions, and all functions in GiST and GIN operator classes, it is necessary to specify the operand data type(s) the function is to be used with.

In a `DROP FUNCTION` clause, the operand data type(s) the function is intended to support must be specified.

*sort\_family\_name*

The name (optionally schema-qualified) of an existing `btree` operator family that describes the sort ordering associated with an ordering operator.

If neither `FOR SEARCH` nor `FOR ORDER BY` is specified, `FOR SEARCH` is the default.

*support\_number*

The index method's support function number for a function associated with the operator family.

*function\_name*

The name (optionally schema-qualified) of a function that is an index method support function for the operator family. If no argument list is specified, the name must be unique in its schema.

*argument\_type*

The parameter data type(s) of the function.

*new\_name*

The new name of the operator family.

*new\_owner*

The new owner of the operator family.

*new\_schema*

The new schema for the operator family.

The OPERATOR and FUNCTION clauses can appear in any order.

## Notes

Notice that the DROP syntax only specifies the “slot” in the operator family, by strategy or support number and input data type(s). The name of the operator or function occupying the slot is not mentioned. Also, for DROP FUNCTION the type(s) to specify are the input data type(s) the function is intended to support; for GiST and GIN indexes this might have nothing to do with the actual input argument types of the function.

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator family is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator family.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before LightDB 8.4, the OPERATOR clause could include a RECHECK option. This is no longer supported because whether an index operator is “lossy” is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

## Examples

The following example command adds cross-data-type operators and support functions to an operator family that already contains B-tree operator classes for data types `int4` and `int2`.

```
ALTER OPERATOR FAMILY integer_ops USING btree ADD
```

```
-- int4 vs int2
OPERATOR 1 < (int4, int2) ,
OPERATOR 2 <= (int4, int2) ,
OPERATOR 3 = (int4, int2) ,
OPERATOR 4 >= (int4, int2) ,
OPERATOR 5 > (int4, int2) ,
FUNCTION 1 btint42cmp(int4, int2) ,
```

```
-- int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ;
```

To remove these entries again:

```
ALTER OPERATOR FAMILY integer_ops USING btree DROP
```

```
-- int4 vs int2
OPERATOR 1 (int4, int2) ,
OPERATOR 2 (int4, int2) ,
OPERATOR 3 (int4, int2) ,
```



```
OPERATOR 4 (int4, int2) ,
OPERATOR 5 (int4, int2) ,
FUNCTION 1 (int4, int2) ,

-- int2 vs int4
OPERATOR 1 (int2, int4) ,
OPERATOR 2 (int2, int4) ,
OPERATOR 3 (int2, int4) ,
OPERATOR 4 (int2, int4) ,
OPERATOR 5 (int2, int4) ,
FUNCTION 1 (int2, int4) ;
```

## Compatibility

There is no `ALTER OPERATOR FAMILY` statement in the SQL standard.

## See Also

`CREATE OPERATOR FAMILY`, `DROP OPERATOR FAMILY`, `CREATE OPERATOR CLASS`,  
`ALTER OPERATOR CLASS`, `DROP OPERATOR CLASS`

---

# ALTER POLICY

ALTER POLICY — change the definition of a row level security policy

## Synopsis

```
ALTER POLICY name ON table_name RENAME TO new_name

ALTER POLICY name ON table_name
    [ TO { role_name | PUBLIC | CURRENT_USER | SESSION_USER }
    [ , ... ] ]
    [ USING ( using_expression ) ]
    [ WITH CHECK ( check_expression ) ]
```

## Description

ALTER POLICY changes the definition of an existing row-level security policy. Note that ALTER POLICY only allows the set of roles to which the policy applies and the USING and WITH CHECK expressions to be modified. To change other properties of a policy, such as the command to which it applies or whether it is permissive or restrictive, the policy must be dropped and recreated.

To use ALTER POLICY, you must own the table that the policy applies to.

In the second form of ALTER POLICY, the role list, *using\_expression*, and *check\_expression* are replaced independently if specified. When one of those clauses is omitted, the corresponding part of the policy is unchanged.

## Parameters

*name*

The name of an existing policy to alter.

*table\_name*

The name (optionally schema-qualified) of the table that the policy is on.

*new\_name*

The new name for the policy.

*role\_name*

The role(s) to which the policy applies. Multiple roles can be specified at one time. To apply the policy to all roles, use PUBLIC.

*using\_expression*

The USING expression for the policy. See CREATE POLICY for details.

*check\_expression*

The WITH CHECK expression for the policy. See CREATE POLICY for details.

## Compatibility

ALTER POLICY is a LightDB extension.

## **See Also**

CREATE POLICY, DROP POLICY

---

# ALTER PROCEDURE

ALTER PROCEDURE — change the definition of a procedure

## Synopsis

```
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    action [ ... ] [ RESTRICT ]
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    RENAME TO new_name
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    SET SCHEMA new_schema
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
    [, ...] ] ) ]
    [ NO ] DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
SET configuration_parameter { TO | = } { value | DEFAULT }
SET configuration_parameter FROM CURRENT
RESET configuration_parameter
RESET ALL
```

## Description

ALTER PROCEDURE changes the definition of a procedure.

You must own the procedure to use ALTER PROCEDURE. To change a procedure's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the procedure's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the procedure. However, a superuser can alter ownership of any procedure anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

*argmode*

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

*argname*

The name of an argument. Note that `ALTER PROCEDURE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the procedure's identity.

*argtype*

The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

*new\_name*

The new name of the procedure.

*new\_owner*

The new owner of the procedure. Note that if the procedure is marked `SECURITY DEFINER`, it will subsequently execute as the new owner.

*new\_schema*

The new schema for the procedure.

*extension\_name*

This form marks the procedure as dependent on the extension, or no longer dependent on the extension if `NO` is specified. A procedure that's marked as dependent on an extension is dropped when the extension is dropped, even if `cascade` is not specified. A procedure can depend upon multiple extensions, and will be dropped when any one of those extensions is dropped.

[ `EXTERNAL` ] `SECURITY INVOKER`

[ `EXTERNAL` ] `SECURITY DEFINER`

Change whether the procedure is a security definer or not. The key word `EXTERNAL` is ignored for SQL conformance. See `CREATE PROCEDURE` for more information about this capability.

*configuration\_parameter*  
*value*

Add or change the assignment to be made to a configuration parameter when the procedure is called. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the procedure-local setting is removed, so that the procedure executes with the value present in its environment. Use `RESET ALL` to clear all procedure-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER PROCEDURE` is executed as the value to be applied when the procedure is entered.

See `SET` and Chapter 17 for more information about allowed parameter names and values.

`RESTRICT`

Ignored for conformance with the SQL standard.

## Examples

To rename the procedure `insert_data` with two arguments of type `integer` to `insert_record`:

```
ALTER PROCEDURE insert_data(integer, integer) RENAME TO
insert_record;
```

To change the owner of the procedure `insert_data` with two arguments of type `integer` to `joe`:

```
ALTER PROCEDURE insert_data(integer, integer) OWNER TO joe;
```

To change the schema of the procedure `insert_data` with two arguments of type `integer` to `accounting`:

```
ALTER PROCEDURE insert_data(integer, integer) SET SCHEMA
accounting;
```

To mark the procedure `insert_data(integer, integer)` as being dependent on the extension `myext`:

```
ALTER PROCEDURE insert_data(integer, integer) DEPENDS ON EXTENSION
myext;
```

To adjust the search path that is automatically set for a procedure:

```
ALTER PROCEDURE check_password(text) SET search_path = admin,
pg_temp;
```

To disable automatic setting of `search_path` for a procedure:

```
ALTER PROCEDURE check_password(text) RESET search_path;
```

The procedure will now execute with whatever search path is used by its caller.

## Compatibility

This statement is partially compatible with the `ALTER PROCEDURE` statement in the SQL standard. The standard allows more properties of a procedure to be modified, but does not provide the ability to rename a procedure, make a procedure a security definer, attach configuration parameter values to a procedure, or change the owner, schema, or volatility of a procedure. The standard also requires the `RESTRICT` key word, which is optional in LightDB.

## See Also

`CREATE PROCEDURE`, `DROP PROCEDURE`, `ALTER FUNCTION`, `ALTER ROUTINE`

---

# ALTER PUBLICATION

ALTER PUBLICATION — change the definition of a publication

## Synopsis

```
ALTER PUBLICATION name ADD TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name SET TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name DROP TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name SET ( publication_parameter [= value]
    [, ... ] )
ALTER PUBLICATION name OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER PUBLICATION name RENAME TO new_name
```

## Description

The command ALTER PUBLICATION can change the attributes of a publication.

The first three variants change which tables are part of the publication. The SET TABLE clause will replace the list of tables in the publication with the specified one. The ADD TABLE and DROP TABLE clauses will add and remove one or more tables from the publication. Note that adding tables to a publication that is already subscribed to will require a ALTER SUBSCRIPTION ... REFRESH PUBLICATION action on the subscribing side in order to become effective.

The fourth variant of this command listed in the synopsis can change all of the publication properties specified in CREATE PUBLICATION. Properties not mentioned in the command retain their previous settings.

The remaining variants change the owner and the name of the publication.

You must own the publication to use ALTER PUBLICATION. Adding a table to a publication additionally requires owning that table. To alter the owner, you must also be a direct or indirect member of the new owning role. The new owner must have CREATE privilege on the database. Also, the new owner of a FOR ALL TABLES publication must be a superuser. However, a superuser can change the ownership of a publication regardless of these restrictions.

## Parameters

*name*

The name of an existing publication whose definition is to be altered.

*table\_name*

Name of an existing table. If ONLY is specified before the table name, only that table is affected. If ONLY is not specified, the table and all its descendant tables (if any) are affected. Optionally, \* can be specified after the table name to explicitly indicate that descendant tables are included.

SET ( *publication\_parameter* [= *value*] [, ... ] )

This clause alters publication parameters originally set by CREATE PUBLICATION. See there for more information.

*new\_owner*

The user name of the new owner of the publication.

*new\_name*

The new name for the publication.

## Examples

Change the publication to publish only deletes and updates:

```
ALTER PUBLICATION noinsert SET (publish = 'update, delete');
```

Add some tables to the publication:

```
ALTER PUBLICATION mypublication ADD TABLE users, departments;
```

## Compatibility

ALTER PUBLICATION is a LightDB extension.

## See Also

CREATE PUBLICATION, DROP PUBLICATION, CREATE SUBSCRIPTION, ALTER SUBSCRIPTION



---

# ALTER ROLE

ALTER ROLE — change a database role

## Synopsis

```
ALTER ROLE role_specification [ WITH ] option [ ... ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER
    |
    CREATEDB | NOCREATEDB
    |
    CREATEROLE | NOCREATEROLE
    |
    INHERIT | NOINHERIT
    |
    LOGIN | NOLOGIN
    |
    REPLICATION | NOREPLICATION
    |
    BYPASSRLS | NOBYPASSRLS
    |
    CONNECTION LIMIT connlimit
    |
    [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL
    |
    VALID UNTIL 'timestamp'
```

```
ALTER ROLE name RENAME TO new_name
```

```
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter { TO | = } { value | DEFAULT }
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter FROM CURRENT
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name
] RESET configuration_parameter
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name
] RESET ALL
```

where *role\_specification* can be:

```
    role_name
    |
    CURRENT_USER
    |
    SESSION_USER
```

## Description

ALTER ROLE changes the attributes of a LightDB role.

The first variant of this command listed in the synopsis can change many of the role attributes that can be specified in CREATE ROLE. (All the possible attributes are covered, except that there are no options for adding or removing memberships; use GRANT and REVOKE for that.) Attributes not mentioned in the command retain their previous settings. Database superusers can change any of these settings for any role. Roles having CREATEROLE privilege can change any of these settings except SUPERUSER, REPLICATION, and BYPASSRLS; but only for non-superuser and non-replication roles. Ordinary roles can only change their own password.

The second variant changes the name of the role. Database superusers can rename any role. Roles having CREATEROLE privilege can rename non-superuser roles. The current session user cannot be renamed. (Connect as a different user if you need to do that.) Because MD5-encrypted passwords use the role name as cryptographic salt, renaming a role clears its password if the password is MD5-encrypted.

The remaining variants change a role's session default for a configuration variable, either for all databases or, when the `IN DATABASE` clause is specified, only for sessions in the named database. If `ALL` is specified instead of a role name, this changes the setting for all roles. Using `ALL` with `IN DATABASE` is effectively the same as using the command `ALTER DATABASE ... SET ...`.

Whenever the role subsequently starts a new session, the specified value becomes the session default, overriding whatever setting is present in `lightdb.conf` or has been received from the `lightdb` command line. This only happens at login time; executing `SET ROLE` or `SET SESSION AUTHORIZATION` does not cause new configuration values to be set. Settings set for all databases are overridden by database-specific settings attached to a role. Settings for specific databases or specific roles override settings for all roles.

Superusers can change anyone's session defaults. Roles having `CREATEROLE` privilege can change defaults for non-superuser roles. Ordinary roles can only set defaults for themselves. Certain configuration variables cannot be set this way, or can only be set if a superuser issues the command. Only superusers can change a setting for all roles in all databases.

## Parameters

*name*

The name of the role whose attributes are to be altered.

`CURRENT_USER`

Alter the current user instead of an explicitly identified role.

`SESSION_USER`

Alter the current session user instead of an explicitly identified role.

`SUPERUSER`

`NOSUPERUSER`

`CREATEDB`

`NOCREATEDB`

`CREATEROLE`

`NOCREATEROLE`

`INHERIT`

`NOINHERIT`

`LOGIN`

`NOLOGIN`

`REPLICATION`

`NOREPLICATION`

`BYPASSRLS`

`NOBYPASSRLS`

`CONNECTION LIMIT` *conlimit*

[ `ENCRYPTED` ] `PASSWORD` '*password*'

`PASSWORD NULL`

`VALID UNTIL` '*timestamp*'

These clauses alter attributes originally set by `CREATE ROLE`. For more information, see the `CREATE ROLE` reference page.

*new\_name*

The new name of the role.

*database\_name*

The name of the database the configuration variable should be set in.

*configuration\_parameter*  
*value*

Set this role's session default for the specified configuration parameter to the given value. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the role-specific variable setting is removed, so the role will inherit the system-wide default setting in new sessions. Use `RESET ALL` to clear all role-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter as the role-specific value. If `IN DATABASE` is specified, the configuration parameter is set or removed for the given role and database only.

Role-specific variable settings take effect only at login; `SET ROLE` and `SET SESSION AUTHORIZATION` do not process role-specific variable settings.

See `SET` and Chapter 17 for more information about allowed parameter names and values.

## Notes

Use `CREATE ROLE` to add new roles, and `DROP ROLE` to remove a role.

`ALTER ROLE` cannot change a role's memberships. Use `GRANT` and `REVOKE` to do that.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. `Itsql` contains a command `\password` that can be used to change a role's password without exposing the cleartext password.

It is also possible to tie a session default to a specific database rather than to a role; see `ALTER DATABASE`. If there is a conflict, database-role-specific settings override role-specific ones, which in turn override database-specific ones.

## Examples

Change a role's password:

```
ALTER ROLE davide WITH PASSWORD 'hu8jmn3';
```

Remove a role's password:

```
ALTER ROLE davide WITH PASSWORD NULL;
```

Change a password expiration date, specifying that the password should expire at midday on 4th May 2015 using the time zone which is one hour ahead of UTC:

```
ALTER ROLE chris VALID UNTIL 'May 4 12:00:00 2015 +1';
```

Make a password valid forever:

```
ALTER ROLE fred VALID UNTIL 'infinity';
```

Give a role the ability to create other roles and new databases:

```
ALTER ROLE miriam CREATEROLE CREATEDB;
```

Give a role a non-default setting of the `maintenance_work_mem` parameter:

```
ALTER ROLE worker_bee SET maintenance_work_mem = 100000;
```

Give a role a non-default, database-specific setting of the `client_min_messages` parameter:

```
ALTER ROLE fred IN DATABASE devel SET client_min_messages = DEBUG;
```

## Compatibility

The `ALTER ROLE` statement is a LightDB extension.

## See Also

`CREATE ROLE`, `DROP ROLE`, `ALTER DATABASE`, `SET`

---

# ALTER ROUTINE

ALTER ROUTINE — change the definition of a routine

## Synopsis

```
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  action [ ... ] [ RESTRICT ]
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  RENAME TO new_name
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  SET SCHEMA new_schema
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  [ NO ] DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
IMMUTABLE | STABLE | VOLATILE
[ NOT ] LEAKPROOF
[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
PARALLEL { UNSAFE | RESTRICTED | SAFE }
COST execution_cost
ROWS result_rows
SET configuration_parameter { TO | = } { value | DEFAULT }
SET configuration_parameter FROM CURRENT
RESET configuration_parameter
RESET ALL
```

## Description

ALTER ROUTINE changes the definition of a routine, which can be an aggregate function, a normal function, or a procedure. See under ALTER AGGREGATE, ALTER FUNCTION, and ALTER PROCEDURE for the description of the parameters, more examples, and further details.

## Examples

To rename the routine `foo` for type `integer` to `foobar`:

```
ALTER ROUTINE foo(integer) RENAME TO foobar;
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

## Compatibility

This statement is partially compatible with the ALTER ROUTINE statement in the SQL standard. See under ALTER FUNCTION and ALTER PROCEDURE for more details. Allowing routine names to refer to aggregate functions is a LightDB extension.

## See Also

ALTER AGGREGATE, ALTER FUNCTION, ALTER PROCEDURE, DROP ROUTINE

Note that there is no `CREATE ROUTINE` command.

---

# ALTER RULE

ALTER RULE — change the definition of a rule

## Synopsis

```
ALTER RULE name ON table_name RENAME TO new_name
```

## Description

ALTER RULE changes properties of an existing rule. Currently, the only available action is to change the rule's name.

To use ALTER RULE, you must own the table or view that the rule applies to.

## Parameters

*name*

The name of an existing rule to alter.

*table\_name*

The name (optionally schema-qualified) of the table or view that the rule applies to.

*new\_name*

The new name for the rule.

## Examples

To rename an existing rule:

```
ALTER RULE notify_all ON emp RENAME TO notify_me;
```

## Compatibility

ALTER RULE is a LightDB language extension, as is the entire query rewrite system.

## See Also

CREATE RULE, DROP RULE

---

# ALTER SCHEMA

ALTER SCHEMA — change the definition of a schema

## Synopsis

```
ALTER SCHEMA name RENAME TO new_name
ALTER SCHEMA name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
```

## Description

ALTER SCHEMA changes the definition of a schema.

You must own the schema to use ALTER SCHEMA. To rename a schema you must also have the CREATE privilege for the database. To alter the owner, you must also be a direct or indirect member of the new owning role, and you must have the CREATE privilege for the database. (Note that superusers have all these privileges automatically.)

## Parameters

*name*

The name of an existing schema.

*new\_name*

The new name of the schema. The new name cannot begin with pg\_, as such names are reserved for system schemas.

*new\_owner*

The new owner of the schema.

## Compatibility

There is no ALTER SCHEMA statement in the SQL standard.

## See Also

CREATE SCHEMA, DROP SCHEMA



---

# ALTER SEQUENCE

ALTER SEQUENCE — change the definition of a sequence generator

## Synopsis

```
ALTER SEQUENCE [ IF EXISTS ] name
  [ AS data_type ]
  [ INCREMENT [ BY ] increment ]
  [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO
MAXVALUE ]
  [ START [ WITH ] start ]
  [ RESTART [ [ WITH ] restart ] ]
  [ CACHE cache ] [ [ NO ] CYCLE ]
  [ OWNED BY { table_name.column_name | NONE } ]
  [ NOORDER ]
  [ ORDER ]
  [ NOCACHE ]
  [ NOCYCLE ]
  [ NOMAXVALUE ]
ALTER SEQUENCE [ IF EXISTS ] name OWNER TO { new_owner |
CURRENT_USER | SESSION_USER }
ALTER SEQUENCE [ IF EXISTS ] name RENAME TO new_name
ALTER SEQUENCE [ IF EXISTS ] name SET SCHEMA new_schema
```

## Description

ALTER SEQUENCE changes the parameters of an existing sequence generator. Any parameters not specifically set in the ALTER SEQUENCE command retain their prior settings.

You must own the sequence to use ALTER SEQUENCE. To change a sequence's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the sequence's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the sequence. However, a superuser can alter ownership of any sequence anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of a sequence to be altered.

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

*data\_type*

The optional clause AS *data\_type* changes the data type of the sequence. Valid types are smallint, integer, and bigint.

Changing the data type automatically changes the minimum and maximum values of the sequence if and only if the previous minimum and maximum values were the minimum or maximum value of the old data type (in other words, if the sequence had been created using NO MINVALUE

or NO MAXVALUE, implicitly or explicitly). Otherwise, the minimum and maximum values are preserved, unless new values are given as part of the same command. If the minimum and maximum values do not fit into the new data type, an error will be generated.

*increment*

The clause INCREMENT BY *increment* is optional. A positive value will make an ascending sequence, a negative one a descending sequence. If unspecified, the old increment value will be maintained.

*minvalue*

NO MINVALUE

The optional clause MINVALUE *minvalue* determines the minimum value a sequence can generate. If NO MINVALUE is specified, the defaults of 1 and the minimum value of the data type for ascending and descending sequences, respectively, will be used. If neither option is specified, the current minimum value will be maintained.

*maxvalue*

NO MAXVALUE

The optional clause MAXVALUE *maxvalue* determines the maximum value for the sequence. If NO MAXVALUE is specified, the defaults of the maximum value of the data type and -1 for ascending and descending sequences, respectively, will be used. If neither option is specified, the current maximum value will be maintained.

If the value of *maxvalue* is greater than INT64\_MAX(9223372036854775807), set *maxvalue* to the maximum value corresponding to the sequence type.

*start*

The optional clause START WITH *start* changes the recorded start value of the sequence. This has no effect on the *current* sequence value; it simply sets the value that future ALTER SEQUENCE RESTART commands will use.

*restart*

The optional clause RESTART [ WITH *restart* ] changes the current value of the sequence. This is similar to calling the `setval` function with `is_called = false`: the specified value will be returned by the *next* call of `nextval`. Writing RESTART with no *restart* value is equivalent to supplying the start value that was recorded by CREATE SEQUENCE or last set by ALTER SEQUENCE START WITH.

In contrast to a `setval` call, a RESTART operation on a sequence is transactional and blocks concurrent transactions from obtaining numbers from the same sequence. If that's not the desired mode of operation, `setval` should be used.

*cache*

The clause CACHE *cache* enables sequence numbers to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache). If unspecified, the old cache value will be maintained.

CYCLE

The optional CYCLE key word can be used to enable the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

NO CYCLE

If the optional NO CYCLE key word is specified, any calls to `nextval` after the sequence has reached its maximum value will return an error. If neither CYCLE or NO CYCLE are specified, the old cycle behavior will be maintained.

OWNED BY *table\_name.column\_name*

OWNED BY NONE

The OWNED BY option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. If specified, this association replaces any previously specified association for the sequence. The specified table must have the same owner and be in the same schema as the sequence. Specifying OWNED BY NONE removes any existing association, making the sequence “free-standing”.

NOORDER

ORDER

NOCACHE

NOCYCLE

The ALTER SEQUENCE statement supports the NOORDER/ORDER/NOCACHE/NOCYCLE keywords, which are intended to fit the syntax of Oracle databases. In the LightDB implementation, these keywords are just syntactic sugar.

*new\_owner*

The user name of the new owner of the sequence.

*new\_name*

The new name for the sequence.

*new\_schema*

The new schema for the sequence.

NOMAXVALUE

For compatibility with Oracle database syntax, the ALTER SEQUENCE statement supports the NOMAXVALUE keyword. The internal logic is the same as NO MAXVALUE.

## Notes

ALTER SEQUENCE will not immediately affect `nextval` results in backends, other than the current one, that have preallocated (cached) sequence values. They will use up all cached values prior to noticing the changed sequence generation parameters. The current backend will be affected immediately.

ALTER SEQUENCE does not affect the `currval` status for the sequence. (Before LightDB 8.3, it sometimes did.)

ALTER SEQUENCE blocks concurrent `nextval`, `currval`, `lastval`, and `setval` calls.

For historical reasons, ALTER TABLE can be used with sequences too; but the only variants of ALTER TABLE that are allowed with sequences are equivalent to the forms shown above.

## Examples

Restart a sequence called `serial`, at 105:

```
ALTER SEQUENCE serial RESTART WITH 105;
```

Alter sequence with ORDER/NOORDER/NOCACHE/NOCYCLE options;

```
alter sequence lt_seq_test1 nocache nocycle noorder;  
alter sequence lt_seq_test1 order nocycle nocache;
```

## Compatibility

ALTER SEQUENCE conforms to the SQL standard, except for the AS, START WITH, OWNED BY, OWNER TO, RENAME TO, and SET SCHEMA clauses, which are LightDB extensions.

## See Also

CREATE SEQUENCE, DROP SEQUENCE

---

# ALTER SERVER

ALTER SERVER — change the definition of a foreign server

## Synopsis

```
ALTER SERVER name [ VERSION 'new_version' ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] ) ]
ALTER SERVER name OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER SERVER name RENAME TO new_name
```

## Description

ALTER SERVER changes the definition of a foreign server. The first form changes the server version string or the generic options of the server (at least one clause is required). The second form changes the owner of the server.

To alter the server you must be the owner of the server. Additionally to alter the owner, you must own the server and also be a direct or indirect member of the new owning role, and you must have USAGE privilege on the server's foreign-data wrapper. (Note that superusers satisfy all these criteria automatically.)

## Parameters

*name*

The name of an existing server.

*new\_version*

New server version.

OPTIONS ( [ ADD | SET | DROP ] *option* ['*value*'] [, ... ] )

Change options for the server. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the server's foreign-data wrapper library.

*new\_owner*

The user name of the new owner of the foreign server.

*new\_name*

The new name for the foreign server.

## Examples

Alter server `foo`, add connection options:

```
ALTER SERVER foo OPTIONS (host 'foo', dbname 'foodb');
```

Alter server `foo`, change version, change `host` option:

```
ALTER SERVER foo VERSION '8.4' OPTIONS (SET host 'baz');
```

## Compatibility

ALTER SERVER conforms to ISO/IEC 9075-9 (SQL/MED). The OWNER TO and RENAME forms are LightDB extensions.

## See Also

CREATE SERVER, DROP SERVER

---

# ALTER SESSION

ALTER SESSION — change a session

## Synopsis

```
ALTER SESSION [ DISABLE | ENABLE ] PARALLEL [ DML | DDL | QUERY ]
```

## Compatibility

In order to be compatible with the use of Oracle databases, the ALTER SESSION command has been added. This command is just a syntactic sugar and is only run in Oracle compatibility mode.

---

# ALTER STATISTICS

ALTER STATISTICS — change the definition of an extended statistics object

## Synopsis

```
ALTER STATISTICS name OWNER TO { new_owner | CURRENT_USER |  
    SESSION_USER }  
ALTER STATISTICS name RENAME TO new_name  
ALTER STATISTICS name SET SCHEMA new_schema  
ALTER STATISTICS name SET STATISTICS new_target
```

## Description

ALTER STATISTICS changes the parameters of an existing extended statistics object. Any parameters not specifically set in the ALTER STATISTICS command retain their prior settings.

You must own the statistics object to use ALTER STATISTICS. To change a statistics object's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the statistics object's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the statistics object. However, a superuser can alter ownership of any statistics object anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of the statistics object to be altered.

*new\_owner*

The user name of the new owner of the statistics object.

*new\_name*

The new name for the statistics object.

*new\_schema*

The new schema for the statistics object.

*new\_target*

The statistic-gathering target for this statistics object for subsequent ANALYZE operations. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the maximum of the statistics target of the referenced columns, if set, or the system default statistics target (default\_statistics\_target). For more information on the use of statistics by the LightDB query planner, refer to Section 14.2.

## Compatibility

There is no ALTER STATISTICS command in the SQL standard.

## See Also

CREATE STATISTICS, DROP STATISTICS



---

# ALTER SUBSCRIPTION

ALTER SUBSCRIPTION — change the definition of a subscription

## Synopsis

```
ALTER SUBSCRIPTION name CONNECTION 'conninfo'
ALTER SUBSCRIPTION name SET PUBLICATION publication_name [, ...]
  [ WITH ( set_publication_option [= value] [, ... ] ) ]
ALTER SUBSCRIPTION name REFRESH PUBLICATION [ WITH ( refresh_option
  [= value] [, ... ] ) ]
ALTER SUBSCRIPTION name ENABLE
ALTER SUBSCRIPTION name DISABLE
ALTER SUBSCRIPTION name SET ( subscription_parameter [= value]
  [, ... ] )
ALTER SUBSCRIPTION name OWNER TO { new_owner | CURRENT_USER |
  SESSION_USER }
ALTER SUBSCRIPTION name RENAME TO new_name
```

## Description

ALTER SUBSCRIPTION can change most of the subscription properties that can be specified in CREATE SUBSCRIPTION.

You must own the subscription to use ALTER SUBSCRIPTION. To alter the owner, you must also be a direct or indirect member of the new owning role. The new owner has to be a superuser. (Currently, all subscription owners must be superusers, so the owner checks will be bypassed in practice. But this might change in the future.)

## Parameters

*name*

The name of a subscription whose properties are to be altered.

CONNECTION '*conninfo*'

This clause alters the connection property originally set by CREATE SUBSCRIPTION. See there for more information.

SET PUBLICATION *publication\_name*

Changes list of subscribed publications. See CREATE SUBSCRIPTION for more information. By default this command will also act like REFRESH PUBLICATION.

*set\_publication\_option* specifies additional options for this operation. The supported options are:

*refresh* (boolean)

When false, the command will not try to refresh table information. REFRESH PUBLICATION should then be executed separately. The default is true.

Additionally, refresh options as described under REFRESH PUBLICATION may be specified.

**REFRESH PUBLICATION**

Fetch missing table information from publisher. This will start replication of tables that were added to the subscribed-to publications since the last invocation of `REFRESH PUBLICATION` or since `CREATE SUBSCRIPTION`.

*refresh\_option* specifies additional options for the refresh operation. The supported options are:

`copy_data` (boolean)

Specifies whether the existing data in the publications that are being subscribed to should be copied once the replication starts. The default is `true`. (Previously subscribed tables are not copied.)

**ENABLE**

Enables the previously disabled subscription, starting the logical replication worker at the end of transaction.

**DISABLE**

Disables the running subscription, stopping the logical replication worker at the end of transaction.

`SET ( subscription_parameter [= value] [, ... ] )`

This clause alters parameters originally set by `CREATE SUBSCRIPTION`. See there for more information. The allowed options are `slot_name` and `synchronous_commit`

*new\_owner*

The user name of the new owner of the subscription.

*new\_name*

The new name for the subscription.

## Examples

Change the publication subscribed by a subscription to `insert_only`:

```
ALTER SUBSCRIPTION mysub SET PUBLICATION insert_only;
```

Disable (stop) the subscription:

```
ALTER SUBSCRIPTION mysub DISABLE;
```

## Compatibility

`ALTER SUBSCRIPTION` is a LightDB extension.

## See Also

`CREATE SUBSCRIPTION`, `DROP SUBSCRIPTION`, `CREATE PUBLICATION`, `ALTER PUBLICATION`

---

# ALTER SYSTEM

ALTER SYSTEM — change a server configuration parameter

## Synopsis

```
ALTER SYSTEM SET configuration_parameter { TO | = } { value |  
'value' | DEFAULT }
```

```
ALTER SYSTEM RESET configuration_parameter  
ALTER SYSTEM RESET ALL
```

## Description

ALTER SYSTEM is used for changing server configuration parameters across the entire database cluster. It can be more convenient than the traditional method of manually editing the `lightdb.conf` file. ALTER SYSTEM writes the given parameter setting to the `lightdb.auto.conf` file, which is read in addition to `lightdb.conf`. Setting a parameter to DEFAULT, or using the RESET variant, removes that configuration entry from the `lightdb.auto.conf` file. Use RESET ALL to remove all such configuration entries.

Values set with ALTER SYSTEM will be effective after the next server configuration reload, or after the next server restart in the case of parameters that can only be changed at server start. A server configuration reload can be commanded by calling the SQL function `pg_reload_conf()`, running `lt_ctl reload`, or sending a SIGHUP signal to the main server process.

Only superusers can use ALTER SYSTEM. Also, since this command acts directly on the file system and cannot be rolled back, it is not allowed inside a transaction block or function.

## Parameters

*configuration\_parameter*

Name of a settable configuration parameter. Available parameters are documented in Chapter 17.

*value*

New value of the parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. DEFAULT can be written to specify removing the parameter and its value from `lightdb.auto.conf`.

## Notes

This command can't be used to set `data_directory`, nor parameters that are not allowed in `lightdb.conf` (e.g., preset options).

See Section 17.1 for other ways to set the parameters.

## Examples

Set the `wal_level`:

```
ALTER SYSTEM SET wal_level = replica;
```

Undo that, restoring whatever setting was effective in `lightdb.conf`:

```
ALTER SYSTEM RESET wal_level;
```

## Compatibility

The `ALTER SYSTEM` statement is a LightDB extension.

## See Also

SET, SHOW

---

# ALTER TABLE

ALTER TABLE — change the definition of a table

## Synopsis

```
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    action [, ... ]
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER TABLE name WITH UPDATE CURRENT_TIMESTAMP
ALTER TABLE name WITH PRIMARY KEY [ smallserial | serial |
    bigserial ]
ALTER TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER TABLE ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
ALTER TABLE [ IF EXISTS ] name
    ATTACH PARTITION partition_name { FOR
    VALUES partition_bound_spec | DEFAULT }
ALTER TABLE [ IF EXISTS ] name
    DETACH PARTITION partition_name
ALTER TABLE [ IF EXISTS ] name
    ADD PARTITION partition_name { VALUES partition_bound_spec }
ALTER TABLE [ IF EXISTS ] name
    DROP PARTITION partition_name [ UPDATE GLOBAL INDEXES ]
ALTER TABLE [ IF EXISTS ] name
    TRUNCATE PARTITION partition_name [ UPDATE INDEXES ]
ALTER TABLE [ IF EXISTS ] name
    MODIFY PARTITION BY [ RANGE | LIST ] (column) { partition_spec
    | ONLINE | index_spec }
ALTER TABLE [ IF EXISTS ] name
    MODIFY ( [ column modify_column_type modify_column_properites ]
    [, ... ] )
```

where *action* is one of:

```
ADD [ COLUMN ] [ IF NOT EXISTS ] column_definition
ADD ( column_definition [, ... ] )
DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT |
CASCADE ]
ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type
[ COLLATE collation ] [ USING expression ]
ALTER [ COLUMN ] column_name SET DEFAULT expression
ALTER [ COLUMN ] column_name DROP DEFAULT
ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
ALTER [ COLUMN ] column_name DROP EXPRESSION [ IF EXISTS ]
ALTER [ COLUMN ] column_name ADD GENERATED { ALWAYS | BY
DEFAULT } AS IDENTITY [ ( sequence_options ) ]
```

---

## ALTER TABLE

---

```
ALTER [ COLUMN ] column_name { SET GENERATED { ALWAYS | BY
DEFAULT } | SET sequence_option | RESTART [ [ WITH ] restart ] }
[... ]
ALTER [ COLUMN ] column_name DROP IDENTITY [ IF EXISTS ]
ADD AUTO_INCREMENT(column_name) [ =N ]
ALTER [ COLUMN ] column_name DROP AUTO_INCREMENT
ALTER [ COLUMN ] column_name SET STATISTICS integer
ALTER [ COLUMN ] column_name SET ( attribute_option = value
[ , ... ] )
ALTER [ COLUMN ] column_name RESET ( attribute_option
[ , ... ] )
ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
EXTENDED | MAIN }
ADD table_constraint [ NOT VALID ] [ DISABLE ]
ADD table_constraint_using_index
ALTER CONSTRAINT constraint_name [ DEFERRABLE | NOT
DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]
VALIDATE CONSTRAINT constraint_name
DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
CASCADE ] [ DROP INDEX ]
DISABLE TRIGGER [ trigger_name | ALL | USER ]
ENABLE TRIGGER [ trigger_name | ALL | USER ]
ENABLE REPLICA TRIGGER trigger_name
ENABLE ALWAYS TRIGGER trigger_name
DISABLE RULE rewrite_rule_name
ENABLE RULE rewrite_rule_name
ENABLE REPLICA RULE rewrite_rule_name
ENABLE ALWAYS RULE rewrite_rule_name
DISABLE ROW LEVEL SECURITY
ENABLE ROW LEVEL SECURITY
FORCE ROW LEVEL SECURITY
NO FORCE ROW LEVEL SECURITY
CLUSTER ON index_name
SET WITHOUT CLUSTER
SET WITHOUT OIDS
SET TABLESPACE new_tablespace
SET { LOGGED | UNLOGGED }
SET ( storage_parameter [= value] [ , ... ] )
RESET ( storage_parameter [ , ... ] )
INHERIT parent_table
NO INHERIT parent_table
OF type_name
NOT OF
OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
REPLICA IDENTITY { DEFAULT | USING INDEX index_name | FULL |
NOTHING }

MODIFY column_name data_type [ USING expression ]
MODIFY column_name DEFAULT expression
MODIFY column_name { NOT NULL | NULL } [ENABLE]
MODIFY column_name GENERATED { ALWAYS | BY DEFAULT } AS
IDENTITY [ ( sequence_options ) ]
MODIFY column_name DROP IDENTITY
MODIFY column_name CONSTRAINT constraint_name { NOT NULL |
NULL } [ENABLE]
MODIFY column_name CONSTRAINT constraint_name UNIQUE
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

---

## ALTER TABLE

---

```
    MODIFY column_name CONSTRAINT constraint_name PRIMARY KEY
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
    MODIFY column_name CONSTRAINT constraint_name
REFERENCES reftable [ ( refcolumn ) ]
    [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON DELETE
referential_action ] [ ON UPDATE referential_action ] [ DEFERRABLE
| NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]
    MODIFY column_name CONSTRAINT constraint_name CHECK '(' a_expr
')' [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED |
INITIALLY IMMEDIATE ]
    DROP PRIMARY KEY [ RESTRICT | CASCADE ] [ DROP INDEX ]
```

and *column\_definition* is:

```
    column_name data_type [ COLLATE collation ] [ column_constraint
[ ... ] ]
```

and *partition\_bound\_spec* is:

```
IN ( partition_bound_expr [, ...] ) |
FROM ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] )
    TO ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS numeric_literal, REMAINDER numeric_literal ) |
LESS THAN ( { partition_bound_expr | MAXVALUE } ) |
( partition_bound_expr [, ...] )
```

and *column\_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  CHECK ( expression ) [ NO INHERIT ] |
  DEFAULT default_expr |
  ON UPDATE CURRENT_TIMESTAMP |
  GENERATED ALWAYS AS ( generation_expr ) STORED |
  GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
[ ( sequence_options ) ] |
  UNIQUE index_parameters |
  PRIMARY KEY index_parameters |
  REFERENCES reftable [ ( refcolumn ) ] [ MATCH FULL | MATCH
PARTIAL | MATCH SIMPLE ]
    [ ON DELETE referential_action ] [ ON UPDATE referential_action
] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

and *table\_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ CHECK ( expression ) [ NO INHERIT ] |
  UNIQUE ( column_name [, ...] ) index_parameters |
  PRIMARY KEY ( column_name [, ...] ) index_parameters |
  EXCLUDE [ USING index_method ] ( exclude_element WITH operator
[, ...] ) index_parameters [ WHERE ( predicate ) ] |
  FOREIGN KEY ( column_name [, ...] ) REFERENCES reftable
[ ( refcolumn [, ...] ) ]
```

```
[ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON
DELETE referential_action ] [ ON UPDATE referential_action ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

and *table\_constraint\_using\_index* is:

```
[ CONSTRAINT constraint_name ]
{ UNIQUE | PRIMARY KEY } USING INDEX index_name
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED |
INITIALLY IMMEDIATE ]
```

*index\_parameters* in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

```
[ INCLUDE ( column_name [, ... ] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ USING INDEX | USING INDEX TABLESPACE tablespace_name ]
```

*exclude\_element* in an EXCLUDE constraint is:

```
{ column_name | ( expression ) } [ opclass ] [ ASC | DESC ] [ NULLS
{ FIRST | LAST } ]
```

*partition\_spec* is:

*partition\_element* [, ...]

and *partition\_element* is:

```
[PARTITION name] [VALUES LESS THAN | VALUES]
( [ { partition_value | MAXVALUE } | { partition_value } ] )
```

*index\_spec* is:

*index\_element* [, ...]

and *index\_element* is:

```
[index name] [ GLOBAL | LOCAL ]
```

*modify\_column\_type* is:

*Typename alter\_using*

and *alter\_using* is:

```
USING a_expr
```

*modify\_column\_properties* is:

```
( [ { NULL | NOT NULL [ ENABLE_P ] | DEFAULT a_expr } ]
[ ... ] )
```

## Description

ALTER TABLE changes the definition of an existing table. There are several subforms described below. Note that the lock level required may differ for each subform. An ACCESS EXCLUSIVE lock is acquired unless explicitly noted. When multiple subcommands are given, the lock acquired will be the strictest one required by any subcommand.

ADD COLUMN [ IF NOT EXISTS ]

This form adds a new column to the table, using the same syntax as CREATE TABLE. If IF NOT EXISTS is specified and a column already exists with this name, no error is thrown.



```
ADD (column_definition [, ...])
```

This form could add multiple columns at once to the table.

```
DROP COLUMN [ IF EXISTS ]
```

This form drops a column from a table. Indexes and table constraints involving the column will be automatically dropped as well. Multivariate statistics referencing the dropped column will also be removed if the removal of the column would cause the statistics to contain data for only a single column. You will need to say `CASCADE` if anything outside the table depends on the column, for example, foreign key references or views. If `IF EXISTS` is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

```
SET DATA TYPE
```

This form changes the type of a column of a table. Indexes and simple table constraints involving the column will be automatically converted to use the new column type by reparsing the originally supplied expression. The optional `COLLATE` clause specifies a collation for the new column; if omitted, the collation is the default for the new column type. The optional `USING` clause specifies how to compute the new column value from the old; if omitted, the default conversion is the same as an assignment cast from old data type to new. A `USING` clause must be provided if there is no implicit or assignment cast from old to new type.

```
SET/DROP DEFAULT
```

These forms set or remove the default value for a column (where removal is equivalent to setting the default value to `NULL`). The new default value will only apply in subsequent `INSERT` or `UPDATE` commands; it does not cause rows already in the table to change.

```
SET/DROP NOT NULL
```

These forms change whether a column is marked to allow null values or to reject null values.

`SET NOT NULL` may only be applied to a column provided none of the records in the table contain a `NULL` value for the column. Ordinarily this is checked during the `ALTER TABLE` by scanning the entire table; however, if a valid `CHECK` constraint is found which proves no `NULL` can exist, then the table scan is skipped.

If this table is a partition, one cannot perform `DROP NOT NULL` on a column if it is marked `NOT NULL` in the parent table. To drop the `NOT NULL` constraint from all the partitions, perform `DROP NOT NULL` on the parent table. Even if there is no `NOT NULL` constraint on the parent, such a constraint can still be added to individual partitions, if desired; that is, the children can disallow nulls even if the parent allows them, but not the other way around.

```
DROP EXPRESSION [ IF EXISTS ]
```

This form turns a stored generated column into a normal base column. Existing data in the columns is retained, but future changes will no longer apply the generation expression.

If `DROP EXPRESSION IF EXISTS` is specified and the column is not a stored generated column, no error is thrown. In this case a notice is issued instead.

```
ADD GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY  
SET GENERATED { ALWAYS | BY DEFAULT }  
DROP IDENTITY [ IF EXISTS ]
```

These forms change whether a column is an identity column or change the generation attribute of an existing identity column. See `CREATE TABLE` for details. Like `SET DEFAULT`, these forms only affect the behavior of subsequent `INSERT` and `UPDATE` commands; they do not cause rows already in the table to change.

If `DROP IDENTITY IF EXISTS` is specified and the column is not an identity column, no error is thrown. In this case a notice is issued instead.

```
ADD AUTO_INCREMENT(column_name) [ =N ]
```

This form alter `column_name` column as an auto increment column, default start at 1, if set `=N`, its start at `N`.

```
DROP AUTO_INCREMENT
```

This form drop column auto increment attribute. After drop, that column could not auto increment on by on.

```
ON UPDATE CURRENT_TIMESTAMP
```

This form enables timestamp column be updated automatically when a row is updated.

```
SET sequence_option
RESTART
```

These forms alter the sequence that underlies an existing identity column. *sequence\_option* is an option supported by `ALTER SEQUENCE` such as `INCREMENT BY`.

```
SET STATISTICS
```

This form sets the per-column statistics-gathering target for subsequent `ANALYZE` operations. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the system default statistics target (`default_statistics_target`). For more information on the use of statistics by the LightDB query planner, refer to Section 14.2.

`SET STATISTICS` acquires a `SHARE UPDATE EXCLUSIVE` lock.

```
SET ( attribute_option = value [, ... ] )
RESET ( attribute_option [, ... ] )
```

This form sets or resets per-attribute options. Currently, the only defined per-attribute options are `n_distinct` and `n_distinct_inherited`, which override the number-of-distinct-values estimates made by subsequent `ANALYZE` operations. `n_distinct` affects the statistics for the table itself, while `n_distinct_inherited` affects the statistics gathered for the table plus its inheritance children. When set to a positive value, `ANALYZE` will assume that the column contains exactly the specified number of distinct nonnull values. When set to a negative value, which must be greater than or equal to -1, `ANALYZE` will assume that the number of distinct nonnull values in the column is linear in the size of the table; the exact count is to be computed by multiplying the estimated table size by the absolute value of the given number. For example, a value of -1 implies that all values in the column are distinct, while a value of -0.5 implies that each value appears twice on the average. This can be useful when the size of the table changes over time, since the multiplication by the number of rows in the table is not performed until query planning time. Specify a value of 0 to revert to estimating the number of distinct values normally. For more information on the use of statistics by the LightDB query planner, refer to Section 14.2.

Changing per-attribute options acquires a `SHARE UPDATE EXCLUSIVE` lock.

```
SET STORAGE
```

This form sets the storage mode for a column. This controls whether this column is held inline or in a secondary `TOAST` table, and whether the data should be compressed or not. `PLAIN` must be used for fixed-length values such as `integer` and is inline, uncompressed. `MAIN` is for inline, compressible data. `EXTERNAL` is for external, uncompressed data, and `EXTENDED` is for external, compressed data. `EXTENDED` is the default for most data types that support non-`PLAIN` storage. Use of `EXTERNAL` will make substring operations on very large `text` and `bytea` values run faster, at the penalty of increased storage space. Note that `SET STORAGE` doesn't itself

change anything in the table, it just sets the strategy to be pursued during future table updates. See Section 64.2 for more information.

```
ADD table_constraint [ NOT VALID ] [ DISABLE ]
```

This form adds a new constraint to a table using the same constraint syntax as CREATE TABLE, plus the option NOT VALID, which is currently only allowed for foreign key and CHECK constraints.

Normally, this form will cause a scan of the table to verify that all existing rows in the table satisfy the new constraint. But if the NOT VALID option is used, this potentially-lengthy scan is skipped. The constraint will still be enforced against subsequent inserts or updates (that is, they'll fail unless there is a matching row in the referenced table, in the case of foreign keys, or they'll fail unless the new row matches the specified check condition). But the database will not assume that the constraint holds for all rows in the table, until it is validated by using the VALIDATE CONSTRAINT option. See Notes below for more information about using the NOT VALID option.

Although most forms of ADD *table\_constraint* require an ACCESS EXCLUSIVE lock, ADD FOREIGN KEY requires only a SHARE ROW EXCLUSIVE lock. Note that ADD FOREIGN KEY also acquires a SHARE ROW EXCLUSIVE lock on the referenced table, in addition to the lock on the table on which the constraint is declared.

Additional restrictions apply when unique or primary key constraints are added to partitioned tables; see CREATE TABLE. Also, foreign key constraints on partitioned tables may not be declared NOT VALID at present.

The DISABLE keyword is added to be compatible with Oracle syntax, and is only syntactic candy and has no practical effect. Available only in Oracle compatibility mode.

```
ADD table_constraint_using_index
```

This form adds a new PRIMARY KEY or UNIQUE constraint to a table based on an existing unique index. All the columns of the index will be included in the constraint.

The index cannot have expression columns nor be a partial index. Also, it must be a b-tree index with default sort ordering. These restrictions ensure that the index is equivalent to one that would be built by a regular ADD PRIMARY KEY or ADD UNIQUE command.

If PRIMARY KEY is specified, and the index's columns are not already marked NOT NULL, then this command will attempt to do ALTER COLUMN SET NOT NULL against each such column. That requires a full table scan to verify the column(s) contain no nulls. In all other cases, this is a fast operation.

If a constraint name is provided then the index will be renamed to match the constraint name. Otherwise the constraint will be named the same as the index.

After this command is executed, the index is “owned” by the constraint, in the same way as if the index had been built by a regular ADD PRIMARY KEY or ADD UNIQUE command. In particular, dropping the constraint will make the index disappear too.

This form is not currently supported on partitioned tables.

### Note

Adding a constraint using an existing index can be helpful in situations where a new constraint needs to be added without blocking table updates for a long time. To do that, create the index using CREATE INDEX CONCURRENTLY, and then install it as an official constraint using this syntax. See the example below.

**ALTER CONSTRAINT**

This form alters the attributes of a constraint that was previously created. Currently only foreign key constraints may be altered.

**VALIDATE CONSTRAINT**

This form validates a foreign key or check constraint that was previously created as `NOT VALID`, by scanning the table to ensure there are no rows for which the constraint is not satisfied. Nothing happens if the constraint is already marked valid. (See Notes below for an explanation of the usefulness of this command.)

This command acquires a `SHARE UPDATE EXCLUSIVE` lock.

**DROP CONSTRAINT [ IF EXISTS ]**

This form drops the specified constraint on a table, along with any index underlying the constraint. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

**DISABLE/ENABLE [ REPLICA | ALWAYS ] TRIGGER**

These forms configure the firing of trigger(s) belonging to the table. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. For a deferred trigger, the enable status is checked when the event occurs, not when the trigger function is actually executed. One can disable or enable a single trigger specified by name, or all triggers on the table, or only user triggers (this option excludes internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints). Disabling or enabling internally generated constraint triggers requires superuser privileges; it should be done with caution since of course the integrity of the constraint cannot be guaranteed if the triggers are not executed.

The trigger firing mechanism is also affected by the configuration variable `session_replication_role`. Simply enabled triggers (the default) will fire when the replication role is "origin" (the default) or "local". Triggers configured as `ENABLE REPLICA` will only fire if the session is in "replica" mode, and triggers configured as `ENABLE ALWAYS` will fire regardless of the current replication role.

The effect of this mechanism is that in the default configuration, triggers do not fire on replicas. This is useful because if a trigger is used on the origin to propagate data between tables, then the replication system will also replicate the propagated data, and the trigger should not fire a second time on the replica, because that would lead to duplication. However, if a trigger is used for another purpose such as creating external alerts, then it might be appropriate to set it to `ENABLE ALWAYS` so that it is also fired on replicas.

This command acquires a `SHARE ROW EXCLUSIVE` lock.

**DISABLE/ENABLE [ REPLICA | ALWAYS ] RULE**

These forms configure the firing of rewrite rules belonging to the table. A disabled rule is still known to the system, but is not applied during query rewriting. The semantics are as for disabled/enabled triggers. This configuration is ignored for `ON SELECT` rules, which are always applied in order to keep views working even if the current session is in a non-default replication role.

The rule firing mechanism is also affected by the configuration variable `session_replication_role`, analogous to triggers as described above.

**DISABLE/ENABLE ROW LEVEL SECURITY**

These forms control the application of row security policies belonging to the table. If enabled and no policies exist for the table, then a default-deny policy is applied. Note that policies can exist

for a table even if row level security is disabled. In this case, the policies will *not* be applied and the policies will be ignored. See also CREATE POLICY.

#### NO FORCE/FORCE ROW LEVEL SECURITY

These forms control the application of row security policies belonging to the table when the user is the table owner. If enabled, row level security policies will be applied when the user is the table owner. If disabled (the default) then row level security will not be applied when the user is the table owner. See also CREATE POLICY.

#### CLUSTER ON

This form selects the default index for future CLUSTER operations. It does not actually re-cluster the table.

Changing cluster options acquires a SHARE UPDATE EXCLUSIVE lock.

#### SET WITHOUT CLUSTER

This form removes the most recently used CLUSTER index specification from the table. This affects future cluster operations that don't specify an index.

Changing cluster options acquires a SHARE UPDATE EXCLUSIVE lock.

#### SET WITHOUT OIDS

Backward-compatible syntax for removing the oid system column. As oid system columns cannot be added anymore, this never has an effect.

#### SET TABLESPACE

This form changes the table's tablespace to the specified tablespace and moves the data file(s) associated with the table to the new tablespace. Indexes on the table, if any, are not moved; but they can be moved separately with additional SET TABLESPACE commands. When applied to a partitioned table, nothing is moved, but any partitions created afterwards with CREATE TABLE PARTITION OF will use that tablespace, unless overridden by a TABLESPACE clause.

All tables in the current database in a tablespace can be moved by using the ALL IN TABLESPACE form, which will lock all tables to be moved first and then move each one. This form also supports OWNED BY, which will only move tables owned by the roles specified. If the NOWAIT option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs are not moved by this command; use ALTER DATABASE or explicit ALTER TABLE invocations instead if desired. The information\_schema relations are not considered part of the system catalogs and will be moved. See also CREATE TABLESPACE.

#### SET { LOGGED | UNLOGGED }

This form changes the table from unlogged to logged or vice-versa (see UNLOGGED). It cannot be applied to a temporary table.

#### SET ( *storage\_parameter* [= *value*] [, ... ] )

This form changes one or more storage parameters for the table. See Storage Parameters in the CREATE TABLE documentation for details on the available parameters. Note that the table contents will not be modified immediately by this command; depending on the parameter you might need to rewrite the table to get the desired effects. That can be done with VACUUM FULL, CLUSTER or one of the forms of ALTER TABLE that forces a table rewrite. For planner related parameters, changes will take effect from the next time the table is locked so currently executing queries will not be affected.

SHARE UPDATE EXCLUSIVE lock will be taken for fillfactor, toast and autovacuum storage parameters, as well as the planner parameter `parallel_workers`.

RESET ( *storage\_parameter* [, ... ] )

This form resets one or more storage parameters to their defaults. As with SET, a table rewrite might be needed to update the table entirely.

INHERIT *parent\_table*

This form adds the target table as a new child of the specified parent table. Subsequently, queries against the parent will include records of the target table. To be added as a child, the target table must already contain all the same columns as the parent (it could have additional columns, too). The columns must have matching data types, and if they have NOT NULL constraints in the parent then they must also have NOT NULL constraints in the child.

There must also be matching child-table constraints for all CHECK constraints of the parent, except those marked non-inheritable (that is, created with ALTER TABLE ... ADD CONSTRAINT ... NO INHERIT) in the parent, which are ignored; all child-table constraints matched must not be marked non-inheritable. Currently UNIQUE, PRIMARY KEY, and FOREIGN KEY constraints are not considered, but this might change in the future.

NO INHERIT *parent\_table*

This form removes the target table from the list of children of the specified parent table. Queries against the parent table will no longer include records drawn from the target table.

OF *type\_name*

This form links the table to a composite type as though CREATE TABLE OF had formed it. The table's list of column names and types must precisely match that of the composite type. The table must not inherit from any other table. These restrictions ensure that CREATE TABLE OF would permit an equivalent table definition.

NOT OF

This form dissociates a typed table from its type.

OWNER TO

This form changes the owner of the table, sequence, view, materialized view, or foreign table to the specified user.

REPLICA IDENTITY

This form changes the information which is written to the write-ahead log to identify rows which are updated or deleted. In most cases, the old value of each column is only logged if it differs from the new value; however, if the old value is stored externally, it is always logged regardless of whether it changed. This option has no effect except when logical replication is in use.

DEFAULT

Records the old values of the columns of the primary key, if any. This is the default for non-system tables.

USING INDEX *index\_name*

Records the old values of the columns covered by the named index, that must be unique, not partial, not deferrable, and include only columns marked NOT NULL. If this index is dropped, the behavior is the same as NOTHING.

## FULL

Records the old values of all columns in the row.

## NOTHING

Records no information about the old row. This is the default for system tables.

## RENAME

The RENAME forms change the name of a table (or an index, sequence, view, materialized view, or foreign table), the name of an individual column in a table, or the name of a constraint of the table. When renaming a constraint that has an underlying index, the index is renamed as well. There is no effect on the stored data.

## WITH UPDATE CURRENT\_TIMESTAMP

The WITH UPDATE CURRENT\_TIMESTAMP forms add the hidden column "ltaut" of a table. The "ltaut" column is equal to "ltaut TIMESTAMP ON UPDATE CURRENT\_TIMESTAMP".

## WITH PRIMARY KEY [ smallserial | serial | bigserial ]

The WITH PRIMARY KEY forms add the hidden column "ltapk" of a table. The "ltapk" column is automatically incremented and is specified the primary key constraint. If tables already have a primary key, WITH PRIMARY KEY is not allowed. You can drop it and modify its types as usual, but only integer, smallint and bigint can be used.

## SET SCHEMA

This form moves the table into another schema. Associated indexes, constraints, and sequences owned by table columns are moved as well.

ATTACH PARTITION *partition\_name* { FOR VALUES *partition\_bound\_spec* | DEFAULT }

This form attaches an existing table (which might itself be partitioned) as a partition of the target table. The table can be attached as a partition for specific values using FOR VALUES or as a default partition by using DEFAULT. For each index in the target table, a corresponding one will be created in the attached table; or, if an equivalent index already exists, it will be attached to the target table's index, as if ALTER INDEX ATTACH PARTITION had been executed. Note that if the existing table is a foreign table, it is currently not allowed to attach the table as a partition of the target table if there are UNIQUE indexes on the target table. (See also CREATE FOREIGN TABLE.) For each user-defined row-level trigger that exists in the target table, a corresponding one is created in the attached table.

A partition using FOR VALUES uses the same syntax for *partition\_bound\_spec* as CREATE TABLE. The partition bound specification must correspond to the partitioning strategy and partition key of the target table. The table to be attached must have all the same columns as the target table and no more; moreover, the column types must also match. Also, it must have all the NOT NULL and CHECK constraints of the target table. Currently FOREIGN KEY constraints are not considered. UNIQUE and PRIMARY KEY constraints from the parent table will be created in the partition, if they don't already exist. If any of the CHECK constraints of the table being attached are marked NO INHERIT, the command will fail; such constraints must be recreated without the NO INHERIT clause.

If the new partition is a regular table, a full table scan is performed to check that existing rows in the table do not violate the partition constraint. It is possible to avoid this scan by adding a valid CHECK constraint to the table that allows only rows satisfying the desired partition constraint before running this command. The CHECK constraint will be used to determine that the table need not be scanned to validate the partition constraint. This does not work, however, if any of the partition keys is an expression and the partition does not accept NULL values. If attaching a list

partition that will not accept NULL values, also add NOT NULL constraint to the partition key column, unless it's an expression.

If the new partition is a foreign table, nothing is done to verify that all the rows in the foreign table obey the partition constraint. (See the discussion in CREATE FOREIGN TABLE about constraints on the foreign table.)

When a table has a default partition, defining a new partition changes the partition constraint for the default partition. The default partition can't contain any rows that would need to be moved to the new partition, and will be scanned to verify that none are present. This scan, like the scan of the new partition, can be avoided if an appropriate CHECK constraint is present. Also like the scan of the new partition, it is always skipped when the default partition is a foreign table.

Attaching a partition acquires a SHARE UPDATE EXCLUSIVE lock on the parent table, in addition to the ACCESS EXCLUSIVE locks on the table being attached and on the default partition (if any).

Further locks must also be held on all sub-partitions if the table being attached is itself a partitioned table. Likewise if the default partition is itself a partitioned table. The locking of the sub-partitions can be avoided by adding a CHECK constraint as described in Section 5.11.2.2.

DETACH PARTITION *partition\_name*

This form detaches the specified partition of the target table. The detached partition continues to exist as a standalone table, but no longer has any ties to the table from which it was detached. Any indexes that were attached to the target table's indexes are detached. Any triggers that were created as clones of those in the target table are removed. SHARE lock is obtained on any tables that reference this partitioned table in foreign key constraints.

ADD PARTITION *partition\_name* { VALUES *partition\_bound\_spec* }

This syntax is used to create new partitions for existing partition tables compatible with Oracle. Supports adding range partition and list partition, and does not support adding hash partition. It is necessary to change the configuration to Oracle compatible mode.

List with default partition feature is included since LightDB 23.3. Please note that if there is a default partition for this partitioned table already, no more partition could be added.

Subpartition will not be created automatically for the current implementation.

DROP PARTITION *partition\_name*

This syntax is used to drop partitions from existing partition tables compatible with Oracle. Supports dropping range partition and list partition, and does not support dropping hash partition. It is necessary to change the configuration to Oracle compatible mode. The parameter UPDATE GLOBAL INDEXES is only syntax compatible, but not function compatible.

TRUNCATE PARTITION *partition\_name* [ UPDATE INDEXES ]

This syntax is used to truncate partitions from existing partition tables compatible with Oracle. It is necessary to change the configuration to Oracle compatible mode. The feature is included in LightDB since release 23.2.

MODIFY PARTITION BY [ RANGE | LIST ] (*column*)

This syntax is used to convert a ordinary table to a partitioned table. Supports convert range partition and list partition (Automatic partition is not supported). Conversion of distributed tables is not supported. It is necessary to change the configuration to Oracle compatible mode.

All the forms of ALTER TABLE that act on a single table, except RENAME, SET SCHEMA, ATTACH PARTITION, and DETACH PARTITION can be combined into a list of multiple alterations to be applied together. For example, it is possible to add several columns and/or alter the type of several



columns in a single command. This is particularly useful with large tables, since only one pass over the table need be made.

You must own the table to use `ALTER TABLE`. To change the schema or tablespace of a table, you must also have `CREATE` privilege on the new schema or tablespace. To add the table as a new child of a parent table, you must own the parent table as well. Also, to attach a table as a new partition of the table, you must own the table being attached. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type or use the `OF` clause, you must also have `USAGE` privilege on the data type.

## Parameters

`IF EXISTS`

Do not throw an error if the table does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing table to alter. If `ONLY` is specified before the table name, only that table is altered. If `ONLY` is not specified, the table and all its descendant tables (if any) are altered. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

*column\_name*

Name of a new or existing column.

*new\_column\_name*

New name for an existing column.

*new\_name*

New name for the table.

*data\_type*

Data type of the new column, or new data type for an existing column.

*table\_constraint*

New table constraint for the table.

*constraint\_name*

Name of a new or existing constraint.

`CASCADE`

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects (see Section 5.14).

`RESTRICT`

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

*trigger\_name*

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the table. (This requires superuser privilege if any of the triggers are internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.)

USER

Disable or enable all triggers belonging to the table except for internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.

*index\_name*

The name of an existing index.

*storage\_parameter*

The name of a table storage parameter.

*value*

The new value for a table storage parameter. This might be a number or a word depending on the parameter.

*parent\_table*

A parent table to associate or de-associate with this table.

*new\_owner*

The user name of the new owner of the table.

*new\_tablespace*

The name of the tablespace to which the table will be moved.

*new\_schema*

The name of the schema to which the table will be moved.

*partition\_name*

The name of the table to attach as a new partition or to detach from this table. Please note that the partition name specified in CREATE/ADD/DROP/TRUNCATE/MODIFY is identical to the partition name in oracle compatible mode, both the table name and partition name is limited to a maximum of 31 characters in length when creating a partition in oracle compatible mode. To view the partition name in oracle compatible mode, please refer to view DBA\_TAB\_PARTITIONS and refer to view DBA\_TAB\_SUBPARTITIONS for subpartition. To view the table that related to the partition, please refer to \d+ command.

*partition\_bound\_spec*

The partition bound specification for a new partition. Refer to CREATE TABLE for more details on the syntax of the same.

DROP INDEX

In order to be compatible with the DROP CONSTRAINT DROP INDEX and DROP PRIMARY KEY DROP INDEX statements of Oracle database, the syntactic sugar of DROP INDEX suffix has been added.

## Notes

The key word `COLUMN` is noise and can be omitted.

When a column is added with `ADD COLUMN` and a non-volatile `DEFAULT` is specified, the default is evaluated at the time of the statement and the result stored in the table's metadata. That value will be used for the column for all existing rows. If no `DEFAULT` is specified, `NULL` is used. In neither case is a rewrite of the table required.

Adding a column with a volatile `DEFAULT` or changing the type of an existing column will require the entire table and its indexes to be rewritten. As an exception, when changing the type of an existing column, if the `USING` clause does not change the column contents and the old type is either binary coercible to the new type or an unconstrained domain over the new type, a table rewrite is not needed; but any indexes on the affected columns must still be rebuilt. Table and/or index rebuilds may take a significant amount of time for a large table; and will temporarily require as much as double the disk space.

Adding a `CHECK` or `NOT NULL` constraint requires scanning the table to verify that existing rows meet the constraint, but does not require a table rewrite.

Similarly, when attaching a new partition it may be scanned to verify that existing rows meet the partition constraint.

The main reason for providing the option to specify multiple changes in a single `ALTER TABLE` is that multiple table scans or rewrites can thereby be combined into a single pass over the table.

Scanning a large table to verify a new foreign key or check constraint can take a long time, and other updates to the table are locked out until the `ALTER TABLE ADD CONSTRAINT` command is committed. The main purpose of the `NOT VALID` constraint option is to reduce the impact of adding a constraint on concurrent updates. With `NOT VALID`, the `ADD CONSTRAINT` command does not scan the table and can be committed immediately. After that, a `VALIDATE CONSTRAINT` command can be issued to verify that existing rows satisfy the constraint. The validation step does not need to lock out concurrent updates, since it knows that other transactions will be enforcing the constraint for rows that they insert or update; only pre-existing rows need to be checked. Hence, validation acquires only a `SHARE UPDATE EXCLUSIVE` lock on the table being altered. (If the constraint is a foreign key then a `ROW SHARE` lock is also required on the table referenced by the constraint.) In addition to improving concurrency, it can be useful to use `NOT VALID` and `VALIDATE CONSTRAINT` in cases where the table is known to contain pre-existing violations. Once the constraint is in place, no new violations can be inserted, and the existing problems can be corrected at leisure until `VALIDATE CONSTRAINT` finally succeeds.

The `DROP COLUMN` form does not physically remove the column, but simply makes it invisible to SQL operations. Subsequent insert and update operations in the table will store a null value for the column. Thus, dropping a column is quick but it will not immediately reduce the on-disk size of your table, as the space occupied by the dropped column is not reclaimed. The space will be reclaimed over time as existing rows are updated.

To force immediate reclamation of space occupied by a dropped column, you can execute one of the forms of `ALTER TABLE` that performs a rewrite of the whole table. This results in reconstructing each row with the dropped column replaced by a null value.

The rewriting forms of `ALTER TABLE` are not MVCC-safe. After a table rewrite, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the rewrite occurred. See Section 13.5 for more details.

The `USING` option of `SET DATA TYPE` can actually specify any expression involving the old values of the row; that is, it can refer to other columns as well as the one being converted. This allows very general conversions to be done with the `SET DATA TYPE` syntax. Because of this flexibility, the `USING` expression is not applied to the column's default value (if any); the result might not be a

constant expression as required for a default. This means that when there is no implicit or assignment cast from old to new type, `SET DATA TYPE` might fail to convert the default even though a `USING` clause is supplied. In such cases, drop the default with `DROP DEFAULT`, perform the `ALTER TYPE`, and then use `SET DEFAULT` to add a suitable new default. Similar considerations apply to indexes and constraints involving the column.

If a table has any descendant tables, it is not permitted to add, rename, or change the type of a column in the parent table without doing the same to the descendants. This ensures that the descendants always have columns matching the parent. Similarly, a `CHECK` constraint cannot be renamed in the parent without also renaming it in all descendants, so that `CHECK` constraints also match between the parent and its descendants. (That restriction does not apply to index-based constraints, however.) Also, because selecting from the parent also selects from its descendants, a constraint on the parent cannot be marked valid unless it is also marked valid for those descendants. In all of these cases, `ALTER TABLE ONLY` will be rejected.

A recursive `DROP COLUMN` operation will remove a descendant table's column only if the descendant does not inherit that column from any other parents and never had an independent definition of the column. A nonrecursive `DROP COLUMN` (i.e., `ALTER TABLE ONLY ... DROP COLUMN`) never removes any descendant columns, but instead marks them as independently defined rather than inherited. A nonrecursive `DROP COLUMN` command will fail for a partitioned table, because all partitions of a table must have the same columns as the partitioning root.

The actions for identity columns (`ADD GENERATED`, `SET` etc., `DROP IDENTITY`), as well as the actions `TRIGGER`, `CLUSTER`, `OWNER`, and `TABLESPACE` never recurse to descendant tables; that is, they always act as though `ONLY` were specified. Adding a constraint recurses only for `CHECK` constraints that are not marked `NO INHERIT`.

Changing any part of a system catalog table is not permitted.

Refer to `CREATE TABLE` for a further description of valid parameters. Chapter 5 has further information on inheritance.

## Examples

To add a column of type `varchar` to a table:

```
ALTER TABLE distributors ADD COLUMN address varchar(30);
```

That will cause all existing rows in the table to be filled with null values for the new column.

To add a column with a non-null default:

```
ALTER TABLE measurements
  ADD COLUMN mtime timestamp with time zone DEFAULT now();
```

Existing rows will be filled with the current time as the value of the new column, and then new rows will receive the time of their insertion.

To add a column and fill it with a value different from the default to be used later:

```
ALTER TABLE transactions
  ADD COLUMN status varchar(30) DEFAULT 'old',
  ALTER COLUMN status SET default 'current';
```

Existing rows will be filled with `old`, but then the default for subsequent commands will be `current`. The effects are the same as if the two sub-commands had been issued in separate `ALTER TABLE` commands.

To drop a column from a table:

```
ALTER TABLE distributors DROP COLUMN address RESTRICT;
```

To change the types of two existing columns in one operation:

```
ALTER TABLE distributors
  ALTER COLUMN address TYPE varchar(80),
  ALTER COLUMN name TYPE varchar(100);
```

To change an integer column containing Unix timestamps to timestamp with time zone via a USING clause:

```
ALTER TABLE foo
  ALTER COLUMN foo_timestamp SET DATA TYPE timestamp with time
  zone
  USING
    timestamp with time zone 'epoch' + foo_timestamp * interval
    '1 second';
```

The same, when the column has a default expression that won't automatically cast to the new data type:

```
ALTER TABLE foo
  ALTER COLUMN foo_timestamp DROP DEFAULT,
  ALTER COLUMN foo_timestamp TYPE timestamp with time zone
  USING
    timestamp with time zone 'epoch' + foo_timestamp * interval
    '1 second',
  ALTER COLUMN foo_timestamp SET DEFAULT now();
```

To add hide "ltaut" column:

```
ALTER TABLE distributors WITH UPDATE CURRENT_TIMESTAMP;
```

To add hide "ltapk" column:

```
ALTER TABLE distributors WITH PRIMARY KEY serial;
```

To rename an existing column:

```
ALTER TABLE distributors RENAME COLUMN address TO city;
```

To rename an existing table:

```
ALTER TABLE distributors RENAME TO suppliers;
```

To rename an existing constraint:

```
ALTER TABLE distributors RENAME CONSTRAINT zipchk TO zip_check;
```

To add a not-null constraint to a column:

## ALTER TABLE

---

```
ALTER TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To remove a not-null constraint from a column:

```
ALTER TABLE distributors ALTER COLUMN street DROP NOT NULL;
```

To add a check constraint to a table and all its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK  
(char_length(zipcode) = 5);
```

To add a check constraint only to a table and not to its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK  
(char_length(zipcode) = 5) NO INHERIT;
```

(The check constraint will not be inherited by future children, either.)

To remove a check constraint from a table and all its children:

```
ALTER TABLE distributors DROP CONSTRAINT zipchk;
```

To remove a check constraint from one table only:

```
ALTER TABLE ONLY distributors DROP CONSTRAINT zipchk;
```

(The check constraint remains in place for any child tables.)

To add a foreign key constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY  
(address) REFERENCES addresses (address);
```

To add a foreign key constraint to a table with the least impact on other work:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY  
(address) REFERENCES addresses (address) NOT VALID;  
ALTER TABLE distributors VALIDATE CONSTRAINT distfk;
```

To add a (multicolumn) unique constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT dist_id_zipcode_key UNIQUE  
(dist_id, zipcode);
```

To add an automatically named primary key constraint to a table, noting that a table can only ever have one primary key:

```
ALTER TABLE distributors ADD PRIMARY KEY (dist_id);
```

To move a table to a different tablespace:

```
ALTER TABLE distributors SET TABLESPACE fasttablespace;
```

To move a table to a different schema:

```
ALTER TABLE myschema.distributors SET SCHEMA yourschema;
```

To recreate a primary key constraint, without blocking updates while the index is rebuilt:

```
CREATE UNIQUE INDEX CONCURRENTLY dist_id_temp_idx ON distributors
(dist_id);
ALTER TABLE distributors DROP CONSTRAINT distributors_pkey,
    ADD CONSTRAINT distributors_pkey PRIMARY KEY USING INDEX
    dist_id_temp_idx;
```

To attach a partition to a range-partitioned table:

```
ALTER TABLE measurement
    ATTACH PARTITION measurement_y2016m07 FOR VALUES FROM
    ('2016-07-01') TO ('2016-08-01');
```

To attach a partition to a list-partitioned table:

```
ALTER TABLE cities
    ATTACH PARTITION cities_ab FOR VALUES IN ('a', 'b');
```

To attach a partition to a hash-partitioned table:

```
ALTER TABLE orders
    ATTACH PARTITION orders_p4 FOR VALUES WITH (MODULUS 4,
    REMAINDER 3);
```

To attach a default partition to a partitioned table:

```
ALTER TABLE cities
    ATTACH PARTITION cities_partdef DEFAULT;
```

To detach a partition from a partitioned table:

```
ALTER TABLE measurement
    DETACH PARTITION measurement_y2015m12;
```

To add a range partition to a partitioned table:

```
ALTER TABLE oracle_partition_range ADD PARTITION
    oracle_partition_range_p4 VALUES LESS THAN (to_date('2022-04-01',
    'yyyy-mm-dd'));
```

To add a list partition to a partitioned table:

```
ALTER TABLE oracle_partition_list ADD PARTITION
    oracle_partition_list_p4 VALUES ('0012');
```

To add a list default partition to a partitioned table: (Oracle compatible mode should be specified for the database)

---

```
ALTER TABLE oracle_partition_list ADD PARTITION
oracle_partition_list_pdef VALUES (DEFAULT);
```

To drop a partition from a partitioned table:

```
ALTER TABLE oracle_partition_range DROP PARTITION
oracle_partition_range_p4;
```

To drop a partition from a partitioned table with update global indexes:

```
ALTER TABLE oracle_partition_range DROP PARTITION
oracle_partition_range_p4 UPDATE GLOBAL INDEXES;
```

To truncate a partition from a partitioned table:

```
ALTER TABLE oracle_partition_range TRUNCATE PARTITION
oracle_partition_range_p4;
```

To convert an ordinary table to a partitioned table:

```
ALTER TABLE ordinary_table MODIFY PARTITION BY RANGE(a)
(
    PARTITION p1 VALUES LESS THAN(10),
    PARTITION p2 VALUES LESS THAN(30),
    PARTITION p3 VALUES LESS THAN(20)
)ONLINE UPDATE INDEXES
(
    a_i global,
    b_i local,
    c_i local,
    d_i global
);
```

```
-- list partition
ALTER TABLE test_list_tab MODIFY PARTITION BY LIST (id) (
    PARTITION even VALUES (2, 4, 6, 8),
    PARTITION odd VALUES (1, 3, 5, 7),
    PARTITION rest VALUES (DEFAULT));
```

Demonstration of the use of DROP INDEX suffix syntactic sugar.

```
create table t1(id number, name varchar2(30));

alter table t1 add constraint pk_t1 primary key (id);

alter table t1 drop constraint pk_t1 drop index;

alter table t1 drop primary key drop index;
```

## Compatibility

The forms ADD (without USING INDEX), DROP [COLUMN], DROP IDENTITY, RESTART, SET DEFAULT, SET DATA TYPE (without USING), SET GENERATED, and SET *sequence\_option*



conform with the SQL standard. The other forms are LightDB extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single ALTER TABLE command is an extension.

ALTER TABLE DROP COLUMN can be used to drop the only column of a table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column tables.

ALTER TABLE MODIFY COLUMN can be used to modify column of a table. This is for oracle compatibility.

## Oracle Compatibility

ALTER TABLE MODIFY COLUMN can be used to modify column of a table.

DROP PRIMARY KEY [ RESTRICT | CASCADE ] can be used to drop primary key.

## See Also

CREATE TABLE

---

# ALTER TABLESPACE

ALTER TABLESPACE — change the definition of a tablespace

## Synopsis

```
ALTER TABLESPACE name RENAME TO new_name
ALTER TABLESPACE name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER TABLESPACE name SET ( tablespace_option = value [, ... ] )
ALTER TABLESPACE name RESET ( tablespace_option [, ... ] )
```

## Description

ALTER TABLESPACE can be used to change the definition of a tablespace.

You must own the tablespace to change the definition of a tablespace. To alter the owner, you must also be a direct or indirect member of the new owning role. (Note that superusers have these privileges automatically.)

## Parameters

*name*

The name of an existing tablespace.

*new\_name*

The new name of the tablespace. The new name cannot begin with `pg_`, as such names are reserved for system tablespaces.

*new\_owner*

The new owner of the tablespace.

*tablespace\_option*

A tablespace parameter to be set or reset. Currently, the only available parameters are `seq_page_cost`, `random_page_cost`, `effective_io_concurrency` and `maintenance_io_concurrency`. Setting these values for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, and the executor's prefetching behavior, as established by the configuration parameters of the same name (see `seq_page_cost`, `random_page_cost`, `effective_io_concurrency`, `maintenance_io_concurrency`). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

## Examples

Rename tablespace `index_space` to `fast_raid`:

```
ALTER TABLESPACE index_space RENAME TO fast_raid;
```

Change the owner of tablespace `index_space`:

```
ALTER TABLESPACE index_space OWNER TO mary;
```

## Compatibility

There is no `ALTER TABLESPACE` statement in the SQL standard.

## See Also

`CREATE TABLESPACE`, `DROP TABLESPACE`

---

# ALTER TEXT SEARCH CONFIGURATION

ALTER TEXT SEARCH CONFIGURATION — change the definition of a text search configuration

## Synopsis

```
ALTER TEXT SEARCH CONFIGURATION name
    ADD MAPPING FOR token_type [, ... ] WITH dictionary_name
    [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] WITH dictionary_name
    [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING REPLACE old_dictionary WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] REPLACE old_dictionary
    WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    DROP MAPPING [ IF EXISTS ] FOR token_type [, ... ]
ALTER TEXT SEARCH CONFIGURATION name RENAME TO new_name
ALTER TEXT SEARCH CONFIGURATION name OWNER TO { new_owner |
    CURRENT_USER | SESSION_USER }
ALTER TEXT SEARCH CONFIGURATION name SET SCHEMA new_schema
```

## Description

ALTER TEXT SEARCH CONFIGURATION changes the definition of a text search configuration. You can modify its mappings from token types to dictionaries, or change the configuration's name or owner.

You must be the owner of the configuration to use ALTER TEXT SEARCH CONFIGURATION.

## Parameters

*name*

The name (optionally schema-qualified) of an existing text search configuration.

*token\_type*

The name of a token type that is emitted by the configuration's parser.

*dictionary\_name*

The name of a text search dictionary to be consulted for the specified token type(s). If multiple dictionaries are listed, they are consulted in the specified order.

*old\_dictionary*

The name of a text search dictionary to be replaced in the mapping.

*new\_dictionary*

The name of a text search dictionary to be substituted for *old\_dictionary*.

*new\_name*

The new name of the text search configuration.

*new\_owner*

The new owner of the text search configuration.

*new\_schema*

The new schema for the text search configuration.

The `ADD MAPPING FOR` form installs a list of dictionaries to be consulted for the specified token type(s); it is an error if there is already a mapping for any of the token types. The `ALTER MAPPING FOR` form does the same, but first removing any existing mapping for those token types. The `ALTER MAPPING REPLACE` forms substitute *new\_dictionary* for *old\_dictionary* anywhere the latter appears. This is done for only the specified token types when `FOR` appears, or for all mappings of the configuration when it doesn't. The `DROP MAPPING` form removes all dictionaries for the specified token type(s), causing tokens of those types to be ignored by the text search configuration. It is an error if there is no mapping for the token types, unless `IF EXISTS` appears.

## Examples

The following example replaces the `english` dictionary with the `swedish` dictionary anywhere that `english` is used within `my_config`.

```
ALTER TEXT SEARCH CONFIGURATION my_config
ALTER MAPPING REPLACE english WITH swedish;
```

## Compatibility

There is no `ALTER TEXT SEARCH CONFIGURATION` statement in the SQL standard.

## See Also

`CREATE TEXT SEARCH CONFIGURATION`, `DROP TEXT SEARCH CONFIGURATION`

---

# ALTER TEXT SEARCH DICTIONARY

ALTER TEXT SEARCH DICTIONARY — change the definition of a text search dictionary

## Synopsis

```
ALTER TEXT SEARCH DICTIONARY name (  
    option [ = value ] [, ... ]  
)  
ALTER TEXT SEARCH DICTIONARY name RENAME TO new_name  
ALTER TEXT SEARCH DICTIONARY name OWNER TO { new_owner |  
    CURRENT_USER | SESSION_USER }  
ALTER TEXT SEARCH DICTIONARY name SET SCHEMA new_schema
```

## Description

ALTER TEXT SEARCH DICTIONARY changes the definition of a text search dictionary. You can change the dictionary's template-specific options, or change the dictionary's name or owner.

You must be the owner of the dictionary to use ALTER TEXT SEARCH DICTIONARY.

## Parameters

*name*

The name (optionally schema-qualified) of an existing text search dictionary.

*option*

The name of a template-specific option to be set for this dictionary.

*value*

The new value to use for a template-specific option. If the equal sign and value are omitted, then any previous setting for the option is removed from the dictionary, allowing the default to be used.

*new\_name*

The new name of the text search dictionary.

*new\_owner*

The new owner of the text search dictionary.

*new\_schema*

The new schema for the text search dictionary.

Template-specific options can appear in any order.

## Examples

The following example command changes the stopword list for a Snowball-based dictionary. Other parameters remain unchanged.

## ALTER TEXT SEARCH DICTIONARY

---

```
ALTER TEXT SEARCH DICTIONARY my_dict ( StopWords = newrussian );
```

The following example command changes the language option to `dutch`, and removes the stopword option entirely.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( language = dutch,  
StopWords );
```

The following example command “updates” the dictionary's definition without actually changing anything.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( dummy );
```

(The reason this works is that the option removal code doesn't complain if there is no such option.) This trick is useful when changing configuration files for the dictionary: the `ALTER` will force existing database sessions to re-read the configuration files, which otherwise they would never do if they had read them earlier.

## Compatibility

There is no `ALTER TEXT SEARCH DICTIONARY` statement in the SQL standard.

## See Also

`CREATE TEXT SEARCH DICTIONARY`, `DROP TEXT SEARCH DICTIONARY`

---

# ALTER TEXT SEARCH PARSER

ALTER TEXT SEARCH PARSER — change the definition of a text search parser

## Synopsis

```
ALTER TEXT SEARCH PARSER name RENAME TO new_name
ALTER TEXT SEARCH PARSER name SET SCHEMA new_schema
```

## Description

ALTER TEXT SEARCH PARSER changes the definition of a text search parser. Currently, the only supported functionality is to change the parser's name.

You must be a superuser to use ALTER TEXT SEARCH PARSER.

## Parameters

*name*

The name (optionally schema-qualified) of an existing text search parser.

*new\_name*

The new name of the text search parser.

*new\_schema*

The new schema for the text search parser.

## Compatibility

There is no ALTER TEXT SEARCH PARSER statement in the SQL standard.

## See Also

CREATE TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER



---

# ALTER TEXT SEARCH TEMPLATE

ALTER TEXT SEARCH TEMPLATE — change the definition of a text search template

## Synopsis

```
ALTER TEXT SEARCH TEMPLATE name RENAME TO new_name
ALTER TEXT SEARCH TEMPLATE name SET SCHEMA new_schema
```

## Description

ALTER TEXT SEARCH TEMPLATE changes the definition of a text search template. Currently, the only supported functionality is to change the template's name.

You must be a superuser to use ALTER TEXT SEARCH TEMPLATE.

## Parameters

*name*

The name (optionally schema-qualified) of an existing text search template.

*new\_name*

The new name of the text search template.

*new\_schema*

The new schema for the text search template.

## Compatibility

There is no ALTER TEXT SEARCH TEMPLATE statement in the SQL standard.

## See Also

CREATE TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

---

# ALTER TRIGGER

ALTER TRIGGER — change the definition of a trigger

## Synopsis

```
ALTER TRIGGER name ON table_name RENAME TO new_name
ALTER TRIGGER name ON table_name [ NO ] DEPENDS ON
EXTENSION extension_name
```

## Description

ALTER TRIGGER changes properties of an existing trigger. The RENAME clause changes the name of the given trigger without otherwise changing the trigger definition. The DEPENDS ON EXTENSION clause marks the trigger as dependent on an extension, such that if the extension is dropped, the trigger will automatically be dropped as well.

You must own the table on which the trigger acts to be allowed to change its properties.

## Parameters

*name*

The name of an existing trigger to alter.

*table\_name*

The name of the table on which this trigger acts.

*new\_name*

The new name for the trigger.

*extension\_name*

The name of the extension that the trigger is to depend on (or no longer dependent on, if NO is specified). A trigger that's marked as dependent on an extension is automatically dropped when the extension is dropped.

## Notes

The ability to temporarily enable or disable a trigger is provided by ALTER TABLE, not by ALTER TRIGGER, because ALTER TRIGGER has no convenient way to express the option of enabling or disabling all of a table's triggers at once.

## Examples

To rename an existing trigger:

```
ALTER TRIGGER emp_stamp ON emp RENAME TO emp_track_chgs;
```

To mark a trigger as being dependent on an extension:

```
ALTER TRIGGER emp_stamp ON emp DEPENDS ON EXTENSION emplib;
```

## Compatibility

ALTER TRIGGER is a LightDB extension of the SQL standard.

## See Also

ALTER TABLE

---

# ALTER TYPE

ALTER TYPE — change the definition of a type

## Synopsis

```
ALTER TYPE name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }  
ALTER TYPE name RENAME TO new_name  
ALTER TYPE name SET SCHEMA new_schema  
ALTER TYPE name RENAME ATTRIBUTE attribute_name  
TO new_attribute_name [ CASCADE | RESTRICT ]  
ALTER TYPE name action [, ... ]  
ALTER TYPE name ADD VALUE [ IF NOT EXISTS ] new_enum_value  
[ { BEFORE | AFTER } neighbor_enum_value ]  
ALTER TYPE name RENAME VALUE existing_enum_value TO new_enum_value  
ALTER TYPE name SET ( property = value [, ... ] )
```

where *action* is one of:

```
ADD ATTRIBUTE attribute_name data_type [ COLLATE collation ]  
[ CASCADE | RESTRICT ]  
DROP ATTRIBUTE [ IF EXISTS ] attribute_name [ CASCADE |  
RESTRICT ]  
ALTER ATTRIBUTE attribute_name [ SET DATA ] TYPE data_type  
[ COLLATE collation ] [ CASCADE | RESTRICT ]
```

## Description

ALTER TYPE changes the definition of an existing type. There are several subforms:

OWNER

This form changes the owner of the type.

RENAME

This form changes the name of the type.

SET SCHEMA

This form moves the type into another schema.

RENAME ATTRIBUTE

This form is only usable with composite types. It changes the name of an individual attribute of the type.

ADD ATTRIBUTE

This form adds a new attribute to a composite type, using the same syntax as CREATE TYPE.

DROP ATTRIBUTE [ IF EXISTS ]

This form drops an attribute from a composite type. If IF EXISTS is specified and the attribute does not exist, no error is thrown. In this case a notice is issued instead.

ALTER ATTRIBUTE ... SET DATA TYPE

This form changes the type of an attribute of a composite type.

ADD VALUE [ IF NOT EXISTS ] [ BEFORE | AFTER ]

This form adds a new value to an enum type. The new value's place in the enum's ordering can be specified as being `BEFORE` or `AFTER` one of the existing values. Otherwise, the new item is added at the end of the list of values.

If `IF NOT EXISTS` is specified, it is not an error if the type already contains the new value: a notice is issued but no other action is taken. Otherwise, an error will occur if the new value is already present.

RENAME VALUE

This form renames a value of an enum type. The value's place in the enum's ordering is not affected. An error will occur if the specified value is not present or the new name is already present.

SET ( *property* = *value* [ , ... ] )

This form is only applicable to base types. It allows adjustment of a subset of the base-type properties that can be set in `CREATE TYPE`. Specifically, these properties can be changed:

- `RECEIVE` can be set to the name of a binary input function, or `NONE` to remove the type's binary input function. Using this option requires superuser privilege.
- `SEND` can be set to the name of a binary output function, or `NONE` to remove the type's binary output function. Using this option requires superuser privilege.
- `TYPMOD_IN` can be set to the name of a type modifier input function, or `NONE` to remove the type's type modifier input function. Using this option requires superuser privilege.
- `TYPMOD_OUT` can be set to the name of a type modifier output function, or `NONE` to remove the type's type modifier output function. Using this option requires superuser privilege.
- `ANALYZE` can be set to the name of a type-specific statistics collection function, or `NONE` to remove the type's statistics collection function. Using this option requires superuser privilege.
- `STORAGE` can be set to `plain`, `extended`, `external`, or `main` (see Section 64.2 for more information about what these mean). However, changing from `plain` to another setting requires superuser privilege (because it requires that the type's C functions all be `TOAST-ready`), and changing to `plain` from another setting is not allowed at all (since the type may already have `TOASTed` values present in the database). Note that changing this option doesn't by itself change any stored data, it just sets the default `TOAST` strategy to be used for table columns created in the future. See `ALTER TABLE` to change the `TOAST` strategy for existing table columns.

See `CREATE TYPE` for more details about these type properties. Note that where appropriate, a change in these properties for a base type will be propagated automatically to domains based on that type.

The `ADD ATTRIBUTE`, `DROP ATTRIBUTE`, and `ALTER ATTRIBUTE` actions can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several attributes and/or alter the type of several attributes in a single command.

You must own the type to use `ALTER TYPE`. To change the schema of a type, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the type's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the type. However, a superuser can alter ownership of any type anyway.) To add an attribute or alter an attribute type, you must also have `USAGE` privilege on the attribute's data type.

## Parameters

*name*

The name (possibly schema-qualified) of an existing type to alter.

*new\_name*

The new name for the type.

*new\_owner*

The user name of the new owner of the type.

*new\_schema*

The new schema for the type.

*attribute\_name*

The name of the attribute to add, alter, or drop.

*new\_attribute\_name*

The new name of the attribute to be renamed.

*data\_type*

The data type of the attribute to add, or the new type of the attribute to alter.

*new\_enum\_value*

The new value to be added to an enum type's list of values, or the new name to be given to an existing value. Like all enum literals, it needs to be quoted.

*neighbor\_enum\_value*

The existing enum value that the new value should be added immediately before or after in the enum type's sort ordering. Like all enum literals, it needs to be quoted.

*existing\_enum\_value*

The existing enum value that should be renamed. Like all enum literals, it needs to be quoted.

*property*

The name of a base-type property to be modified; see above for possible values.

CASCADE

Automatically propagate the operation to typed tables of the type being altered, and their descendants.

RESTRICT

Refuse the operation if the type being altered is the type of a typed table. This is the default.

## Notes

If ALTER TYPE ... ADD VALUE (the form that adds a new value to an enum type) is executed inside a transaction block, the new value cannot be used until after the transaction has been committed.

Comparisons involving an added enum value will sometimes be slower than comparisons involving only original members of the enum type. This will usually only occur if `BEFORE` or `AFTER` is used to set the new value's sort position somewhere other than at the end of the list. However, sometimes it will happen even though the new value is added at the end (this occurs if the OID counter “wrapped around” since the original creation of the enum type). The slowdown is usually insignificant; but if it matters, optimal performance can be regained by dropping and recreating the enum type, or by dumping and restoring the database.

## Examples

To rename a data type:

```
ALTER TYPE electronic_mail RENAME TO email;
```

To change the owner of the type `email` to `joe`:

```
ALTER TYPE email OWNER TO joe;
```

To change the schema of the type `email` to `customers`:

```
ALTER TYPE email SET SCHEMA customers;
```

To add a new attribute to a composite type:

```
ALTER TYPE compfoo ADD ATTRIBUTE f3 int;
```

To add a new value to an enum type in a particular sort position:

```
ALTER TYPE colors ADD VALUE 'orange' AFTER 'red';
```

To rename an enum value:

```
ALTER TYPE colors RENAME VALUE 'purple' TO 'mauve';
```

To create binary I/O functions for an existing base type:

```
CREATE FUNCTION mytypesend(mytype) RETURNS bytea ...;
CREATE FUNCTION mytyperecv(internal, oid, integer) RETURNS
  mytype ...;
ALTER TYPE mytype SET (
  SEND = mytypesend,
  RECEIVE = mytyperecv
);
```

## Compatibility

The variants to add and drop attributes are part of the SQL standard; the other variants are LightDB extensions.

## See Also

CREATE TYPE, DROP TYPE

---

# ALTER USER

ALTER USER — change a database role

## Synopsis

```
ALTER USER role_specification [ WITH ] option [ ... ]
```

where *option* can be:

```
SUPERUSER | NOSUPERUSER
|
CREATEDB | NOCREATEDB
|
CREATEROLE | NOCREATEROLE
|
INHERIT | NOINHERIT
|
LOGIN | NOLOGIN
|
REPLICATION | NOREPLICATION
|
BYPASSRLS | NOBYPASSRLS
|
CONNECTION LIMIT conlimit
|
[ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL
|
VALID UNTIL 'timestamp'
```

```
ALTER USER name RENAME TO new_name
```

```
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter { TO | = } { value | DEFAULT }
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter FROM CURRENT
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] RESET configuration_parameter
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] RESET ALL
```

where *role\_specification* can be:

```
role_name
|
CURRENT_USER
|
SESSION_USER
```

## Description

ALTER USER is now an alias for ALTER ROLE.

## Compatibility

The ALTER USER statement is a LightDB extension. The SQL standard leaves the definition of users to the implementation.

## See Also

ALTER ROLE



---

# ALTER USER MAPPING

ALTER USER MAPPING — change the definition of a user mapping

## Synopsis

```
ALTER USER MAPPING FOR { user_name | USER | CURRENT_USER |  
SESSION_USER | PUBLIC }  
SERVER server_name  
OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

## Description

ALTER USER MAPPING changes the definition of a user mapping.

The owner of a foreign server can alter user mappings for that server for any user. Also, a user can alter a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

## Parameters

*user\_name*

User name of the mapping. CURRENT\_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

*server\_name*

Server name of the user mapping.

```
OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

Change options for the user mapping. The new options override any previously specified options. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; options are also validated by the server's foreign-data wrapper.

## Examples

Change the password for user mapping bob, server foo:

```
ALTER USER MAPPING FOR bob SERVER foo OPTIONS (SET password  
'public');
```

## Compatibility

ALTER USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). There is a subtle syntax issue: The standard omits the FOR key word. Since both CREATE USER MAPPING and DROP USER MAPPING use FOR in analogous positions, and IBM DB2 (being the other major SQL/MED implementation) also requires it for ALTER USER MAPPING, LightDB diverges from the standard here in the interest of consistency and interoperability.

## See Also

CREATE USER MAPPING, DROP USER MAPPING

---

# ALTER VIEW

ALTER VIEW — change the definition of a view

## Synopsis

```
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name SET
  DEFAULT expression
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name DROP
  DEFAULT
ALTER VIEW [ IF EXISTS ] name OWNER TO { new_owner | CURRENT_USER |
  SESSION_USER }
ALTER VIEW [ IF EXISTS ] name RENAME [ COLUMN ] column_name
  TO new_column_name
ALTER VIEW [ IF EXISTS ] name RENAME TO new_name
ALTER VIEW [ IF EXISTS ] name SET SCHEMA new_schema
ALTER VIEW [ IF EXISTS ] name SET ( view_option_name
  [= view_option_value] [, ... ] )
ALTER VIEW [ IF EXISTS ] name RESET ( view_option_name [, ... ] )
```

## Description

ALTER VIEW changes various auxiliary properties of a view. (If you want to modify the view's defining query, use CREATE OR REPLACE VIEW.)

You must own the view to use ALTER VIEW. To change a view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the view. However, a superuser can alter ownership of any view anyway.)

## Parameters

*name*

The name (optionally schema-qualified) of an existing view.

*column\_name*

Name of an existing column.

*new\_column\_name*

New name for an existing column.

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

SET/DROP DEFAULT

These forms set or remove the default value for a column. A view column's default value is substituted into any INSERT or UPDATE command whose target is the view, before applying any rules or triggers for the view. The view's default will therefore take precedence over any default values from underlying relations.

*new\_owner*

The user name of the new owner of the view.

*new\_name*

The new name for the view.

*new\_schema*

The new schema for the view.

SET ( *view\_option\_name* [= *view\_option\_value*] [, ... ] )

RESET ( *view\_option\_name* [, ... ] )

Sets or resets a view option. Currently supported options are:

*check\_option* (enum)

Changes the check option of the view. The value must be `local` or `cascaded`.

*security\_barrier* (boolean)

Changes the security-barrier property of the view. The value must be Boolean value, such as `true` or `false`.

## Notes

For historical reasons, `ALTER TABLE` can be used with views too; but the only variants of `ALTER TABLE` that are allowed with views are equivalent to the ones shown above.

## Examples

To rename the view `foo` to `bar`:

```
ALTER VIEW foo RENAME TO bar;
```

To attach a default column value to an updatable view:

```
CREATE TABLE base_table (id int, ts timestamptz);
CREATE VIEW a_view AS SELECT * FROM base_table;
ALTER VIEW a_view ALTER COLUMN ts SET DEFAULT now();
INSERT INTO base_table(id) VALUES(1); -- ts will receive a NULL
INSERT INTO a_view(id) VALUES(2); -- ts will receive the current
time
```

## Compatibility

`ALTER VIEW` is a LightDB extension of the SQL standard.

## See Also

`CREATE VIEW`, `DROP VIEW`

---

# ANALYZE

ANALYZE — collect statistics about a database

## Synopsis

```
ANALYZE [ ( option [, ...] ) ] [ table_and_columns [, ...] ]
ANALYZE [ VERBOSE ] [ table_and_columns [, ...] ]
```

where *option* can be one of:

```
VERBOSE [ boolean ]
SKIP_LOCKED [ boolean ]
```

and *table\_and\_columns* is:

```
table_name [ ( column_name [, ...] ) ]
```

## Description

ANALYZE collects statistics about the contents of tables in the database, and stores the results in the `pg_statistic` system catalog. Subsequently, the query planner uses these statistics to help determine the most efficient execution plans for queries.

Without a *table\_and\_columns* list, ANALYZE processes every table and materialized view in the current database that the current user has permission to analyze. With a list, ANALYZE processes only those table(s). It is further possible to give a list of column names for a table, in which case only the statistics for those columns are collected.

When the option list is surrounded by parentheses, the options can be written in any order. The parenthesized syntax was added in LightDB 11; the unparenthesized syntax is deprecated.

## Parameters

VERBOSE

Enables display of progress messages.

SKIP\_LOCKED

Specifies that ANALYZE should not wait for any conflicting locks to be released when beginning work on a relation: if a relation cannot be locked immediately without waiting, the relation is skipped. Note that even with this option, ANALYZE may still block when opening the relation's indexes or when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while ANALYZE ordinarily processes all partitions of specified partitioned tables, this option will cause ANALYZE to skip all partitions if there is a conflicting lock on the partitioned table.

*boolean*

Specifies whether the selected option should be turned on or off. You can write TRUE, ON, or 1 to enable the option, and FALSE, OFF, or 0 to disable it. The *boolean* value can also be omitted, in which case TRUE is assumed.

*table\_name*

The name (possibly schema-qualified) of a specific table to analyze. If omitted, all regular tables, partitioned tables, and materialized views in the current database are analyzed (but not foreign tables). If the specified table is a partitioned table, both the inheritance statistics of the partitioned table as a whole and statistics of the individual partitions are updated.

*column\_name*

The name of a specific column to analyze. Defaults to all columns.

## Outputs

When `VERBOSE` is specified, `ANALYZE` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

## Notes

To analyze a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to analyze all tables in their databases, except shared catalogs. (The restriction for shared catalogs means that a true database-wide `ANALYZE` can only be performed by a superuser.) `ANALYZE` will skip over any tables that the calling user does not have permission to analyze.

Foreign tables are analyzed only when explicitly selected. Not all foreign data wrappers support `ANALYZE`. If the table's wrapper does not support `ANALYZE`, the command prints a warning and does nothing.

In the default LightDB configuration, the autovacuum daemon (see Section 22.1.6) takes care of automatic analyzing of tables when they are first loaded with data, and as they change throughout regular operation. When autovacuum is disabled, it is a good idea to run `ANALYZE` periodically, or just after making major changes in the contents of a table. Accurate statistics will help the planner to choose the most appropriate query plan, and thereby improve the speed of query processing. A common strategy for read-mostly databases is to run `VACUUM` and `ANALYZE` once a day during a low-usage time of day. (This will not be sufficient if there is heavy update activity.)

`ANALYZE` requires only a read lock on the target table, so it can run in parallel with other activity on the table.

The statistics collected by `ANALYZE` usually include a list of some of the most common values in each column and a histogram showing the approximate data distribution in each column. One or both of these can be omitted if `ANALYZE` deems them uninteresting (for example, in a unique-key column, there are no common values) or if the column data type does not support the appropriate operators. There is more information about the statistics in Chapter 22.

For large tables, `ANALYZE` takes a random sample of the table contents, rather than examining every row. This allows even very large tables to be analyzed in a small amount of time. Note, however, that the statistics are only approximate, and will change slightly each time `ANALYZE` is run, even if the actual table contents did not change. This might result in small changes in the planner's estimated costs shown by `EXPLAIN`. In rare situations, this non-determinism will cause the planner's choices of query plans to change after `ANALYZE` is run. To avoid this, raise the amount of statistics collected by `ANALYZE`, as described below.

The extent of analysis can be controlled by adjusting the `default_statistics_target` configuration variable, or on a column-by-column basis by setting the per-column statistics target with `ALTER TABLE ... ALTER COLUMN ... SET STATISTICS` (see `ALTER TABLE`). The target value sets the maximum number of entries in the most-common-value list and the maximum number of bins in the histogram. The default target value is 100, but this can be adjusted up or down to trade off accuracy of planner estimates against the time taken for `ANALYZE` and the amount of space occupied in `pg_statistic`. In particular, setting the statistics target to zero disables collection of statistics

for that column. It might be useful to do that for columns that are never used as part of the `WHERE`, `GROUP BY`, or `ORDER BY` clauses of queries, since the planner will have no use for statistics on such columns.

The largest statistics target among the columns being analyzed determines the number of table rows sampled to prepare the statistics. Increasing the target causes a proportional increase in the time and space needed to do `ANALYZE`.

One of the values estimated by `ANALYZE` is the number of distinct values that appear in each column. Because only a subset of the rows are examined, this estimate can sometimes be quite inaccurate, even with the largest possible statistics target. If this inaccuracy leads to bad query plans, a more accurate value can be determined manually and then installed with `ALTER TABLE ... ALTER COLUMN ... SET (n_distinct = ...)` (see `ALTER TABLE`).

If the table being analyzed has one or more children, `ANALYZE` will gather statistics twice: once on the rows of the parent table only, and a second time on the rows of the parent table with all of its children. This second set of statistics is needed when planning queries that traverse the entire inheritance tree. The autovacuum daemon, however, will only consider inserts or updates on the parent table itself when deciding whether to trigger an automatic analyze for that table. If that table is rarely inserted into or updated, the inheritance statistics will not be up to date unless you run `ANALYZE` manually.

For partitioned tables, `ANALYZE` gathers statistics by sampling rows from all partitions; in addition, it will recurse into each partition and update its statistics. Each leaf partition is analyzed only once, even with multi-level partitioning. No statistics are collected for only the parent table (without data from its partitions), because with partitioning it's guaranteed to be empty.

By contrast, if the table being analyzed has inheritance children, `ANALYZE` gathers two sets of statistics: one on the rows of the parent table only, and a second including rows of both the parent table and all of its children. This second set of statistics is needed when planning queries that process the inheritance tree as a whole. The child tables themselves are not individually analyzed in this case.

The autovacuum daemon does not process partitioned tables, nor does it process inheritance parents if only the children are ever modified. It is usually necessary to periodically run a manual `ANALYZE` to keep the statistics of the table hierarchy up to date.

If any child tables or partitions are foreign tables whose foreign data wrappers do not support `ANALYZE`, those tables are ignored while gathering inheritance statistics.

If the table being analyzed is completely empty, `ANALYZE` will not record new statistics for that table. Any existing statistics will be retained.

## Compatibility

There is no `ANALYZE` statement in the SQL standard.

## See Also

`VACUUM`, `vacuumdb`, Section 17.4.4, Section 22.1.6

---

# BEGIN

BEGIN — start a transaction block

## Synopsis

```
BEGIN [ WORK | TRANSACTION ] [ transaction_mode [, ...] ]
```

where *transaction\_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ  
COMMITTED | READ UNCOMMITTED }  
READ WRITE | READ ONLY  
[ NOT ] DEFERRABLE
```

## Description

BEGIN initiates a transaction block, that is, all statements after a BEGIN command will be executed in a single transaction until an explicit COMMIT or ROLLBACK is given. By default (without BEGIN), LightDB executes transactions in “autocommit” mode, that is, each statement is executed in its own transaction and a commit is implicitly performed at the end of the statement (if execution was successful, otherwise a rollback is done).

Statements are executed more quickly in a transaction block, because transaction start/commit requires significant CPU and disk activity. Execution of multiple statements inside a transaction is also useful to ensure consistency when making several related changes: other sessions will be unable to see the intermediate states wherein not all the related updates have been done.

If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed.

## Parameters

WORK  
TRANSACTION

Optional key words. They have no effect.

Refer to SET TRANSACTION for information on the meaning of the other parameters to this statement.

## Notes

START TRANSACTION has the same functionality as BEGIN.

Use COMMIT or ROLLBACK to terminate a transaction block.

Issuing BEGIN when already inside a transaction block will provoke a warning message. The state of the transaction is not affected. To nest transactions within a transaction block, use savepoints (see SAVEPOINT).

For reasons of backwards compatibility, the commas between successive *transaction\_modes* can be omitted.

## Examples

To begin a transaction block:

```
BEGIN;
```

## Compatibility

BEGIN is a LightDB language extension. It is equivalent to the SQL-standard command START TRANSACTION, whose reference page contains additional compatibility information.

The DEFERRABLE *transaction\_mode* is a LightDB language extension.

Incidentally, the BEGIN key word is used for a different purpose in embedded SQL. You are advised to be careful about the transaction semantics when porting database applications.

## See Also

COMMIT, ROLLBACK, START TRANSACTION, SAVEPOINT



---

# CALL

CALL — invoke a procedure

## Synopsis

```
CALL name ( [ argument ] [ , ... ] )
```

## Description

CALL executes a procedure.

If the procedure has any output parameters, then a result row will be returned, containing the values of those parameters.

## Parameters

*name*

The name (optionally schema-qualified) of the procedure.

*argument*

An input argument for the procedure call. See Section 4.3 for the full details on function and procedure call syntax, including use of named parameters.

## Notes

The user must have EXECUTE privilege on the procedure in order to be allowed to invoke it.

To call a function (not a procedure), use SELECT instead.

If CALL is executed in a transaction block, then the called procedure cannot execute transaction control statements. Transaction control statements are only allowed if CALL is executed in its own transaction.

PL/pgSQL handles output parameters in CALL commands differently; see Section 41.6.3.

## Examples

```
CALL do_db_maintenance();
```

## Compatibility

CALL conforms to the SQL standard.

## See Also

CREATE PROCEDURE

---

# CHECKPOINT

CHECKPOINT — force a write-ahead log checkpoint

## Synopsis

CHECKPOINT

## Description

A checkpoint is a point in the write-ahead log sequence at which all data files have been updated to reflect the information in the log. All data files will be flushed to disk. Refer to Section 27.4 for more details about what happens during a checkpoint.

The CHECKPOINT command forces an immediate checkpoint when the command is issued, without waiting for a regular checkpoint scheduled by the system (controlled by the settings in Section 17.5.2). CHECKPOINT is not intended for use during normal operation.

If executed during recovery, the CHECKPOINT command will force a restartpoint (see Section 27.4) rather than writing a new checkpoint.

Only superusers can call CHECKPOINT.

## Compatibility

The CHECKPOINT command is a LightDB language extension.

---

# CLOSE

CLOSE — close a cursor

## Synopsis

```
CLOSE { name | ALL }
```

## Description

CLOSE frees the resources associated with an open cursor. After the cursor is closed, no subsequent operations are allowed on it. A cursor should be closed when it is no longer needed.

Every non-holdable open cursor is implicitly closed when a transaction is terminated by COMMIT or ROLLBACK. A holdable cursor is implicitly closed if the transaction that created it aborts via ROLLBACK. If the creating transaction successfully commits, the holdable cursor remains open until an explicit CLOSE is executed, or the client disconnects.

## Parameters

*name*

The name of an open cursor to close.

ALL

Close all open cursors.

## Notes

LightDB does not have an explicit OPEN cursor statement; a cursor is considered open when it is declared. Use the DECLARE statement to declare a cursor.

You can see all available cursors by querying the `pg_cursors` system view.

If a cursor is closed after a savepoint which is later rolled back, the CLOSE is not rolled back; that is, the cursor remains closed.

## Examples

Close the cursor `liahona`:

```
CLOSE liahona;
```

## Compatibility

CLOSE is fully conforming with the SQL standard. CLOSE ALL is a LightDB extension.

## See Also

DECLARE, FETCH, MOVE

---

# CLUSTER

CLUSTER — cluster a table according to an index

## Synopsis

```
CLUSTER [VERBOSE] table_name [ USING index_name ]  
CLUSTER [VERBOSE]
```

## Description

CLUSTER instructs LightDB to cluster the table specified by *table\_name* based on the index specified by *index\_name*. The index must already have been defined on *table\_name*.

When a table is clustered, it is physically reordered based on the index information. Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order. (If one wishes, one can periodically recluster by issuing the command again. Also, setting the table's `fillfactor` storage parameter to less than 100% can aid in preserving cluster ordering during updates, since updated rows are kept on the same page if enough space is available there.)

When a table is clustered, LightDB remembers which index it was clustered by. The form `CLUSTER table_name` reclusters the table using the same index as before. You can also use the `CLUSTER` or `SET WITHOUT CLUSTER` forms of `ALTER TABLE` to set the index to be used for future cluster operations, or to clear any previous setting.

CLUSTER without any parameter reclusters all the previously-clustered tables in the current database that the calling user owns, or all such tables if called by a superuser. This form of CLUSTER cannot be executed inside a transaction block.

When a table is being clustered, an `ACCESS EXCLUSIVE` lock is acquired on it. This prevents any other database operations (both reads and writes) from operating on the table until the CLUSTER is finished.

## Parameters

*table\_name*

The name (possibly schema-qualified) of a table.

*index\_name*

The name of an index.

VERBOSE

Prints a progress report as each table is clustered.

## Notes

In cases where you are accessing single rows randomly within a table, the actual order of the data in the table is unimportant. However, if you tend to access some data more than others, and there is an index that groups them together, you will benefit from using CLUSTER. If you are requesting a range of indexed values from a table, or a single indexed value that has multiple rows that match, CLUSTER will help because once the index identifies the table page for the first row that matches,

all other rows that match are probably already on the same table page, and so you save disk accesses and speed up the query.

CLUSTER can re-sort the table using either an index scan on the specified index, or (if the index is a b-tree) a sequential scan followed by sorting. It will attempt to choose the method that will be faster, based on planner cost parameters and available statistical information.

When an index scan is used, a temporary copy of the table is created that contains the table data in the index order. Temporary copies of each index on the table are created as well. Therefore, you need free space on disk at least equal to the sum of the table size and the index sizes.

When a sequential scan and sort is used, a temporary sort file is also created, so that the peak temporary space requirement is as much as double the table size, plus the index sizes. This method is often faster than the index scan method, but if the disk space requirement is intolerable, you can disable this choice by temporarily setting `enable_sort` to `off`.

It is advisable to set `maintenance_work_mem` to a reasonably large value (but not more than the amount of RAM you can dedicate to the CLUSTER operation) before clustering.

Because the planner records statistics about the ordering of tables, it is advisable to run ANALYZE on the newly clustered table. Otherwise, the planner might make poor choices of query plans.

Because CLUSTER remembers which indexes are clustered, one can cluster the tables one wants clustered manually the first time, then set up a periodic maintenance script that executes CLUSTER without any parameters, so that the desired tables are periodically reclustered.

## Examples

Cluster the table `employees` on the basis of its index `employees_ind`:

```
CLUSTER employees USING employees_ind;
```

Cluster the `employees` table using the same index that was used before:

```
CLUSTER employees;
```

Cluster all tables in the database that have previously been clustered:

```
CLUSTER;
```

## Compatibility

There is no CLUSTER statement in the SQL standard.

The syntax

```
CLUSTER index_name ON table_name
```

is also supported for compatibility with pre-8.3 LightDB versions.

## See Also

`clusterdb`

---

# COMMENT

COMMENT — define or change the comment of an object

## Synopsis

```
COMMENT ON
{
ACCESS METHOD object_name |
AGGREGATE aggregate_name ( aggregate_signature ) |
CAST ( source_type AS target_type ) |
COLLATION object_name |
COLUMN relation_name.column_name |
CONSTRAINT constraint_name ON table_name |
CONSTRAINT constraint_name ON DOMAIN domain_name |
CONVERSION object_name |
DATABASE object_name |
DOMAIN object_name |
EXTENSION object_name |
EVENT TRIGGER object_name |
FOREIGN DATA WRAPPER object_name |
FOREIGN TABLE object_name |
FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
INDEX object_name |
LARGE OBJECT large_object_oid |
MATERIALIZED VIEW object_name |
OPERATOR operator_name ( left_type, right_type ) |
OPERATOR CLASS object_name USING index_method |
OPERATOR FAMILY object_name USING index_method |
POLICY policy_name ON table_name |
[ PROCEDURAL ] LANGUAGE object_name |
PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
PUBLICATION object_name |
ROLE object_name |
ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
RULE rule_name ON table_name |
SCHEMA object_name |
SEQUENCE object_name |
SERVER object_name |
STATISTICS object_name |
SUBSCRIPTION object_name |
TABLE object_name |
TABLESPACE object_name |
TEXT SEARCH CONFIGURATION object_name |
TEXT SEARCH DICTIONARY object_name |
TEXT SEARCH PARSER object_name |
TEXT SEARCH TEMPLATE object_name |
TRANSFORM FOR type_name LANGUAGE lang_name |
TRIGGER trigger_name ON table_name |
TYPE object_name |
VIEW object_name
```

```

} IS 'text'

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]

```

## Description

COMMENT stores a comment about a database object.

Only one comment string is stored for each object, so to modify a comment, issue a new COMMENT command for the same object. To remove a comment, write NULL in place of the text string. Comments are automatically dropped when their object is dropped.

A SHARE UPDATE EXCLUSIVE lock is acquired on the object to be commented.

For most kinds of object, only the object's owner can set the comment. Roles don't have owners, so the rule for COMMENT ON ROLE is that you must be superuser to comment on a superuser role, or have the CREATEROLE privilege to comment on non-superuser roles. Likewise, access methods don't have owners either; you must be superuser to comment on an access method. Of course, a superuser can comment on anything.

Comments can be viewed using Itsql's \d family of commands. Other user interfaces to retrieve comments can be built atop the same built-in functions that Itsql uses, namely obj\_description, col\_description, and shobj\_description (see Table 9.74).

## Parameters

```

object_name
relation_name.column_name
aggregate_name
constraint_name
function_name
operator_name
policy_name
procedure_name
routine_name
rule_name
trigger_name

```

The name of the object to be commented. Names of tables, aggregates, collations, conversions, domains, foreign tables, functions, indexes, operators, operator classes, operator families, procedures, routines, sequences, statistics, text search objects, types, and views can be schema-qualified. When commenting on a column, *relation\_name* must refer to a table, view, composite type, or foreign table.

```

table_name
domain_name

```

When creating a comment on a constraint, a trigger, a rule or a policy these parameters specify the name of the table or domain on which that object is defined.

```

source_type

```

The name of the source data type of the cast.

*target\_type*

The name of the target data type of the cast.

*argmode*

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that COMMENT does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

*argname*

The name of a function, procedure, or aggregate argument. Note that COMMENT does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

*argtype*

The data type of a function, procedure, or aggregate argument.

*large\_object\_oid*

The OID of the large object.

*left\_type*

*right\_type*

The data type(s) of the operator's arguments (optionally schema-qualified). Write NONE for the missing argument of a prefix or postfix operator.

PROCEDURAL

This is a noise word.

*type\_name*

The name of the data type of the transform.

*lang\_name*

The name of the language of the transform.

*text*

The new comment, written as a string literal; or NULL to drop the comment.

## Notes

There is presently no security mechanism for viewing comments: any user connected to a database can see all the comments for objects in that database. For shared objects such as databases, roles, and tablespaces, comments are stored globally so any user connected to any database in the cluster can see all the comments for shared objects. Therefore, don't put security-critical information in comments.

## Examples

Attach a comment to the table `mytable`:



## COMMENT

---

```
COMMENT ON TABLE mytable IS 'This is my table.';
```

Remove it again:

```
COMMENT ON TABLE mytable IS NULL;
```

Some more examples:

```
COMMENT ON ACCESS METHOD gin IS 'GIN index access method';
COMMENT ON AGGREGATE my_aggregate (double precision) IS 'Computes
  sample variance';
COMMENT ON CAST (text AS int4) IS 'Allow casts from text to int4';
COMMENT ON COLLATION "fr_CA" IS 'Canadian French';
COMMENT ON COLUMN my_table.my_column IS 'Employee ID number';
COMMENT ON CONVERSION my_conv IS 'Conversion to UTF8';
COMMENT ON CONSTRAINT bar_col_cons ON bar IS 'Constrains column
  col';
COMMENT ON CONSTRAINT dom_col_constr ON DOMAIN dom IS 'Constrains
  col of domain';
COMMENT ON DATABASE my_database IS 'Development Database';
COMMENT ON DOMAIN my_domain IS 'Email Address Domain';
COMMENT ON EVENT TRIGGER abort_ddl IS 'Aborts all DDL commands';
COMMENT ON EXTENSION hstore IS 'implements the hstore data type';
COMMENT ON FOREIGN DATA WRAPPER mywrapper IS 'my foreign data
  wrapper';
COMMENT ON FOREIGN TABLE my_foreign_table IS 'Employee Information
  in other database';
COMMENT ON FUNCTION my_function (timestamp) IS 'Returns Roman
  Numeral';
COMMENT ON INDEX my_index IS 'Enforces uniqueness on employee ID';
COMMENT ON LANGUAGE plpython IS 'Python support for stored
  procedures';
COMMENT ON LARGE OBJECT 346344 IS 'Planning document';
COMMENT ON MATERIALIZED VIEW my_matview IS 'Summary of order
  history';
COMMENT ON OPERATOR ^ (text, text) IS 'Performs intersection of two
  texts';
COMMENT ON OPERATOR - (NONE, integer) IS 'Unary minus';
COMMENT ON OPERATOR CLASS int4ops USING btree IS '4 byte integer
  operators for btrees';
COMMENT ON OPERATOR FAMILY integer_ops USING btree IS 'all integer
  operators for btrees';
COMMENT ON POLICY my_policy ON mytable IS 'Filter rows by users';
COMMENT ON PROCEDURE my_proc (integer, integer) IS 'Runs a report';
COMMENT ON PUBLICATION alltables IS 'Publishes all operations on
  all tables';
COMMENT ON ROLE my_role IS 'Administration group for finance
  tables';
COMMENT ON ROUTINE my_routine (integer, integer) IS 'Runs a routine
  (which is a function or procedure)';
COMMENT ON RULE my_rule ON my_table IS 'Logs updates of employee
  records';
COMMENT ON SCHEMA my_schema IS 'Departmental data';
COMMENT ON SEQUENCE my_sequence IS 'Used to generate primary keys';
COMMENT ON SERVER myserver IS 'my foreign server';
COMMENT ON STATISTICS my_statistics IS 'Improves planner row
  estimations';
```

```
COMMENT ON SUBSCRIPTION alltables IS 'Subscription for all
operations on all tables';
COMMENT ON TABLE my_schema.my_table IS 'Employee Information';
COMMENT ON TABLESPACE my_tablespace IS 'Tablespace for indexes';
COMMENT ON TEXT SEARCH CONFIGURATION my_config IS 'Special word
filtering';
COMMENT ON TEXT SEARCH DICTIONARY swedish IS 'Snowball stemmer for
Swedish language';
COMMENT ON TEXT SEARCH PARSER my_parser IS 'Splits text into
words';
COMMENT ON TEXT SEARCH TEMPLATE snowball IS 'Snowball stemmer';
COMMENT ON TRANSFORM FOR hstore LANGUAGE plpythonu IS 'Transform
between hstore and Python dict';
COMMENT ON TRIGGER my_trigger ON my_table IS 'Used for RI';
COMMENT ON TYPE complex IS 'Complex number data type';
COMMENT ON VIEW my_view IS 'View of departmental costs';
```

## Compatibility

There is no COMMENT command in the SQL standard.

---

# COMMIT

COMMIT — commit the current transaction

## Synopsis

```
COMMIT [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

## Description

COMMIT commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs.

## Parameters

WORK  
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

## Notes

Use ROLLBACK to abort a transaction.

Issuing COMMIT when not inside a transaction does no harm, but it will provoke a warning message. COMMIT AND CHAIN when not inside a transaction is an error.

## Examples

To commit the current transaction and make all changes permanent:

```
COMMIT ;
```

## Compatibility

The command COMMIT conforms to the SQL standard. The form COMMIT TRANSACTION is a LightDB extension.

## See Also

BEGIN, ROLLBACK

---

# COMMIT PREPARED

COMMIT PREPARED — commit a transaction that was earlier prepared for two-phase commit

## Synopsis

```
COMMIT PREPARED transaction_id
```

## Description

COMMIT PREPARED commits a transaction that is in prepared state.

## Parameters

```
transaction_id
```

The transaction identifier of the transaction that is to be committed.

## Notes

To commit a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is committed immediately.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

## Examples

Commit the transaction identified by the transaction identifier `foobar`:

```
COMMIT PREPARED 'foobar';
```

## Compatibility

COMMIT PREPARED is a LightDB extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

## See Also

PREPARE TRANSACTION, ROLLBACK PREPARED

---

# COPY

COPY — copy data between a file and a table

## Synopsis

```
COPY table_name [ ( column_name [, ...] ) ]
    FROM { 'filename' | PROGRAM 'command' | STDIN }
    [ [ WITH ] ( option [, ...] ) ]
    [ WHERE condition ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
    TO { 'filename' | PROGRAM 'command' | STDOUT }
    [ [ WITH ] ( option [, ...] ) ]
```

where *option* can be one of:

```
FORMAT format_name
FREEZE [ boolean ]
DELIMITER 'delimiter_character'
NULL 'null_string'
HEADER [ boolean ]
QUOTE 'quote_character'
ESCAPE 'escape_character'
FORCE_QUOTE { ( column_name [, ...] ) | * }
FORCE_NOT_NULL ( column_name [, ...] )
FORCE_NULL ( column_name [, ...] )
ENCODING 'encoding_name'
```

## Description

COPY moves data between LightDB tables and standard file-system files. COPY TO copies the contents of a table *to* a file, while COPY FROM copies data *from* a file to a table (appending the data to whatever is in the table already). COPY TO can also copy the results of a SELECT query.

If a column list is specified, COPY TO copies only the data in the specified columns to the file. For COPY FROM, each field in the file is inserted, in order, into the specified column. Table columns not specified in the COPY FROM column list will receive their default values.

COPY with a file name instructs the LightDB server to directly read from or write to a file. The file must be accessible by the LightDB user (the user ID the server runs as) and the name must be specified from the viewpoint of the server. When PROGRAM is specified, the server executes the given command and reads from the standard output of the program, or writes to the standard input of the program. The command must be specified from the viewpoint of the server, and be executable by the LightDB user. When STDIN or STDOUT is specified, data is transmitted via the connection between the client and the server.

## Parameters

*table\_name*

The name (optionally schema-qualified) of an existing table.

*column\_name*

An optional list of columns to be copied. If no column list is specified, all columns of the table except generated columns will be copied.

*query*

A SELECT, VALUES, INSERT, UPDATE or DELETE command whose results are to be copied. Note that parentheses are required around the query.

For INSERT, UPDATE and DELETE queries a RETURNING clause must be provided, and the target relation must not have a conditional rule, nor an ALSO rule, nor an INSTEAD rule that expands to multiple statements.

*filename*

The path name of the input or output file. An input file name can be an absolute or relative path, but an output file name must be an absolute path. Windows users might need to use an E ' ' string and double any backslashes used in the path name.

## PROGRAM

A command to execute. In COPY FROM, the input is read from standard output of the command, and in COPY TO, the output is written to the standard input of the command.

Note that the command is invoked by the shell, so if you need to pass any arguments to shell command that come from an untrusted source, you must be careful to strip or escape any special characters that might have a special meaning for the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in it.

## STDIN

Specifies that input comes from the client application.

## STDOUT

Specifies that output goes to the client application.

*boolean*

Specifies whether the selected option should be turned on or off. You can write TRUE, ON, or 1 to enable the option, and FALSE, OFF, or 0 to disable it. The *boolean* value can also be omitted, in which case TRUE is assumed.

## FORMAT

Selects the data format to be read or written: `text`, `csv` (Comma Separated Values), or `binary`. The default is `text`.

## FREEZE

Requests copying the data with rows already frozen, just as they would be after running the VACUUM FREEZE command. This is intended as a performance option for initial data loading. Rows will be frozen only if the table being loaded has been created or truncated in the current subtransaction, there are no cursors open and there are no older snapshots held by this transaction. It is currently not possible to perform a COPY FREEZE on a partitioned table.

Note that all other sessions will immediately be able to see the data once it has been successfully loaded. This violates the normal rules of MVCC visibility and users specifying should be aware of the potential problems this might cause.

## DELIMITER

Specifies the character that separates columns within each row (line) of the file. The default is a tab character in text format, a combination of up to 3 single one-byte characters is supported(Text), a comma in CSV format. This must be a single one-byte character(CSV). This option is not allowed when using binary format.

## NULL

Specifies the string that represents a null value. The default is \N (backslash-N) in text format, and an unquoted empty string in CSV format. You might prefer an empty string even in text format for cases where you don't want to distinguish nulls from empty strings. This option is not allowed when using binary format.

**Note**

When using COPY FROM, any data item that matches this string will be stored as a null value, so you should make sure that you use the same string as you used with COPY TO.

## HEADER

Specifies that the file contains a header line with the names of each column in the file. On output, the first line contains the column names from the table, and on input, the first line is ignored. This option is allowed only when using CSV format.

## QUOTE

Specifies the quoting character to be used when a data value is quoted. The default is double-quote. This must be a single one-byte character. This option is allowed only when using CSV format.

## ESCAPE

Specifies the character that should appear before a data character that matches the QUOTE value. The default is the same as the QUOTE value (so that the quoting character is doubled if it appears in the data). This must be a single one-byte character. This option is allowed only when using CSV format.

## FORCE\_QUOTE

Forces quoting to be used for all non-NULL values in each specified column. NULL output is never quoted. If \* is specified, non-NULL values will be quoted in all columns. This option is allowed only in COPY TO, and only when using CSV format.

## FORCE\_NOT\_NULL

Do not match the specified columns' values against the null string. In the default case where the null string is empty, this means that empty values will be read as zero-length strings rather than nulls, even when they are not quoted. This option is allowed only in COPY FROM, and only when using CSV format.

## FORCE\_NULL

Match the specified columns' values against the null string, even if it has been quoted, and if a match is found set the value to NULL. In the default case where the null string is empty, this converts a quoted empty string into NULL. This option is allowed only in COPY FROM, and only when using CSV format.

## ENCODING

Specifies that the file is encoded in the *encoding\_name*. If this option is omitted, the current client encoding is used. See the Notes below for more details.

## WHERE

The optional WHERE clause has the general form

WHERE *condition*

where *condition* is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will not be inserted to the table. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

Currently, subqueries are not allowed in WHERE expressions, and the evaluation does not see any changes made by the COPY itself (this matters when the expression contains calls to `VOLATILE` functions).

## Outputs

On successful completion, a COPY command returns a command tag of the form

COPY *count*

The *count* is the number of rows copied.

### Note

Itsql will print this command tag only if the command was not `COPY ... TO STDOUT`, or the equivalent Itsql meta-command `\copy ... to stdout`. This is to prevent confusing the command tag with the data that was just printed.

## Notes

`COPY TO` can be used only with plain tables, not views, and does not copy rows from child tables or child partitions. For example, `COPY table TO` copies the same rows as `SELECT * FROM ONLY table`. The syntax `COPY (SELECT * FROM table) TO ...` can be used to dump all of the rows in an inheritance hierarchy, partitioned table, or view.

`COPY FROM` can be used with plain, foreign, or partitioned tables or with views that have `INSTEAD OF INSERT` triggers.

You must have select privilege on the table whose values are read by `COPY TO`, and insert privilege on the table into which values are inserted by `COPY FROM`. It is sufficient to have column privileges on the column(s) listed in the command.

If row-level security is enabled for the table, the relevant `SELECT` policies will apply to `COPY table TO` statements. Currently, `COPY FROM` is not supported for tables with row-level security. Use equivalent `INSERT` statements instead.

Files named in a COPY command are read or written directly by the server, not by the client application. Therefore, they must reside on or be accessible to the database server machine, not the client. They must be accessible to and readable or writable by the LightDB user (the user ID the server runs as), not the client. Similarly, the command specified with `PROGRAM` is executed directly by the server, not by the client application, must be executable by the LightDB



user. COPY naming a file or command is only allowed to database superusers or users who are granted one of the default roles `pg_read_server_files`, `pg_write_server_files`, or `pg_execute_server_program`, since it allows reading or writing any file or running a program that the server has privileges to access.

Do not confuse COPY with the `ltsql` instruction `\copy`. `\copy` invokes `COPY FROM STDIN` or `COPY TO STDOUT`, and then fetches/stores the data in a file accessible to the `ltsql` client. Thus, file accessibility and access rights depend on the client rather than the server when `\copy` is used.

It is recommended that the file name used in COPY always be specified as an absolute path. This is enforced by the server in the case of `COPY TO`, but for `COPY FROM` you do have the option of reading from a file specified by a relative path. The path will be interpreted relative to the working directory of the server process (normally the cluster's data directory), not the client's working directory.

Executing a command with `PROGRAM` might be restricted by the operating system's access control mechanisms, such as SELinux.

`COPY FROM` will invoke any triggers and check constraints on the destination table. However, it will not invoke rules.

For identity columns, the `COPY FROM` command will always write the column values provided in the input data, like the `INSERT` option `OVERRIDING SYSTEM VALUE`.

`COPY` input and output is affected by `DateStyle`. To ensure portability to other LightDB installations that might use non-default `DateStyle` settings, `DateStyle` should be set to `ISO` before using `COPY TO`. It is also a good idea to avoid dumping data with `IntervalStyle` set to `sql_standard`, because negative interval values might be misinterpreted by a server that has a different setting for `IntervalStyle`.

Input data is interpreted according to `ENCODING` option or the current client encoding, and output data is encoded in `ENCODING` or the current client encoding, even if the data does not pass through the client but is read from or written to a file directly by the server.

`COPY` stops operation at the first error. This should not lead to problems in the event of a `COPY TO`, but the target table will already have received earlier rows in a `COPY FROM`. These rows will not be visible or accessible, but they still occupy disk space. This might amount to a considerable amount of wasted disk space if the failure happened well into a large copy operation. You might wish to invoke `VACUUM` to recover the wasted space.

`FORCE_NULL` and `FORCE_NOT_NULL` can be used simultaneously on the same column. This results in converting quoted null strings to null values and unquoted null strings to empty strings.

## File Formats

### Text Format

When the `text` format is used, the data read or written is a text file with one line per table row. Columns in a row are separated by the delimiter character. The column values themselves are strings generated by the output function, or acceptable to the input function, of each attribute's data type. The specified null string is used in place of columns that are null. `COPY FROM` will raise an error if any line of the input file contains more or fewer columns than are expected.

End of data can be represented by a single line containing just backslash-period (`\.`). An end-of-data marker is not necessary when reading from a file, since the end of file serves perfectly well; it is needed only when copying data to or from client applications using pre-3.0 client protocol.

Backslash characters (`\`) can be used in the `COPY` data to quote data characters that might otherwise be taken as row or column delimiters. In particular, the following characters *must* be preceded by a backslash if they appear as part of a column value: backslash itself, newline, carriage return, and the current delimiter character.

The specified null string is sent by `COPY TO` without adding any backslashes; conversely, `COPY FROM` matches the input against the null string before removing backslashes. Therefore, a null string such as `\N` cannot be confused with the actual data value `\N` (which would be represented as `\\N`).

The following special backslash sequences are recognized by `COPY FROM`:

Sequence	Represents
<code>\b</code>	Backspace (ASCII 8)
<code>\f</code>	Form feed (ASCII 12)
<code>\n</code>	Newline (ASCII 10)
<code>\r</code>	Carriage return (ASCII 13)
<code>\t</code>	Tab (ASCII 9)
<code>\v</code>	Vertical tab (ASCII 11)
<code>\digits</code>	Backslash followed by one to three octal digits specifies the byte with that numeric code
<code>\xdigits</code>	Backslash <code>x</code> followed by one or two hex digits specifies the byte with that numeric code

Presently, `COPY TO` will never emit an octal or hex-digits backslash sequence, but it does use the other sequences listed above for those control characters.

Any other backslashed character that is not mentioned in the above table will be taken to represent itself. However, beware of adding backslashes unnecessarily, since that might accidentally produce a string matching the end-of-data marker (`\.`) or the null string (`\N` by default). These strings will be recognized before any other backslash processing is done.

It is strongly recommended that applications generating `COPY` data convert data newlines and carriage returns to the `\n` and `\r` sequences respectively. At present it is possible to represent a data carriage return by a backslash and carriage return, and to represent a data newline by a backslash and newline. However, these representations might not be accepted in future releases. They are also highly vulnerable to corruption if the `COPY` file is transferred across different machines (for example, from Unix to Windows or vice versa).

All backslash sequences are interpreted after encoding conversion. The bytes specified with the octal and hex-digit backslash sequences must form valid characters in the database encoding.

`COPY TO` will terminate each row with a Unix-style newline ("`\n`"). Servers running on Microsoft Windows instead output carriage return/newline ("`\r\n`"), but only for `COPY` to a server file; for consistency across platforms, `COPY TO STDOUT` always sends "`\n`" regardless of server platform. `COPY FROM` can handle lines ending with newlines, carriage returns, or carriage return/newlines. To reduce the risk of error due to un-backslashed newlines or carriage returns that were meant as data, `COPY FROM` will complain if the line endings in the input are not all alike.

## CSV Format

This format option is used for importing and exporting the Comma Separated Value (CSV) file format used by many other programs, such as spreadsheets. Instead of the escaping rules used by LightDB's standard text format, it produces and recognizes the common CSV escaping mechanism.

The values in each record are separated by the `DELIMITER` character. If the value contains the delimiter character, the `QUOTE` character, the `NULL` string, a carriage return, or line feed character, then the whole value is prefixed and suffixed by the `QUOTE` character, and any occurrence within the value of a `QUOTE` character or the `ESCAPE` character is preceded by the escape character. You can also use `FORCE_QUOTE` to force quotes when outputting non-`NULL` values in specific columns.

The CSV format has no standard way to distinguish a `NULL` value from an empty string. LightDB's `COPY` handles this by quoting. A `NULL` is output as the `NULL` parameter string and is not quoted,

while a non-NULL value matching the NULL parameter string is quoted. For example, with the default settings, a NULL is written as an unquoted empty string, while an empty string data value is written with double quotes (" "). Reading values follows similar rules. You can use `FORCE_NOT_NULL` to prevent NULL input comparisons for specific columns. You can also use `FORCE_NULL` to convert quoted null string data values to NULL.

Because backslash is not a special character in the CSV format, `\.`, the end-of-data marker, could also appear as a data value. To avoid any misinterpretation, a `\.` data value appearing as a lone entry on a line is automatically quoted on output, and on input, if quoted, is not interpreted as the end-of-data marker. If you are loading a file created by another application that has a single unquoted column and might have a value of `\.`, you might need to quote that value in the input file.

### Note

In CSV format, all characters are significant. A quoted value surrounded by white space, or any characters other than `DELIMITER`, will include those characters. This can cause errors if you import data from a system that pads CSV lines with white space out to some fixed width. If such a situation arises you might need to preprocess the CSV file to remove the trailing white space, before importing the data into LightDB.

### Note

CSV format will both recognize and produce CSV files with quoted values containing embedded carriage returns and line feeds. Thus the files are not strictly one line per table row like text-format files.

### Note

Many programs produce strange and occasionally perverse CSV files, so the file format is more a convention than a standard. Thus you might encounter some files that cannot be imported using this mechanism, and `COPY` might produce files that other programs cannot process.

## Binary Format

The `binary` format option causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the text and CSV formats, but a binary-format file is less portable across machine architectures and LightDB versions. Also, the binary format is very data type specific; for example it will not work to output binary data from a `smallint` column and read it into an `integer` column, even though that would work fine in text format.

The `binary` file format consists of a file header, zero or more tuples containing the row data, and a file trailer. Headers and data are in network byte order.

## File Header

The file header consists of 15 bytes of fixed fields, followed by a variable-length header extension area. The fixed fields are:

### Signature

11-byte sequence `PGCOPY\n\377\r\n\0` — note that the zero byte is a required part of the signature. (The signature is designed to allow easy identification of files that have been munged

---

by a non-8-bit-clean transfer. This signature will be changed by end-of-line-translation filters, dropped zero bytes, dropped high bits, or parity changes.)

#### Flags field

32-bit integer bit mask to denote important aspects of the file format. Bits are numbered from 0 (LSB) to 31 (MSB). Note that this field is stored in network byte order (most significant byte first), as are all the integer fields used in the file format. Bits 16–31 are reserved to denote critical file format issues; a reader should abort if it finds an unexpected bit set in this range. Bits 0–15 are reserved to signal backwards-compatible format issues; a reader should simply ignore any unexpected bits set in this range. Currently only one flag bit is defined, and the rest must be zero:

#### Bit 16

If 1, OIDs are included in the data; if 0, not. Oid system columns are not supported in LightDB anymore, but the format still contains the indicator.

#### Header extension area length

32-bit integer, length in bytes of remainder of header, not including self. Currently, this is zero, and the first tuple follows immediately. Future changes to the format might allow additional data to be present in the header. A reader should silently skip over any header extension data it does not know what to do with.

The header extension area is envisioned to contain a sequence of self-identifying chunks. The flags field is not intended to tell readers what is in the extension area. Specific design of header extension contents is left for a later release.

This design allows for both backwards-compatible header additions (add header extension chunks, or set low-order flag bits) and non-backwards-compatible changes (set high-order flag bits to signal such changes, and add supporting data to the extension area if needed).

## Tuples

Each tuple begins with a 16-bit integer count of the number of fields in the tuple. (Presently, all tuples in a table will have the same count, but that might not always be true.) Then, repeated for each field in the tuple, there is a 32-bit length word followed by that many bytes of field data. (The length word does not include itself, and can be zero.) As a special case, -1 indicates a NULL field value. No value bytes follow in the NULL case.

There is no alignment padding or any other extra data between fields.

Presently, all data values in a binary-format file are assumed to be in binary format (format code one). It is anticipated that a future extension might add a header field that allows per-column format codes to be specified.

To determine the appropriate binary format for the actual tuple data you should consult the LightDB source, in particular the `*send` and `*recv` functions for each column's data type (typically these functions are found in the `src/backend/utills/adt/` directory of the source distribution).

If OIDs are included in the file, the OID field immediately follows the field-count word. It is a normal field except that it's not included in the field-count. Note that oid system columns are not supported in current versions of LightDB.

## File Trailer

The file trailer consists of a 16-bit integer word containing -1. This is easily distinguished from a tuple's field-count word.

A reader should report an error if a field-count word is neither -1 nor the expected number of columns. This provides an extra check against somehow getting out of sync with the data.

## Examples

The following example copies a table to the client using the vertical bar (|) as the field delimiter:

```
COPY country TO STDOUT (DELIMITER '|');
```

The following example copies a table to the client using the vertical bar (ABC) as the field delimiter:

```
COPY country TO STDOUT (DELIMITER 'ABC');
```

To copy data from a file into the country table:

```
COPY country FROM '/usr1/proj/bray/sql/country_data';
```

To copy into a file just the countries whose names start with 'A':

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%') TO '/usr1/proj/bray/sql/a_list_countries.copy';
```

To copy into a compressed file, you can pipe the output through an external compression program:

```
COPY country TO PROGRAM 'gzip > /usr1/proj/bray/sql/country_data.gz';
```

Here is a sample of data suitable for copying into a table from STDIN:

```
AF      AFGHANISTAN
AL      ALBANIA
DZ      ALGERIA
ZM      ZAMBIA
ZW      ZIMBABWE
```

Note that the white space on each line is actually a tab character.

The following is the same data, output in binary format. The data is shown after filtering through the Unix utility `od -c`. The table has three columns; the first has type `char(2)`, the second has type `text`, and the third has type `integer`. All the rows have a null value in the third column.

```
0000000  P  G  C  O  P  Y  \n 377  \r  \n  \0  \0  \0  \0  \0
  \0
0000020  \0  \0  \0  \0 003  \0  \0  \0 002  A  F  \0  \0  \0 013
  A
0000040  F  G  H  A  N  I  S  T  A  N 377 377 377 377  \0
 003
0000060  \0  \0  \0 002  A  L  \0  \0  \0 007  A  L  B  A  N
  I
0000100  A 377 377 377 377  \0 003  \0  \0  \0 002  D  Z  \0  \0
  \0
0000120 007  A  L  G  E  R  I  A 377 377 377 377  \0 003  \0
  \0
0000140  \0 002  Z  M  \0  \0  \0 006  Z  A  M  B  I  A 377
 377
```

```

0000160 377 377 \0 003 \0 \0 \0 002 z W \0 \0 \0 \b z
I
0000200 M B A B W E 377 377 377 377 377 377

```

## Compatibility

There is no COPY statement in the SQL standard.

The following syntax is supported:

```

COPY table_name [ ( column_name [, ...] ) ]
  FROM { 'filename' | STDIN }
  [ [ WITH ]
    [ BINARY ]
    [ DELIMITER [ AS ] 'delimiter_character' ]
    [ NULL [ AS ] 'null_string' ]
    [ CSV [ HEADER ]
      [ QUOTE [ AS ] 'quote_character' ]
      [ ESCAPE [ AS ] 'escape_character' ]
      [ FORCE NOT NULL column_name [, ...] ] ] ] ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
  TO { 'filename' | STDOUT }
  [ [ WITH ]
    [ BINARY ]
    [ DELIMITER [ AS ] 'delimiter_character' ]
    [ NULL [ AS ] 'null_string' ]
    [ CSV [ HEADER ]
      [ QUOTE [ AS ] 'quote_character' ]
      [ ESCAPE [ AS ] 'escape_character' ]
      [ FORCE QUOTE { column_name [, ...] | * } ] ] ] ]

```

Note that in this syntax, BINARY and CSV are treated as independent keywords, not as arguments of a FORMAT option.

The following syntax is also supported:

```

COPY [ BINARY ] table_name
  FROM { 'filename' | STDIN }
  [ [USING] DELIMITERS 'delimiter_character' ]
  [ WITH NULL AS 'null_string' ]

COPY [ BINARY ] table_name
  TO { 'filename' | STDOUT }
  [ [USING] DELIMITERS 'delimiter_character' ]
  [ WITH NULL AS 'null_string' ]

```

---

# CREATE ACCESS METHOD

CREATE ACCESS METHOD — define a new access method

## Synopsis

```
CREATE ACCESS METHOD name
    TYPE access_method_type
    HANDLER handler_function
```

## Description

CREATE ACCESS METHOD creates a new access method.

The access method name must be unique within the database.

Only superusers can define new access methods.

## Parameters

*name*

The name of the access method to be created.

*access\_method\_type*

This clause specifies the type of access method to define. Only TABLE and INDEX are supported at present.

*handler\_function*

*handler\_function* is the name (possibly schema-qualified) of a previously registered function that represents the access method. The handler function must be declared to take a single argument of type `internal`, and its return type depends on the type of access method; for TABLE access methods, it must be `table_am_handler` and for INDEX access methods, it must be `index_am_handler`. The C-level API that the handler function must implement varies depending on the type of access method. The table access method API is described in Chapter 57 and the index access method API is described in Chapter 58.

## Examples

Create an index access method `heptree` with handler function `heptree_handler`:

```
CREATE ACCESS METHOD heptree TYPE INDEX HANDLER heptree_handler;
```

## Compatibility

CREATE ACCESS METHOD is a LightDB extension.

## See Also

DROP ACCESS METHOD, CREATE OPERATOR CLASS, CREATE OPERATOR FAMILY

---

# CREATE AGGREGATE

CREATE AGGREGATE — define a new aggregate function

## Synopsis

```
CREATE [ OR REPLACE ] AGGREGATE name ( [ argmode ] [ argname
] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = combinefunc ]
    [ , SERIALFUNC = serialfunc ]
    [ , DESERIALFUNC = deserialfunc ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mffunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE |
READ_WRITE } ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
)
```

```
CREATE [ OR REPLACE ] AGGREGATE name ( [ [ argmode ] [ argname
] arg_data_type [ , ... ] ]
                                ORDER BY [ argmode ] [ argname
] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , INITCOND = initial_condition ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
    [ , HYPOTHETICAL ]
)
```

or the old syntax

```
CREATE [ OR REPLACE ] AGGREGATE name (
    BASETYPE = base_type,
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
```



```

    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = combinefunc ]
    [ , SERIALFUNC = serialfunc ]
    [ , DESERIALFUNC = deserialfunc ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mfunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE |
READ_WRITE } ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
)

```

## Description

CREATE AGGREGATE defines a new aggregate function. CREATE OR REPLACE AGGREGATE will either define a new aggregate function or replace an existing definition. Some basic and commonly-used aggregate functions are included with the distribution; they are documented in Section 9.21. If one defines new types or needs an aggregate function not already provided, then CREATE AGGREGATE can be used to provide the desired features.

When replacing an existing definition, the argument types, result type, and number of direct arguments may not be changed. Also, the new definition must be of the same kind (ordinary aggregate, ordered-set aggregate, or hypothetical-set aggregate) as the old one.

If a schema name is given (for example, CREATE AGGREGATE *myschema.myagg* . . .) then the aggregate function is created in the specified schema. Otherwise it is created in the current schema.

An aggregate function is identified by its name and input data type(s). Two aggregates in the same schema can have the same name if they operate on different input types. The name and input data type(s) of an aggregate must also be distinct from the name and input data type(s) of every ordinary function in the same schema. This behavior is identical to overloading of ordinary function names (see CREATE FUNCTION).

A simple aggregate function is made from one or two ordinary functions: a state transition function *sfunc*, and an optional final calculation function *ffunc*. These are used as follows:

```

sfunc( internal-state, next-data-values ) ---> next-internal-state
ffunc( internal-state ) ---> aggregate-value

```

LightDB creates a temporary variable of data type *stype* to hold the current internal state of the aggregate. At each input row, the aggregate argument value(s) are calculated and the state transition function is invoked with the current state value and the new argument value(s) to calculate a new internal state value. After all the rows have been processed, the final function is invoked once to calculate the aggregate's return value. If there is no final function then the ending state value is returned as-is.

An aggregate function can provide an initial condition, that is, an initial value for the internal state value. This is specified and stored in the database as a value of type `text`, but it must be a valid external representation of a constant of the state value data type. If it is not supplied then the state value starts out null.

If the state transition function is declared “strict”, then it cannot be called with null inputs. With such a transition function, aggregate execution behaves as follows. Rows with any null input values are

ignored (the function is not called and the previous state value is retained). If the initial state value is null, then at the first row with all-nonnull input values, the first argument value replaces the state value, and the transition function is invoked at each subsequent row with all-nonnull input values. This is handy for implementing aggregates like `max`. Note that this behavior is only available when `state_data_type` is the same as the first `arg_data_type`. When these types are different, you must supply a nonnull initial condition or use a nonstrict transition function.

If the state transition function is not strict, then it will be called unconditionally at each input row, and must deal with null inputs and null state values for itself. This allows the aggregate author to have full control over the aggregate's handling of null values.

If the final function is declared “strict”, then it will not be called when the ending state value is null; instead a null result will be returned automatically. (Of course this is just the normal behavior of strict functions.) In any case the final function has the option of returning a null value. For example, the final function for `avg` returns null when it sees there were zero input rows.

Sometimes it is useful to declare the final function as taking not just the state value, but extra parameters corresponding to the aggregate's input values. The main reason for doing this is if the final function is polymorphic and the state value's data type would be inadequate to pin down the result type. These extra parameters are always passed as NULL (and so the final function must not be strict when the `FINALFUNC_EXTRA` option is used), but nonetheless they are valid parameters. The final function could for example make use of `get_fn_expr_argtype` to identify the actual argument type in the current call.

An aggregate can optionally support *moving-aggregate mode*, as described in Section 36.12.1. This requires specifying the `MSFUNC`, `MINVFUNC`, and `MSTYPE` parameters, and optionally the `MSSPACE`, `MFINALFUNC`, `MFINALFUNC_EXTRA`, `MFINALFUNC_MODIFY`, and `MINITCOND` parameters. Except for `MINVFUNC`, these parameters work like the corresponding simple-aggregate parameters without `M`; they define a separate implementation of the aggregate that includes an inverse transition function.

The syntax with `ORDER BY` in the parameter list creates a special type of aggregate called an *ordered-set aggregate*; or if `HYPOTHETICAL` is specified, then a *hypothetical-set aggregate* is created. These aggregates operate over groups of sorted values in order-dependent ways, so that specification of an input sort order is an essential part of a call. Also, they can have *direct* arguments, which are arguments that are evaluated only once per aggregation rather than once per input row. Hypothetical-set aggregates are a subclass of ordered-set aggregates in which some of the direct arguments are required to match, in number and data types, the aggregated argument columns. This allows the values of those direct arguments to be added to the collection of aggregate-input rows as an additional “hypothetical” row.

An aggregate can optionally support *partial aggregation*, as described in Section 36.12.4. This requires specifying the `COMBINEFUNC` parameter. If the `state_data_type` is `internal`, it's usually also appropriate to provide the `SERIALFUNC` and `DESERIALFUNC` parameters so that parallel aggregation is possible. Note that the aggregate must also be marked `PARALLEL SAFE` to enable parallel aggregation.

Aggregates that behave like `MIN` or `MAX` can sometimes be optimized by looking into an index instead of scanning every input row. If this aggregate can be so optimized, indicate it by specifying a *sort operator*. The basic requirement is that the aggregate must yield the first element in the sort ordering induced by the operator; in other words:

```
SELECT agg(col) FROM tab;
```

must be equivalent to:

```
SELECT col FROM tab ORDER BY col USING sortop LIMIT 1;
```

Further assumptions are that the aggregate ignores null inputs, and that it delivers a null result if and only if there were no non-null inputs. Ordinarily, a data type's < operator is the proper sort operator for MIN, and > is the proper sort operator for MAX. Note that the optimization will never actually take effect unless the specified operator is the "less than" or "greater than" strategy member of a B-tree index operator class.

To be able to create an aggregate function, you must have USAGE privilege on the argument types, the state type(s), and the return type, as well as EXECUTE privilege on the supporting functions.

## Parameters

*name*

The name (optionally schema-qualified) of the aggregate function to create.

*argmode*

The mode of an argument: IN or VARIADIC. (Aggregate functions do not support OUT arguments.) If omitted, the default is IN. Only the last argument can be marked VARIADIC.

*argname*

The name of an argument. This is currently only useful for documentation purposes. If omitted, the argument has no name.

*arg\_data\_type*

An input data type on which this aggregate function operates. To create a zero-argument aggregate function, write \* in place of the list of argument specifications. (An example of such an aggregate is count (\*).)

*base\_type*

In the old syntax for CREATE AGGREGATE, the input data type is specified by a basetype parameter rather than being written next to the aggregate name. Note that this syntax allows only one input parameter. To define a zero-argument aggregate function with this syntax, specify the basetype as "ANY" (not \*). Ordered-set aggregates cannot be defined with the old syntax.

*sfunc*

The name of the state transition function to be called for each input row. For a normal *N*-argument aggregate function, the *sfunc* must take *N*+1 arguments, the first being of type *state\_data\_type* and the rest matching the declared input data type(s) of the aggregate. The function must return a value of type *state\_data\_type*. This function takes the current state value and the current input data value(s), and returns the next state value.

For ordered-set (including hypothetical-set) aggregates, the state transition function receives only the current state value and the aggregated arguments, not the direct arguments. Otherwise it is the same.

*state\_data\_type*

The data type for the aggregate's state value.

*state\_data\_size*

The approximate average size (in bytes) of the aggregate's state value. If this parameter is omitted or is zero, a default estimate is used based on the *state\_data\_type*. The planner uses this value to estimate the memory required for a grouped aggregate query.

*ffunc*

The name of the final function called to compute the aggregate's result after all input rows have been traversed. For a normal aggregate, this function must take a single argument of type *state\_data\_type*. The return data type of the aggregate is defined as the return type of this function. If *ffunc* is not specified, then the ending state value is used as the aggregate's result, and the return type is *state\_data\_type*.

For ordered-set (including hypothetical-set) aggregates, the final function receives not only the final state value, but also the values of all the direct arguments.

If `FINALFUNC_EXTRA` is specified, then in addition to the final state value and any direct arguments, the final function receives extra NULL values corresponding to the aggregate's regular (aggregated) arguments. This is mainly useful to allow correct resolution of the aggregate result type when a polymorphic aggregate is being defined.

`FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE }`

This option specifies whether the final function is a pure function that does not modify its arguments. `READ_ONLY` indicates it does not; the other two values indicate that it may change the transition state value. See Notes below for more detail. The default is `READ_ONLY`, except for ordered-set aggregates, for which the default is `READ_WRITE`.

*combinefunc*

The *combinefunc* function may optionally be specified to allow the aggregate function to support partial aggregation. If provided, the *combinefunc* must combine two *state\_data\_type* values, each containing the result of aggregation over some subset of the input values, to produce a new *state\_data\_type* that represents the result of aggregating over both sets of inputs. This function can be thought of as an *sfunc*, where instead of acting upon an individual input row and adding it to the running aggregate state, it adds another aggregate state to the running state.

The *combinefunc* must be declared as taking two arguments of the *state\_data\_type* and returning a value of the *state\_data\_type*. Optionally this function may be "strict". In this case the function will not be called when either of the input states are null; the other state will be taken as the correct result.

For aggregate functions whose *state\_data\_type* is *internal*, the *combinefunc* must not be strict. In this case the *combinefunc* must ensure that null states are handled correctly and that the state being returned is properly stored in the aggregate memory context.

*serialfunc*

An aggregate function whose *state\_data\_type* is *internal* can participate in parallel aggregation only if it has a *serialfunc* function, which must serialize the aggregate state into a *bytea* value for transmission to another process. This function must take a single argument of type *internal* and return type *bytea*. A corresponding *deserialfunc* is also required.

*deserialfunc*

Deserialize a previously serialized aggregate state back into *state\_data\_type*. This function must take two arguments of types *bytea* and *internal*, and produce a result of type *internal*. (Note: the second, *internal* argument is unused, but is required for type safety reasons.)

*initial\_condition*

The initial setting for the state value. This must be a string constant in the form accepted for the data type *state\_data\_type*. If not specified, the state value starts out null.

*msfunc*

The name of the forward state transition function to be called for each input row in moving-aggregate mode. This is exactly like the regular transition function, except that its first argument and result are of type *mstate\_data\_type*, which might be different from *state\_data\_type*.

*minvfunc*

The name of the inverse state transition function to be used in moving-aggregate mode. This function has the same argument and result types as *msfunc*, but it is used to remove a value from the current aggregate state, rather than add a value to it. The inverse transition function must have the same strictness attribute as the forward state transition function.

*mstate\_data\_type*

The data type for the aggregate's state value, when using moving-aggregate mode.

*mstate\_data\_size*

The approximate average size (in bytes) of the aggregate's state value, when using moving-aggregate mode. This works the same as *state\_data\_size*.

*mffunc*

The name of the final function called to compute the aggregate's result after all input rows have been traversed, when using moving-aggregate mode. This works the same as *ffunc*, except that its first argument's type is *mstate\_data\_type* and extra dummy arguments are specified by writing `MFINALFUNC_EXTRA`. The aggregate result type determined by *mffunc* or *mstate\_data\_type* must match that determined by the aggregate's regular implementation.

`MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE }`

This option is like `FINALFUNC_MODIFY`, but it describes the behavior of the moving-aggregate final function.

*minimal\_condition*

The initial setting for the state value, when using moving-aggregate mode. This works the same as *initial\_condition*.

*sort\_operator*

The associated sort operator for a MIN- or MAX-like aggregate. This is just an operator name (possibly schema-qualified). The operator is assumed to have the same input data types as the aggregate (which must be a single-argument normal aggregate).

`PARALLEL = { SAFE | RESTRICTED | UNSAFE }`

The meanings of `PARALLEL SAFE`, `PARALLEL RESTRICTED`, and `PARALLEL UNSAFE` are the same as in `CREATE FUNCTION`. An aggregate will not be considered for parallelization if it is marked `PARALLEL UNSAFE` (which is the default!) or `PARALLEL RESTRICTED`. Note that the parallel-safety markings of the aggregate's support functions are not consulted by the planner, only the marking of the aggregate itself.

**HYPOTHETICAL**

For ordered-set aggregates only, this flag specifies that the aggregate arguments are to be processed according to the requirements for hypothetical-set aggregates: that is, the last few direct arguments must match the data types of the aggregated (`WITHIN GROUP`) arguments. The `HYPOTHETICAL` flag has no effect on run-time behavior, only on parse-time resolution of the data types and collations of the aggregate's arguments.

The parameters of `CREATE AGGREGATE` can be written in any order, not just the order illustrated above.

## Notes

In parameters that specify support function names, you can write a schema name if needed, for example `SFUNC = public.sum`. Do not write argument types there, however — the argument types of the support functions are determined from other parameters.

Ordinarily, LightDB functions are expected to be true functions that do not modify their input values. However, an aggregate transition function, *when used in the context of an aggregate*, is allowed to cheat and modify its transition-state argument in place. This can provide substantial performance benefits compared to making a fresh copy of the transition state each time.

Likewise, while an aggregate final function is normally expected not to modify its input values, sometimes it is impractical to avoid modifying the transition-state argument. Such behavior must be declared using the `FINALFUNC_MODIFY` parameter. The `READ_WRITE` value indicates that the final function modifies the transition state in unspecified ways. This value prevents use of the aggregate as a window function, and it also prevents merging of transition states for aggregate calls that share the same input values and transition functions. The `SHAREABLE` value indicates that the transition function cannot be applied after the final function, but multiple final-function calls can be performed on the ending transition state value. This value prevents use of the aggregate as a window function, but it allows merging of transition states. (That is, the optimization of interest here is not applying the same final function repeatedly, but applying different final functions to the same ending transition state value. This is allowed as long as none of the final functions are marked `READ_WRITE`.)

If an aggregate supports moving-aggregate mode, it will improve calculation efficiency when the aggregate is used as a window function for a window with moving frame start (that is, a frame start mode other than `UNBOUNDED PRECEDING`). Conceptually, the forward transition function adds input values to the aggregate's state when they enter the window frame from the bottom, and the inverse transition function removes them again when they leave the frame at the top. So, when values are removed, they are always removed in the same order they were added. Whenever the inverse transition function is invoked, it will thus receive the earliest added but not yet removed argument value(s). The inverse transition function can assume that at least one row will remain in the current state after it removes the oldest row. (When this would not be the case, the window function mechanism simply starts a fresh aggregation, rather than using the inverse transition function.)

The forward transition function for moving-aggregate mode is not allowed to return `NULL` as the new state value. If the inverse transition function returns `NULL`, this is taken as an indication that the inverse function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value.

If no moving-aggregate implementation is supplied, the aggregate can still be used with moving frames, but LightDB will recompute the whole aggregation whenever the start of the frame moves. Note that whether or not the aggregate supports moving-aggregate mode, LightDB can handle a moving frame end without recalculation; this is done by continuing to add new values to the aggregate's state. This is why use of an aggregate as a window function requires that the final function be read-only: it must not damage the aggregate's state value, so that the aggregation can be continued even after an aggregate result value has been obtained for one set of frame boundaries.

The syntax for ordered-set aggregates allows `VARIADIC` to be specified for both the last direct parameter and the last aggregated (`WITHIN GROUP`) parameter. However, the current implementation restricts use of `VARIADIC` in two ways. First, ordered-set aggregates can only use `VARIADIC "any"`, not other variadic array types. Second, if the last direct parameter is `VARIADIC "any"`, then there can be only one aggregated parameter and it must also be `VARIADIC "any"`. (In the representation used in the system catalogs, these two parameters are merged into a single `VARIADIC "any"` item, since `pg_proc` cannot represent functions with more than one `VARIADIC` parameter.)

If the aggregate is a hypothetical-set aggregate, the direct arguments that match the VARIADIC "any" parameter are the hypothetical ones; any preceding parameters represent additional direct arguments that are not constrained to match the aggregated arguments.

Currently, ordered-set aggregates do not need to support moving-aggregate mode, since they cannot be used as window functions.

Partial (including parallel) aggregation is currently not supported for ordered-set aggregates. Also, it will never be used for aggregate calls that include DISTINCT or ORDER BY clauses, since those semantics cannot be supported during partial aggregation.

## Examples

See Section 36.12.

## Compatibility

CREATE AGGREGATE is a LightDB language extension. The SQL standard does not provide for user-defined aggregate functions.

## See Also

ALTER AGGREGATE, DROP AGGREGATE

---

# CREATE CAST

CREATE CAST — define a new cast

## Synopsis

```
CREATE CAST (source_type AS target_type)
  WITH FUNCTION function_name [ (argument_type [, ...]) ]
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

```
CREATE CAST (source_type AS target_type)
  WITHOUT FUNCTION
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

```
CREATE CAST (source_type AS target_type)
  WITH INOUT
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

## Description

CREATE CAST defines a new cast. A cast specifies how to perform a conversion between two data types. For example,

```
SELECT CAST(42 AS float8);
```

converts the integer constant 42 to type float8 by invoking a previously specified function, in this case float8(int4). (If no suitable cast has been defined, the conversion fails.)

Two types can be *binary coercible*, which means that the conversion can be performed “for free” without invoking any function. This requires that corresponding values use the same internal representation. For instance, the types text and varchar are binary coercible both ways. Binary coercibility is not necessarily a symmetric relationship. For example, the cast from xml to text can be performed for free in the present implementation, but the reverse direction requires a function that performs at least a syntax check. (Two types that are binary coercible both ways are also referred to as binary compatible.)

You can define a cast as an *I/O conversion cast* by using the WITH INOUT syntax. An I/O conversion cast is performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type. In many common cases, this feature avoids the need to write a separate cast function for conversion. An I/O conversion cast acts the same as a regular function-based cast; only the implementation is different.

By default, a cast can be invoked only by an explicit cast request, that is an explicit CAST(*x* AS *typename*) or *x* : *typename* construct.

If the cast is marked AS ASSIGNMENT then it can be invoked implicitly when assigning a value to a column of the target data type. For example, supposing that foo.f1 is a column of type text, then:

```
INSERT INTO foo (f1) VALUES (42);
```

will be allowed if the cast from type integer to type text is marked AS ASSIGNMENT, otherwise not. (We generally use the term *assignment cast* to describe this kind of cast.)



If the cast is marked `AS IMPLICIT` then it can be invoked implicitly in any context, whether assignment or internally in an expression. (We generally use the term *implicit cast* to describe this kind of cast.) For example, consider this query:

```
SELECT 2 + 4.0;
```

The parser initially marks the constants as being of type `integer` and `numeric` respectively. There is no `integer + numeric` operator in the system catalogs, but there is a `numeric + numeric` operator. The query will therefore succeed if a cast from `integer` to `numeric` is available and is marked `AS IMPLICIT` — which in fact it is. The parser will apply the implicit cast and resolve the query as if it had been written

```
SELECT CAST ( 2 AS numeric ) + 4.0;
```

Now, the catalogs also provide a cast from `numeric` to `integer`. If that cast were marked `AS IMPLICIT` — which it is not — then the parser would be faced with choosing between the above interpretation and the alternative of casting the `numeric` constant to `integer` and applying the `integer + integer` operator. Lacking any knowledge of which choice to prefer, it would give up and declare the query ambiguous. The fact that only one of the two casts is implicit is the way in which we teach the parser to prefer resolution of a mixed `numeric-and-integer` expression as `numeric`; there is no built-in knowledge about that.

It is wise to be conservative about marking casts as implicit. An overabundance of implicit casting paths can cause LightDB to choose surprising interpretations of commands, or to be unable to resolve commands at all because there are multiple possible interpretations. A good rule of thumb is to make a cast implicitly invocable only for information-preserving transformations between types in the same general type category. For example, the cast from `int2` to `int4` can reasonably be implicit, but the cast from `float8` to `int4` should probably be assignment-only. Cross-type-category casts, such as `text` to `int4`, are best made explicit-only.

### Note

Sometimes it is necessary for usability or standards-compliance reasons to provide multiple implicit casts among a set of types, resulting in ambiguity that cannot be avoided as above. The parser has a fallback heuristic based on *type categories* and *preferred types* that can help to provide desired behavior in such cases. See `CREATE TYPE` for more information.

To be able to create a cast, you must own the source or the target data type and have `USAGE` privilege on the other type. To create a binary-coercible cast, you must be superuser. (This restriction is made because an erroneous binary-coercible cast conversion can easily crash the server.)

## Parameters

*source\_type*

The name of the source data type of the cast.

*target\_type*

The name of the target data type of the cast.

*function\_name*[(*argument\_type* [, ...])]

The function used to perform the cast. The function name can be schema-qualified. If it is not, the function will be looked up in the schema search path. The function's result data type must match

the target type of the cast. Its arguments are discussed below. If no argument list is specified, the function name must be unique in its schema.

WITHOUT FUNCTION

Indicates that the source type is binary-coercible to the target type, so no function is required to perform the cast.

WITH INOUT

Indicates that the cast is an I/O conversion cast, performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type.

AS ASSIGNMENT

Indicates that the cast can be invoked implicitly in assignment contexts.

AS IMPLICIT

Indicates that the cast can be invoked implicitly in any context.

Cast implementation functions can have one to three arguments. The first argument type must be identical to or binary-coercible from the cast's source type. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise. (Bizarrely, the SQL standard demands different behaviors for explicit and implicit casts in some cases. This argument is supplied for functions that must implement such casts. It is not recommended that you design your own data types so that this matters.)

The return type of a cast function must be identical to or binary-coercible to the cast's target type.

Ordinarily a cast must have different source and target data types. However, it is allowed to declare a cast with identical source and target types if it has a cast implementation function with more than one argument. This is used to represent type-specific length coercion functions in the system catalogs. The named function is used to coerce a value of the type to the type modifier value given by its second argument.

When a cast has different source and target types and a function that takes more than one argument, it supports converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two cast steps, one to convert between data types and a second to apply the modifier.

A cast to or from a domain type currently has no effect. Casting to or from a domain uses the casts associated with its underlying type.

## Notes

Use `DROP CAST` to remove user-defined casts.

Remember that if you want to be able to convert types both ways you need to declare casts both ways explicitly.

It is normally not necessary to create casts between user-defined types and the standard string types (`text`, `varchar`, and `char(n)`), as well as user-defined types that are defined to be in the string category). LightDB provides automatic I/O conversion casts for that. The automatic casts to string types are treated as assignment casts, while the automatic casts from string types are explicit-only. You can override this behavior by declaring your own cast to replace an automatic cast, but usually the only reason to do so is if you want the conversion to be more easily invocable than the standard assignment-only or explicit-only setting. Another possible reason is that you want the conversion to

behave differently from the type's I/O function; but that is sufficiently surprising that you should think twice about whether it's a good idea. (A small number of the built-in types do indeed have different behaviors for conversions, mostly because of requirements of the SQL standard.)

While not required, it is recommended that you continue to follow this old convention of naming cast implementation functions after the target data type. Many users are used to being able to cast data types using a function-style notation, that is *typename(x)*. This notation is in fact nothing more nor less than a call of the cast implementation function; it is not specially treated as a cast. If your conversion functions are not named to support this convention then you will have surprised users. Since LightDB allows overloading of the same function name with different argument types, there is no difficulty in having multiple conversion functions from different types that all use the target type's name.

### Note

Actually the preceding paragraph is an oversimplification: there are two cases in which a function-call construct will be treated as a cast request without having matched it to an actual function. If a function call *name(x)* does not exactly match any existing function, but *name* is the name of a data type and `pg_cast` provides a binary-coercible cast to this type from the type of *x*, then the call will be construed as a binary-coercible cast. This exception is made so that binary-coercible casts can be invoked using functional syntax, even though they lack any function. Likewise, if there is no `pg_cast` entry but the cast would be to or from a string type, the call will be construed as an I/O conversion cast. This exception allows I/O conversion casts to be invoked using functional syntax.

### Note

There is also an exception to the exception: I/O conversion casts from composite types to string types cannot be invoked using functional syntax, but must be written in explicit cast syntax (either `CAST` or `::` notation). This exception was added because after the introduction of automatically-provided I/O conversion casts, it was found too easy to accidentally invoke such a cast when a function or column reference was intended.

## Examples

To create an assignment cast from type `bigint` to type `int4` using the function `int4(bigint)`:

```
CREATE CAST (bigint AS int4) WITH FUNCTION int4(bigint) AS
ASSIGNMENT;
```

(This cast is already predefined in the system.)

## Compatibility

The `CREATE CAST` command conforms to the SQL standard, except that SQL does not make provisions for binary-coercible types or extra arguments to implementation functions. `AS IMPLICIT` is a LightDB extension, too.

## See Also

`CREATE FUNCTION`, `CREATE TYPE`, `DROP CAST`

---

# CREATE COLLATION

CREATE COLLATION — define a new collation

## Synopsis

```
CREATE COLLATION [ IF NOT EXISTS ] name (  
    [ LOCALE = locale, ]  
    [ LC_COLLATE = lc_collate, ]  
    [ LC_CTYPE = lc_ctype, ]  
    [ PROVIDER = provider, ]  
    [ DETERMINISTIC = boolean, ]  
    [ VERSION = version ]  
)  
CREATE COLLATION [ IF NOT EXISTS ] name FROM existing_collation
```

## Description

CREATE COLLATION defines a new collation using the specified operating system locale settings, or by copying an existing collation.

To be able to create a collation, you must have CREATE privilege on the destination schema.

## Parameters

IF NOT EXISTS

Do not throw an error if a collation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing collation is anything like the one that would have been created.

*name*

The name of the collation. The collation name can be schema-qualified. If it is not, the collation is defined in the current schema. The collation name must be unique within that schema. (The system catalogs can contain collations with the same name for other encodings, but these are ignored if the database encoding does not match.)

*locale*

This is a shortcut for setting LC\_COLLATE and LC\_CTYPE at once. If you specify this, you cannot specify either of those parameters.

*lc\_collate*

Use the specified operating system locale for the LC\_COLLATE locale category.

*lc\_ctype*

Use the specified operating system locale for the LC\_CTYPE locale category.

*provider*

Specifies the provider to use for locale services associated with this collation. Possible values are: `icu`, `libc`. `libc` is the default. The available choices depend on the operating system and build options.

**DETERMINISTIC**

Specifies whether the collation should use deterministic comparisons. The default is true. A deterministic comparison considers strings that are not byte-wise equal to be unequal even if they are considered logically equal by the comparison. LightDB breaks ties using a byte-wise comparison. Comparison that is not deterministic can make the collation be, say, case- or accent-insensitive. For that, you need to choose an appropriate `LC_COLLATE` setting *and* set the collation to not deterministic here.

Nondeterministic collations are only supported with the ICU provider.

***version***

Specifies the version string to store with the collation. Normally, this should be omitted, which will cause the version to be computed from the actual version of the collation as provided by the operating system. This option is intended to be used by `lt_upgrade` for copying the version from an existing installation.

See also `ALTER COLLATION` for how to handle collation version mismatches.

***existing\_collation***

The name of an existing collation to copy. The new collation will have the same properties as the existing one, but it will be an independent object.

## Notes

`CREATE COLLATION` takes a `SHARE ROW EXCLUSIVE` lock, which is self-conflicting, on the `pg_collation` system catalog, so only one `CREATE COLLATION` command can run at a time.

Use `DROP COLLATION` to remove user-defined collations.

See Section 21.2.2.3 for more information on how to create collations.

When using the `libc` collation provider, the locale must be applicable to the current database encoding. See `CREATE DATABASE` for the precise rules.

## Examples

To create a collation from the operating system locale `fr_FR.utf8` (assuming the current database encoding is UTF8):

```
CREATE COLLATION french (locale = 'fr_FR.utf8');
```

To create a collation using the ICU provider using German phone book sort order:

```
CREATE COLLATION german_phonebook (provider = icu, locale = 'de-u-co-phonebk');
```

To create a collation from an existing collation:

```
CREATE COLLATION german FROM "de_DE";
```

This can be convenient to be able to use operating-system-independent collation names in applications.

## Compatibility

There is a `CREATE COLLATION` statement in the SQL standard, but it is limited to copying an existing collation. The syntax to create a new collation is a LightDB extension.

## **See Also**

ALTER COLLATION, DROP COLLATION

---

# CREATE CONVERSION

CREATE CONVERSION — define a new encoding conversion

## Synopsis

```
CREATE [ DEFAULT ] CONVERSION name
    FOR source_encoding TO dest_encoding FROM function_name
```

## Description

CREATE CONVERSION defines a new conversion between two character set encodings.

Conversions that are marked DEFAULT can be used for automatic encoding conversion between client and server. To support that usage, two conversions, from encoding A to B *and* from encoding B to A, must be defined.

To be able to create a conversion, you must have EXECUTE privilege on the function and CREATE privilege on the destination schema.

## Parameters

DEFAULT

The DEFAULT clause indicates that this conversion is the default for this particular source to destination encoding. There should be only one default encoding in a schema for the encoding pair.

*name*

The name of the conversion. The conversion name can be schema-qualified. If it is not, the conversion is defined in the current schema. The conversion name must be unique within a schema.

*source\_encoding*

The source encoding name.

*dest\_encoding*

The destination encoding name.

*function\_name*

The function used to perform the conversion. The function name can be schema-qualified. If it is not, the function will be looked up in the path.

The function must have the following signature:

```
conv_proc(
    integer, -- source encoding ID
    integer, -- destination encoding ID
    cstring, -- source string (null terminated C string)
    internal, -- destination (fill with a null terminated C
    string)
```

```
    integer    -- source string length
) RETURNS void;
```

## Notes

Neither the source nor the destination encoding can be `SQL_ASCII`, as the server's behavior for cases involving the `SQL_ASCII` “encoding” is hard-wired.

Use `DROP CONVERSION` to remove user-defined conversions.

The privileges required to create a conversion might be changed in a future release.

## Examples

To create a conversion from encoding `UTF8` to `LATIN1` using `myfunc`:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc;
```

## Compatibility

`CREATE CONVERSION` is a LightDB extension. There is no `CREATE CONVERSION` statement in the SQL standard, but a `CREATE TRANSLATION` statement that is very similar in purpose and syntax.

## See Also

`ALTER CONVERSION`, `CREATE FUNCTION`, `DROP CONVERSION`



---

# CREATE DATABASE

CREATE DATABASE — create a new database

## Synopsis

```
CREATE DATABASE name
    [ [ WITH ] [ OWNER [=] user_name ]
      [ TEMPLATE [=] template ]
      [ ENCODING [=] encoding ]
      [ LOCALE [=] locale ]
      [ LC_COLLATE [=] lc_collate ]
      [ LC_CTYPE [=] lc_ctype ]
      [ TABLESPACE [=] tablespace_name ]
      [ ALLOW_CONNECTIONS [=] allowconn ]
      [ CONNECTION LIMIT [=] conlimit ]
      [ IS_TEMPLATE [=] istemplate ] ]
    [ LIGHTDB_SYNTAX_COMPATIBLE_TYPE [=] compa_type ] ]
    [=] mysql_lower_case ] ]
    [ LIGHTDB_ASCII_ZERO_STORE_VALUE
    [=] ascii_zero_store_value ] ]
```

## Description

CREATE DATABASE creates a new LightDB database.

To create a database, you must be a superuser or have the special CREATEDB privilege. See CREATE ROLE.

Before LightDB 23.4, by default, the new database will be created by cloning the standard system database `template1`. Starting from LightDB 23.4, the standard system database is not `template1` anymore, it will be one of `template_pg`, `template_oracle` or `template_mysql`.

**Table 270. Different syntax compatible mode LIGHTDB\_SYNTAX\_COMPATIBLE\_TYPE support different template:**

Template	LIGHTDB_SYNTAX_COMPATIBLE_TYPE		
	off	oracle	mysql
template0	support	support	support
template1	not support	not support	not support
template_pg	support	not support	not support
template_oracle	not support	support	not support
template_mysql	not support	not support	support

The syntax compatible mode of the database must be one of `off`, `oracle` or `mysql` when be created. If the syntax compatible mode and the template are incompatible, an error will be reported. If the GUC parameter `lightdb_ignore_template_compatible_type_mismatch` have be set as `true`, the template option will be ignored, and the syntax compatible mode `off`, `oracle` and `mysql` will use `template_pg`, `template_oracle` and `template_mysql` as default templates in turn.

A different template can be specified by writing `TEMPLATE name`. In particular, by writing `TEMPLATE template0`, you can create a pristine database (one where no user-defined objects exist and where the system objects have not been altered) containing only the standard objects predefined by your version of LightDB. This is useful if you wish to avoid copying any installation-local objects that might have been added to the standard system database.

Please be aware that if a user-created template is provided during the database creation process, the compatibility mode check is bypassed.

## Parameters

*name*

The name of a database to create.

*user\_name*

The role name of the user who will own the new database, or `DEFAULT` to use the default (namely, the user executing the command). To create a database owned by another role, you must be a direct or indirect member of that role, or be a superuser.

*template*

The name of the template from which to create the new database, or `DEFAULT` to use the default template (`template1`).

*encoding*

Character set encoding to use in the new database. Specify a string constant (e.g., `'SQL_ASCII'`), or an integer encoding number, or `DEFAULT` to use the default encoding (namely, the encoding of the template database). The character sets supported by the LightDB server are described in Section 21.3.1. See below for additional restrictions.

*locale*

This is a shortcut for setting `LC_COLLATE` and `LC_CTYPE` at once. If you specify this, you cannot specify either of those parameters.

### Tip

The other locale settings `lc_messages`, `lc_monetary`, `lc_numeric`, and `lc_time` are not fixed per database and are not set by this command. If you want to make them the default for a specific database, you can use `ALTER DATABASE . . . SET`.

*lc\_collate*

Collation order (`LC_COLLATE`) to use in the new database. This affects the sort order applied to strings, e.g., in queries with `ORDER BY`, as well as the order used in indexes on text columns. The default is to use the collation order of the template database. See below for additional restrictions.

*lc\_ctype*

Character classification (`LC_CTYPE`) to use in the new database. This affects the categorization of characters, e.g., lower, upper and digit. The default is to use the character classification of the template database. See below for additional restrictions.

*tablespace\_name*

The name of the tablespace that will be associated with the new database, or `DEFAULT` to use the template database's tablespace, since 22.3, default tablespace is `users`. This tablespace will be

the default tablespace used for objects created in this database. See CREATE TABLESPACE for more information.

*allowconn*

If false then no one can connect to this database. The default is true, allowing connections (except as restricted by other mechanisms, such as GRANT/REVOKE CONNECT).

*conlimit*

How many concurrent connections can be made to this database. -1 (the default) means no limit.

*istemplate*

If true, then this database can be cloned by any user with CREATEDB privileges; if false (the default), then only superusers or the owner of the database can clone it.

*compa\_type*

If the value is oracle, then this database can use some oracle's features. If the value is mysql, then this database can use some mysql's features. If the value is off, then this database can not use above features. The default value is specified by lightdb\_syntax\_compatible\_type

For more information about oracle's features and mysql's features, See lightdb\_dblevel\_syntax\_compatible\_type

*mysql\_lower\_case*

In MySQL compatibility mode, whether to enable the all-lowercase feature of table names. The *mysql\_lower\_case* value is one of (1, true, on, 0, false, off), the default value is 1. (1,true,on): enable (0,false,off): disable

*ascii\_zero\_store\_value*

Lightdb 23.3 introduced a new database level GUC parameter *lightdb\_ascii\_zero\_store\_value*, the value must be within the valid range of 0 to 32, inclusive of both 0 and 32, it is a database level GUC parameter, it could not be changed once the database be created.

For more information about GUC *lightdb\_ascii\_zero\_store\_value*, See *lightdb\_ascii\_zero\_store\_value*

Optional parameters can be written in any order, not only the order illustrated above.

## Notes

CREATE DATABASE cannot be executed inside a transaction block.

Errors along the line of "could not initialize database directory" are most likely related to insufficient permissions on the data directory, a full disk, or other file system problems.

Use DROP DATABASE to remove a database.

The program createdb is a wrapper program around this command, provided for convenience.

Database-level configuration parameters (set via ALTER DATABASE) and database-level permissions (set via GRANT) are not copied from the template database.

Although it is possible to copy a database other than the standard system database by specifying its name as the template, this is not (yet) intended as a general-purpose "COPY DATABASE" facility.

The principal limitation is that no other sessions can be connected to the template database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; otherwise, new connections to the template database are locked out until `CREATE DATABASE` completes. See Section 20.3 for more information.

The character set encoding specified for the new database must be compatible with the chosen locale settings (`LC_COLLATE` and `LC_CTYPE`). If the locale is `C` (or equivalently `POSIX`), then all encodings are allowed, but for other locale settings there is only one encoding that will work properly. (On Windows, however, UTF-8 encoding can be used with any locale.) `CREATE DATABASE` will allow superusers to specify `SQL_ASCII` encoding regardless of the locale settings, but this choice is deprecated and may result in misbehavior of character-string functions if data that is not encoding-compatible with the locale is stored in the database.

The encoding and locale settings must match those of the template database, except when `template0` is used as template. This is because other databases might contain data that does not match the specified encoding, or might contain indexes whose sort ordering is affected by `LC_COLLATE` and `LC_CTYPE`. Copying such data would result in a database that is corrupt according to the new settings. `template0`, however, is known to not contain any data or indexes that would be affected.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection “slot” remains for the database, it is possible that both will fail. Also, the limit is not enforced against superusers or background worker processes.

Since version 23.1, LightDB supports the creation of users with the same name when the `CREATE DATABASE` command is executed. This feature takes effect only in oracle compatibility mode and does not support distribution<sup>1</sup>. The automatically created user with the same name has the `CREATE#CONNECT#TEMPORARY` and `LOGIN` permission for the created database.

## Examples

To create a new database:

```
CREATE DATABASE lusiadas;
```

To create a database `sales` owned by user `salesapp` with a default tablespace of `salesspace`:

```
CREATE DATABASE sales OWNER salesapp TABLESPACE salesspace;
```

To create a database `music` with a different locale:

```
CREATE DATABASE music
  LOCALE 'sv_SE.utf8'
  TEMPLATE template0;
```

In this example, the `TEMPLATE template0` clause is required if the specified locale is different from the one in `template1`. (If it is not, then specifying the locale explicitly is redundant.)

To create a database `music2` with a different locale and a different character set encoding:

```
CREATE DATABASE music2
  LOCALE 'sv_SE.iso885915'
  ENCODING LATIN9
  TEMPLATE template0;
```

---

<sup>1</sup> <http://www.light-pg.com/docs/canopy/current/index.html>

---

## CREATE DATABASE

---

The specified locale and encoding settings must match, or an error will be reported.

Note that locale names are specific to the operating system, so that the above commands might not work in the same way everywhere.

Query the list of databases and the list of users before creating database testdb:

```
lightdb@postgres=# \l
```

```
                                List of databases
   Name          | Owner   | Encoding | Collate  | Ctype    |
   Access privileges
-----+-----+-----+-----+-----+
lt_test         | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
postgres       | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
template0      | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
=c/lightdb     | +      |          |             |             |
lightdb=CtC/lightdb
templatel      | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
=c/lightdb     | +      |          |             |             |
lightdb=CtC/lightdb
template_pg    | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
=c/lightdb     | +      |          |             |             |
lightdb=CtC/lightdb
template_mysql | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
=c/lightdb     | +      |          |             |             |
lightdb=CtC/lightdb
template_oracle | lightdb | UTF8     | zh_CN.UTF-8 | zh_CN.UTF-8 |
=c/lightdb     | +      |          |             |             |
lightdb=CtC/lightdb
(7 rows)
```

```
lightdb@postgres=#
```

```
lightdb@postgres=# \du
```

```
                                List of roles
   Role name | Attributes
   Member of
-----+-----+-----+
lightdb     | Superuser, Create role, Create DB, Replication, Bypass
RLS | {}
```

```
lightdb@postgres=#
```

To create a database in oracle compatibility mode#

```
lightdb@postgres=# create database testdb with
lightdb_syntax_compatible_type oracle;
NOTICE: auto create user "testdb" success
CREATE DATABASE
lightdb@postgres=#
```

Query the database list and user list again:

```
lightdb@postgres=# \l
```

List of databases				
Name	Owner	Encoding	Collate	Ctype
Access privileges				
lt_test	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
postgres	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
template0	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=c/lightdb	+			
lightdb=CTc/lightdb				
template1	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=c/lightdb	+			
lightdb=CTc/lightdb				
template_pg	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=c/lightdb	+			
lightdb=CTc/lightdb				
template_mysql	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=c/lightdb	+			
lightdb=CTc/lightdb				
template_oracle	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=c/lightdb	+			
lightdb=CTc/lightdb				
testdb	lightdb	UTF8	zh_CN.UTF-8	zh_CN.UTF-8
=Tc/lightdb	+			
lightdb=CTc/lightdb+				
testdb=CTc/lightdb				

(8 rows)

```
lightdb@postgres=#
```

```
lightdb@postgres=# \du
```

List of roles	
Role name	Attributes
Member of	
lightdb	Superuser, Create role, Create DB, Replication, Bypass RLS
testdb	

```
lightdb@postgres=#
```

## Compatibility

There is no CREATE DATABASE statement in the SQL standard. Databases are equivalent to catalogs, whose creation is implementation-defined.

## **See Also**

ALTER DATABASE, DROP DATABASE

---

# CREATE DOMAIN

CREATE DOMAIN — define a new domain

## Synopsis

```
CREATE DOMAIN name [ AS ] data_type
    [ COLLATE collation ]
    [ DEFAULT expression ]
    [ constraint [ ... ] ]
```

where *constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL | NULL | CHECK (expression) }
```

## Description

CREATE DOMAIN creates a new domain. A domain is essentially a data type with optional constraints (restrictions on the allowed set of values). The user who defines a domain becomes its owner.

If a schema name is given (for example, CREATE DOMAIN `myschema.mydomain ...`) then the domain is created in the specified schema. Otherwise it is created in the current schema. The domain name must be unique among the types and domains existing in its schema.

Domains are useful for abstracting common constraints on fields into a single location for maintenance. For example, several tables might contain email address columns, all requiring the same CHECK constraint to verify the address syntax. Define a domain rather than setting up each table's constraint individually.

To be able to create a domain, you must have USAGE privilege on the underlying type.

## Parameters

*name*

The name (optionally schema-qualified) of a domain to be created.

*data\_type*

The underlying data type of the domain. This can include array specifiers.

*collation*

An optional collation for the domain. If no collation is specified, the domain has the same collation behavior as its underlying data type. The underlying type must be collatable if COLLATE is specified.

DEFAULT *expression*

The DEFAULT clause specifies a default value for columns of the domain data type. The value is any variable-free expression (but subqueries are not allowed). The data type of the default expression must match the data type of the domain. If no default value is specified, then the default value is the null value.



The default expression will be used in any insert operation that does not specify a value for the column. If a default value is defined for a particular column, it overrides any default associated with the domain. In turn, the domain default overrides any default value associated with the underlying data type.

`CONSTRAINT constraint_name`

An optional name for a constraint. If not specified, the system generates a name.

`NOT NULL`

Values of this domain are prevented from being null (but see notes below).

`NULL`

Values of this domain are allowed to be null. This is the default.

This clause is only intended for compatibility with nonstandard SQL databases. Its use is discouraged in new applications.

`CHECK (expression)`

CHECK clauses specify integrity constraints or tests which values of the domain must satisfy. Each constraint must be an expression producing a Boolean result. It should use the key word `VALUE` to refer to the value being tested. Expressions evaluating to `TRUE` or `UNKNOWN` succeed. If the expression produces a `FALSE` result, an error is reported and the value is not allowed to be converted to the domain type.

Currently, CHECK expressions cannot contain subqueries nor refer to variables other than `VALUE`.

When a domain has multiple CHECK constraints, they will be tested in alphabetical order by name. (LightDB versions before 9.5 did not honor any particular firing order for CHECK constraints.)

## Notes

Domain constraints, particularly `NOT NULL`, are checked when converting a value to the domain type. It is possible for a column that is nominally of the domain type to read as null despite there being such a constraint. For example, this can happen in an outer-join query, if the domain column is on the nullable side of the outer join. A more subtle example is

```
INSERT INTO tab (domcol) VALUES ((SELECT domcol FROM tab WHERE
false));
```

The empty scalar sub-SELECT will produce a null value that is considered to be of the domain type, so no further constraint checking is applied to it, and the insertion will succeed.

It is very difficult to avoid such problems, because of SQL's general assumption that a null value is a valid value of every data type. Best practice therefore is to design a domain's constraints so that a null value is allowed, and then to apply column `NOT NULL` constraints to columns of the domain type as needed, rather than directly to the domain type.

LightDB assumes that CHECK constraints' conditions are immutable, that is, they will always give the same result for the same input value. This assumption is what justifies examining CHECK constraints only when a value is first converted to be of a domain type, and not at other times. (This is essentially the same as the treatment of table CHECK constraints, as described in Section 5.4.1.)

An example of a common way to break this assumption is to reference a user-defined function in a CHECK expression, and then change the behavior of that function. LightDB does not disallow that, but it will not notice if there are stored values of the domain type that now violate the CHECK constraint.

That would cause a subsequent database dump and restore to fail. The recommended way to handle such a change is to drop the constraint (using `ALTER DOMAIN`), adjust the function definition, and re-add the constraint, thereby rechecking it against stored data.

## Examples

This example creates the `us_postal_code` data type and then uses the type in a table definition. A regular expression test is used to verify that the value looks like a valid US postal code:

```
CREATE DOMAIN us_postal_code AS TEXT
CHECK (
    VALUE ~ '^\\d{5}$'
OR VALUE ~ '^\\d{5}-\\d{4}$'
);

CREATE TABLE us_snail_addy (
    address_id SERIAL PRIMARY KEY,
    street1 TEXT NOT NULL,
    street2 TEXT,
    street3 TEXT,
    city TEXT NOT NULL,
    postal us_postal_code NOT NULL
);
```

## Compatibility

The command `CREATE DOMAIN` conforms to the SQL standard.

## See Also

`ALTER DOMAIN`, `DROP DOMAIN`

---

# CREATE EVENT TRIGGER

CREATE EVENT TRIGGER — define a new event trigger

## Synopsis

```
CREATE EVENT TRIGGER name
  ON event
  [ WHEN filter_variable IN (filter_value [, ... ]) [ AND ... ] ]
  EXECUTE { FUNCTION | PROCEDURE } function_name()
```

## Description

CREATE EVENT TRIGGER creates a new event trigger. Whenever the designated event occurs and the WHEN condition associated with the trigger, if any, is satisfied, the trigger function will be executed. For a general introduction to event triggers, see Chapter 38. The user who creates an event trigger becomes its owner.

## Parameters

*name*

The name to give the new trigger. This name must be unique within the database.

*event*

The name of the event that triggers a call to the given function. See Section 38.1 for more information on event names.

*filter\_variable*

The name of a variable used to filter events. This makes it possible to restrict the firing of the trigger to a subset of the cases in which it is supported. Currently the only supported *filter\_variable* is TAG.

*filter\_value*

A list of values for the associated *filter\_variable* for which the trigger should fire. For TAG, this means a list of command tags (e.g., 'DROP FUNCTION').

*function\_name*

A user-supplied function that is declared as taking no argument and returning type `event_trigger`.

In the syntax of CREATE EVENT TRIGGER, the keywords FUNCTION and PROCEDURE are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword PROCEDURE here is historical and deprecated.

## Notes

Only superusers can create event triggers.

Event triggers are disabled in single-user mode (see `lightdb`). If an erroneous event trigger disables the database so much that you can't even drop the trigger, restart in single-user mode and you'll be able to do that.

## Examples

Forbid the execution of any DDL command:

```
CREATE OR REPLACE FUNCTION abort_any_command()  
  RETURNS event_trigger  
  LANGUAGE plpgsql  
  AS $$  
BEGIN  
  RAISE EXCEPTION 'command % is disabled', tg_tag;  
END;  
$$;  
  
CREATE EVENT TRIGGER abort_ddl ON ddl_command_start  
  EXECUTE FUNCTION abort_any_command();
```

## Compatibility

There is no CREATE EVENT TRIGGER statement in the SQL standard.

## See Also

ALTER EVENT TRIGGER, DROP EVENT TRIGGER, CREATE FUNCTION

---

# CREATE EXTENSION

CREATE EXTENSION — install an extension

## Synopsis

```
CREATE EXTENSION [ IF NOT EXISTS ] extension_name
    [ WITH ] [ SCHEMA schema_name ]
    [ VERSION version ]
    [ CASCADE ]
```

## Description

CREATE EXTENSION loads a new extension into the current database. There must not be an extension of the same name already loaded.

Loading an extension essentially amounts to running the extension's script file. The script will typically create new SQL objects such as functions, data types, operators and index support methods. CREATE EXTENSION additionally records the identities of all the created objects, so that they can be dropped again if DROP EXTENSION is issued.

The user who runs CREATE EXTENSION becomes the owner of the extension for purposes of later privilege checks, and normally also becomes the owner of any objects created by the extension's script.

Loading an extension ordinarily requires the same privileges that would be required to create its component objects. For many extensions this means superuser privileges are needed. However, if the extension is marked *trusted* in its control file, then it can be installed by any user who has CREATE privilege on the current database. In this case the extension object itself will be owned by the calling user, but the contained objects will be owned by the bootstrap superuser (unless the extension's script explicitly assigns them to the calling user). This configuration gives the calling user the right to drop the extension, but not to modify individual objects within it.

## Parameters

IF NOT EXISTS

Do not throw an error if an extension with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing extension is anything like the one that would have been created from the currently-available script file.

*extension\_name*

The name of the extension to be installed. LightDB will create the extension using details from the file `SHAREDIR/extension/extension_name.control`.

*schema\_name*

The name of the schema in which to install the extension's objects, given that the extension allows its contents to be relocated. The named schema must already exist. If not specified, and the extension's control file does not specify a schema either, the current default object creation schema is used.

If the extension specifies a `schema` parameter in its control file, then that schema cannot be overridden with a `SCHEMA` clause. Normally, an error will be raised if a `SCHEMA` clause is given and it conflicts with the extension's `schema` parameter. However, if the `CASCADE` clause is also

given, then *schema\_name* is ignored when it conflicts. The given *schema\_name* will be used for installation of any needed extensions that do not specify *schema* in their control files.

Remember that the extension itself is not considered to be within any schema: extensions have unqualified names that must be unique database-wide. But objects belonging to the extension can be within schemas.

*version*

The version of the extension to install. This can be written as either an identifier or a string literal. The default version is whatever is specified in the extension's control file.

CASCADE

Automatically install any extensions that this extension depends on that are not already installed. Their dependencies are likewise automatically installed, recursively. The `SCHEMA` clause, if given, applies to all extensions that get installed this way. Other options of the statement are not applied to automatically-installed extensions; in particular, their default versions are always selected.

## Notes

Before you can use `CREATE EXTENSION` to load an extension into a database, the extension's supporting files must be installed. Information about installing the extensions supplied with LightDB can be found in Additional Supplied Modules.

The extensions currently available for loading can be identified from the `pg_available_extensions` or `pg_available_extension_versions` system views.

### Caution

Installing an extension as superuser requires trusting that the extension's author wrote the extension installation script in a secure fashion. It is not terribly difficult for a malicious user to create trojan-horse objects that will compromise later execution of a carelessly-written extension script, allowing that user to acquire superuser privileges. However, trojan-horse objects are only hazardous if they are in the `search_path` during script execution, meaning that they are in the extension's installation target schema or in the schema of some extension it depends on. Therefore, a good rule of thumb when dealing with extensions whose scripts have not been carefully vetted is to install them only into schemas for which `CREATE` privilege has not been and will not be granted to any untrusted users. Likewise for any extensions they depend on.

The extensions supplied with LightDB are believed to be secure against installation-time attacks of this sort, except for a few that depend on other extensions. As stated in the documentation for those extensions, they should be installed into secure schemas, or installed into the same schemas as the extensions they depend on, or both.

For information about writing new extensions, see Section 36.17.

## Examples

Install the `hstore` extension into the current database, placing its objects in schema `addons`:

```
CREATE EXTENSION hstore SCHEMA addons;
```

Another way to accomplish the same thing:

```
SET search_path = addons;  
CREATE EXTENSION hstore;
```

## Compatibility

CREATE EXTENSION is a LightDB extension.

## See Also

ALTER EXTENSION, DROP EXTENSION

---

# CREATE FOREIGN DATA WRAPPER

CREATE FOREIGN DATA WRAPPER — define a new foreign-data wrapper

## Synopsis

```
CREATE FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( option 'value' [, ... ] ) ]
```

## Description

CREATE FOREIGN DATA WRAPPER creates a new foreign-data wrapper. The user who defines a foreign-data wrapper becomes its owner.

The foreign-data wrapper name must be unique within the database.

Only superusers can create foreign-data wrappers.

## Parameters

*name*

The name of the foreign-data wrapper to be created.

HANDLER *handler\_function*

*handler\_function* is the name of a previously registered function that will be called to retrieve the execution functions for foreign tables. The handler function must take no arguments, and its return type must be `fdw_handler`.

It is possible to create a foreign-data wrapper with no handler function, but foreign tables using such a wrapper can only be declared, not accessed.

VALIDATOR *validator\_function*

*validator\_function* is the name of a previously registered function that will be called to check the generic options given to the foreign-data wrapper, as well as options for foreign servers, user mappings and foreign tables using the foreign-data wrapper. If no validator function or NO VALIDATOR is specified, then options will not be checked at creation time. (Foreign-data wrappers will possibly ignore or reject invalid option specifications at run time, depending on the implementation.) The validator function must take two arguments: one of type `text[]`, which will contain the array of options as stored in the system catalogs, and one of type `oid`, which will be the OID of the system catalog containing the options. The return type is ignored; the function should report invalid options using the `ereport(ERROR)` function.

OPTIONS ( *option* '*value*' [, ... ] )

This clause specifies options for the new foreign-data wrapper. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Option names must be unique.

## Notes

LightDB's foreign-data functionality is still under active development. Optimization of queries is primitive (and mostly left to the wrapper, too). Thus, there is considerable room for future performance improvements.



## Examples

Create a useless foreign-data wrapper dummy:

```
CREATE FOREIGN DATA WRAPPER dummy;
```

Create a foreign-data wrapper `file` with handler function `file_fdw_handler`:

```
CREATE FOREIGN DATA WRAPPER file HANDLER file_fdw_handler;
```

Create a foreign-data wrapper `mywrapper` with some options:

```
CREATE FOREIGN DATA WRAPPER mywrapper  
    OPTIONS (debug 'true');
```

## Compatibility

`CREATE FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), with the exception that the `HANDLER` and `VALIDATOR` clauses are extensions and the standard clauses `LIBRARY` and `LANGUAGE` are not implemented in LightDB.

Note, however, that the SQL/MED functionality as a whole is not yet conforming.

## See Also

`ALTER FOREIGN DATA WRAPPER`, `DROP FOREIGN DATA WRAPPER`, `CREATE SERVER`,  
`CREATE USER MAPPING`, `CREATE FOREIGN TABLE`

---

# CREATE FOREIGN TABLE

CREATE FOREIGN TABLE — define a new foreign table

## Synopsis

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name ( [
    { column_name data_type [ OPTIONS ( option 'value' [, ... ] ) ]
  [ COLLATE collation ] [ column_constraint [ ... ] ]
    | table_constraint }
    [, ... ]
] )
[ INHERITS ( parent_table [, ... ] ) ]
SERVER server_name
[ OPTIONS ( option 'value' [, ... ] ) ]
```

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
PARTITION OF parent_table [ (
    { column_name [ WITH OPTIONS ] [ column_constraint [ ... ] ]
    | table_constraint }
    [, ... ]
) ]
{ FOR VALUES partition_bound_spec | DEFAULT }
SERVER server_name
[ OPTIONS ( option 'value' [, ... ] ) ]
```

where *column\_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  CHECK ( expression ) [ NO INHERIT ] |
  DEFAULT default_expr |
  GENERATED ALWAYS AS ( generation_expr ) STORED }
```

and *table\_constraint* is:

```
[ CONSTRAINT constraint_name ]
CHECK ( expression ) [ NO INHERIT ]
```

and *partition\_bound\_spec* is:

```
IN ( partition_bound_expr [, ...] ) |
FROM ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] )
TO ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS numeric_literal, REMAINDER numeric_literal )
```

## Description

CREATE FOREIGN TABLE creates a new foreign table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, CREATE FOREIGN TABLE myschema.mytable ...) then the table is created in the specified schema. Otherwise it is created in the current schema. The

name of the foreign table must be distinct from the name of any other foreign table, table, sequence, index, view, or materialized view in the same schema.

CREATE FOREIGN TABLE also automatically creates a data type that represents the composite type corresponding to one row of the foreign table. Therefore, foreign tables cannot have the same name as any existing data type in the same schema.

If PARTITION OF clause is specified then the table is created as a partition of `parent_table` with specified bounds.

To be able to create a foreign table, you must have USAGE privilege on the foreign server, as well as USAGE privilege on all column types used in the table.

## Parameters

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

*table\_name*

The name (optionally schema-qualified) of the table to be created.

*column\_name*

The name of a column to be created in the new table.

*data\_type*

The data type of the column. This can include array specifiers. For more information on the data types supported by LightDB, refer to Chapter 8.

COLLATE *collation*

The COLLATE clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

INHERITS ( *parent\_table* [, ... ] )

The optional INHERITS clause specifies a list of tables from which the new foreign table automatically inherits all columns. Parent tables can be plain tables or foreign tables. See the similar form of CREATE TABLE for more details.

PARTITION OF *parent\_table* { FOR VALUES *partition\_bound\_spec* | DEFAULT }

This form can be used to create the foreign table as partition of the given parent table with specified partition bound values. See the similar form of CREATE TABLE for more details. Note that it is currently not allowed to create the foreign table as a partition of the parent table if there are UNIQUE indexes on the parent table. (See also ALTER TABLE ATTACH PARTITION.)

CONSTRAINT *constraint\_name*

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

NOT NULL

The column is not allowed to contain null values.

NULL

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

CHECK ( *expression* ) [ NO INHERIT ]

The CHECK clause specifies an expression producing a Boolean result which each row in the foreign table is expected to satisfy; that is, the expression should produce TRUE or UNKNOWN, never FALSE, for all rows in the foreign table. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, CHECK expressions cannot contain subqueries nor refer to variables other than columns of the current row. The system column `tableoid` may be referenced, but not any other system column.

A constraint marked with NO INHERIT will not propagate to child tables.

DEFAULT *default\_expr*

The DEFAULT clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (subqueries and cross-references to other columns in the current table are not allowed). The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

GENERATED ALWAYS AS ( *generation\_expr* ) STORED

This clause creates the column as a *generated column*. The column cannot be written to, and when read the result of the specified expression will be returned.

The keyword STORED is required to signify that the column will be computed on write. (The computed value will be presented to the foreign-data wrapper for storage and must be returned on reading.)

The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

*server\_name*

The name of an existing foreign server to use for the foreign table. For details on defining a server, see CREATE SERVER.

OPTIONS ( *option* 'value' [, ...] )

Options to be associated with the new foreign table or one of its columns. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name).

## Notes

Constraints on foreign tables (such as CHECK or NOT NULL clauses) are not enforced by the core LightDB system, and most foreign data wrappers do not attempt to enforce them either; that is, the

constraint is simply assumed to hold true. There would be little point in such enforcement since it would only apply to rows inserted or updated via the foreign table, and not to rows modified by other means, such as directly on the remote server. Instead, a constraint attached to a foreign table should represent a constraint that is being enforced by the remote server.

Some special-purpose foreign data wrappers might be the only access mechanism for the data they access, and in that case it might be appropriate for the foreign data wrapper itself to perform constraint enforcement. But you should not assume that a wrapper does that unless its documentation says so.

Although LightDB does not attempt to enforce constraints on foreign tables, it does assume that they are correct for purposes of query optimization. If there are rows visible in the foreign table that do not satisfy a declared constraint, queries on the table might produce errors or incorrect answers. It is the user's responsibility to ensure that the constraint definition matches reality.

### Caution

When a foreign table is used as a partition of a partitioned table, there is an implicit constraint that its contents must satisfy the partitioning rule. Again, it is the user's responsibility to ensure that that is true, which is best done by installing a matching constraint on the remote server.

Within a partitioned table containing foreign-table partitions, an UPDATE that changes the partition key value can cause a row to be moved from a local partition to a foreign-table partition, provided the foreign data wrapper supports tuple routing. However it is not currently possible to move a row from a foreign-table partition to another partition. An UPDATE that would require doing that will fail due to the partitioning constraint, assuming that that is properly enforced by the remote server.

Similar considerations apply to generated columns. Stored generated columns are computed on insert or update on the local LightDB server and handed to the foreign-data wrapper for writing out to the foreign data store, but it is not enforced that a query of the foreign table returns values for stored generated columns that are consistent with the generation expression. Again, this might result in incorrect query results.

## Examples

Create foreign table `films`, which will be accessed through the server `film_server`:

```
CREATE FOREIGN TABLE films (  
    code          char(5) NOT NULL,  
    title         varchar(40) NOT NULL,  
    did           integer NOT NULL,  
    date_prod    date,  
    kind         varchar(10),  
    len          interval hour to minute  
)  
SERVER film_server;
```

Create foreign table `measurement_y2016m07`, which will be accessed through the server `server_07`, as a partition of the range partitioned table `measurement`:

```
CREATE FOREIGN TABLE measurement_y2016m07  
    PARTITION OF measurement FOR VALUES FROM ('2016-07-01') TO  
    ('2016-08-01')  
    SERVER server_07;
```

## Compatibility

The `CREATE FOREIGN TABLE` command largely conforms to the SQL standard; however, much as with `CREATE TABLE`, `NULL` constraints and zero-column foreign tables are permitted. The ability to specify column default values is also a LightDB extension. Table inheritance, in the form defined by LightDB, is nonstandard.

## See Also

`ALTER FOREIGN TABLE`, `DROP FOREIGN TABLE`, `CREATE TABLE`, `CREATE SERVER`, `IMPORT FOREIGN SCHEMA`

---

# CREATE FUNCTION

CREATE FUNCTION — define a new function

## Synopsis

```
CREATE [ OR REPLACE ] FUNCTION
    name ( [ [ argmode ] [ argname ] argtype [ { DEFAULT |
= } default_expr ] [, ...] ] )
    [ RETURNS rettype
      | RETURNS TABLE ( column_name column_type [, ...] ) ]
    { LANGUAGE lang_name
      | TRANSFORM { FOR TYPE type_name } [, ... ]
      | WINDOW
      | { IMMUTABLE | STABLE | VOLATILE }
      | [ NOT ] LEAKPROOF
      | { CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT |
STRICT }
      | { [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY
DEFINER }
      | PARALLEL { UNSAFE | RESTRICTED | SAFE }
      | COST execution_cost
      | ROWS result_rows
      | SUPPORT support_function
      | SET configuration_parameter { TO value | = value | FROM
CURRENT }
      | AS 'definition'
      | AS 'obj_file', 'link_symbol'
    } ...
```

## Description

CREATE FUNCTION defines a new function. CREATE OR REPLACE FUNCTION will either create a new function, or replace an existing definition. To be able to define a function, the user must have the USAGE privilege on the language.

If a schema name is included, then the function is created in the specified schema. Otherwise it is created in the current schema. The name of the new function must not match any existing function or procedure with the same input argument types in the same schema. However, functions and procedures of different argument types can share a name (this is called *overloading*).

To replace the current definition of an existing function, use CREATE OR REPLACE FUNCTION. It is not possible to change the name or argument types of a function this way (if you tried, you would actually be creating a new, distinct function). Also, CREATE OR REPLACE FUNCTION will not let you change the return type of an existing function. To do that, you must drop and recreate the function. (When using OUT parameters, that means you cannot change the types of any OUT parameters except by dropping the function.)

When CREATE OR REPLACE FUNCTION is used to replace an existing function, the ownership and permissions of the function do not change. All other function properties are assigned the values specified or implied in the command. You must own the function to replace it (this includes being a member of the owning role).

If you drop and then recreate a function, the new function is not the same entity as the old; you will have to drop existing rules, views, triggers, etc. that refer to the old function. Use CREATE OR REPLACE

FUNCTION to change a function definition without breaking objects that refer to the function. Also, ALTER FUNCTION can be used to change most of the auxiliary properties of an existing function.

The user that creates the function becomes the owner of the function.

To be able to create a function, you must have USAGE privilege on the argument types and the return type.

Refer to Section 36.3 for further information on writing functions.

## Parameters

*name*

The name (optionally schema-qualified) of the function to create.

*argmode*

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Only OUT arguments can follow a VARIADIC one. Also, OUT and INOUT arguments cannot be used together with the RETURNS TABLE notation.

*argname*

The name of an argument. Some languages (including SQL and PL/pgSQL) let you use the name in the function body. For other languages the name of an input argument is just extra documentation, so far as the function itself is concerned; but you can use input argument names when calling a function to improve readability (see Section 4.3). In any case, the name of an output argument is significant, because it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

*argtype*

The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. Pseudo-types indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a function independent of changes to the definition of a table.

*default\_expr*

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. Only input (including INOUT) parameters can have a default value. All input parameters following a parameter with a default value must have default values as well.

*rettype*

The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or can reference the type of a table column. Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. If the function is not supposed to return a value, specify `void` as the return type.

When there are OUT or INOUT parameters, the RETURNS clause can be omitted. If present, it must agree with the result type implied by the output parameters: RECORD if there are multiple output parameters, or the same type as the single output parameter.

The SETOF modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing `table_name.column_name%TYPE`.



*column\_name*

The name of an output column in the RETURNS TABLE syntax. This is effectively another way of declaring a named OUT parameter, except that RETURNS TABLE also implies RETURNS SETOF.

*column\_type*

The data type of an output column in the RETURNS TABLE syntax.

*lang\_name*

The name of the language that the function is implemented in. It can be `sql`, `c`, `internal`, or the name of a user-defined procedural language, e.g., `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

TRANSFORM { FOR TYPE *type\_name* } [, ... ] }

Lists which transforms a call to the function should apply. Transforms convert between SQL types and language-specific data types; see CREATE TRANSFORM. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

WINDOW

WINDOW indicates that the function is a *window function* rather than a plain function. This is currently only useful for functions written in C. The WINDOW attribute cannot be changed when replacing an existing function definition.

IMMUTABLE

STABLE

VOLATILE

These attributes inform the query optimizer about the behavior of the function. At most one choice can be specified. If none of these appear, VOLATILE is the default assumption.

IMMUTABLE indicates that the function cannot modify the database and always returns the same result when given the same argument values; that is, it does not do database lookups or otherwise use information not directly present in its argument list. If this option is given, any call of the function with all-constant arguments can be immediately replaced with the function value.

STABLE indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same argument values, but that its result could change across SQL statements. This is the appropriate selection for functions whose results depend on database lookups, parameter variables (such as the current time zone), etc. (It is inappropriate for AFTER triggers that wish to query rows modified by the current command.) Also note that the `current_timestamp` family of functions qualify as stable, since their values do not change within a transaction.

VOLATILE indicates that the function value can change even within a single table scan, so no optimizations can be made. Relatively few database functions are volatile in this sense; some examples are `random()`, `curval()`, `timeofday()`. But note that any function that has side-effects must be classified volatile, even if its result is quite predictable, to prevent calls from being optimized away; an example is `setval()`.

For additional details see Section 36.7.

LEAKPROOF

LEAKPROOF indicates that the function has no side effects. It reveals no information about its arguments other than by its return value. For example, a function which throws an error message

for some argument values but not others, or which includes the argument values in any error message, is not leakproof. This affects how the system executes queries against views created with the `security_barrier` option or tables with row level security enabled. The system will enforce conditions from security policies and security barrier views before any user-supplied conditions from the query itself that contain non-leakproof functions, in order to prevent the inadvertent exposure of data. Functions and operators marked as leakproof are assumed to be trustworthy, and may be executed before conditions from security policies and security barrier views. In addition, functions which do not take arguments or which are not passed any arguments from the security barrier view or table do not have to be marked as leakproof to be executed before security conditions. See `CREATE VIEW` and Section 39.5. This option can only be set by the superuser.

`CALLED ON NULL INPUT`  
`RETURNS NULL ON NULL INPUT`  
`STRICT`

`CALLED ON NULL INPUT` (the default) indicates that the function will be called normally when some of its arguments are null. It is then the function author's responsibility to check for null values if necessary and respond appropriately.

`RETURNS NULL ON NULL INPUT` or `STRICT` indicates that the function always returns null whenever any of its arguments are null. If this parameter is specified, the function is not executed when there are null arguments; instead a null result is assumed automatically.

`[EXTERNAL] SECURITY INVOKER`  
`[EXTERNAL] SECURITY DEFINER`

`SECURITY INVOKER` indicates that the function is to be executed with the privileges of the user that calls it. That is the default. `SECURITY DEFINER` specifies that the function is to be executed with the privileges of the user that owns it.

The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all functions not only external ones.

`PARALLEL`

`PARALLEL UNSAFE` indicates that the function can't be executed in parallel mode and the presence of such a function in an SQL statement forces a serial execution plan. This is the default. `PARALLEL RESTRICTED` indicates that the function can be executed in parallel mode, but the execution is restricted to parallel group leader. `PARALLEL SAFE` indicates that the function is safe to run in parallel mode without restriction.

Functions should be labeled parallel unsafe if they modify any database state, or if they make changes to the transaction such as using sub-transactions, or if they access sequences or attempt to make persistent changes to settings (e.g., `setval`). They should be labeled as parallel restricted if they access temporary tables, client connection state, cursors, prepared statements, or miscellaneous backend-local state which the system cannot synchronize in parallel mode (e.g., `setseed` cannot be executed other than by the group leader because a change made by another process would not be reflected in the leader). In general, if a function is labeled as being safe when it is restricted or unsafe, or if it is labeled as being restricted when it is in fact unsafe, it may throw errors or produce wrong answers when used in a parallel query. C-language functions could in theory exhibit totally undefined behavior if mislabeled, since there is no way for the system to protect itself against arbitrary C code, but in most likely cases the result will be no worse than for any other function. If in doubt, functions should be labeled as `UNSAFE`, which is the default.

`COST execution_cost`

A positive number giving the estimated execution cost for the function, in units of `cpu_operator_cost`. If the function returns a set, this is the cost per returned row. If the cost is not specified, 1 unit is assumed for C-language and internal functions, and 100 units for functions in

all other languages. Larger values cause the planner to try to avoid evaluating the function more often than necessary.

ROWS *result\_rows*

A positive number giving the estimated number of rows that the planner should expect the function to return. This is only allowed when the function is declared to return a set. The default assumption is 1000 rows.

SUPPORT *support\_function*

The name (optionally schema-qualified) of a *planner support function* to use for this function. See Section 36.11 for details. You must be superuser to use this option.

*configuration\_parameter*

*value*

The SET clause causes the specified configuration parameter to be set to the specified value when the function is entered, and then restored to its prior value when the function exits. SET FROM CURRENT saves the value of the parameter that is current when CREATE FUNCTION is executed as the value to be applied when the function is entered.

If a SET clause is attached to a function, then the effects of a SET LOCAL command executed inside the function for the same variable are restricted to the function: the configuration parameter's prior value is still restored at function exit. However, an ordinary SET command (without LOCAL) overrides the SET clause, much as it would do for a previous SET LOCAL command: the effects of such a command will persist after function exit, unless the current transaction is rolled back.

See SET and Chapter 17 for more information about allowed parameter names and values.

*definition*

A string constant defining the function; the meaning depends on the language. It can be an internal function name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the function definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function definition must be escaped by doubling them.

*obj\_file, link\_symbol*

This form of the AS clause is used for dynamically loadable C language functions when the function name in the C language source code is not the same as the name of the SQL function. The string *obj\_file* is the name of the shared library file containing the compiled C function, and is interpreted as for the LOAD command. The string *link\_symbol* is the function's link symbol, that is, the name of the function in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL function being defined. The C names of all functions must be different, so you must give overloaded C functions different C names (for example, use the argument types as part of the C names).

When repeated CREATE FUNCTION calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

## Overloading

LightDB allows function *overloading*; that is, the same name can be used for several different functions so long as they have distinct input argument types. Whether or not you use it, this capability entails security precautions when calling functions in databases where some users mistrust other users; see Section 10.3.

Two functions are considered the same if they have the same names and *input* argument types, ignoring any OUT parameters. Thus for example these declarations conflict:

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, out text) ...
```

Functions that have different argument type lists will not be considered to conflict at creation time, but if defaults are provided they might conflict in use. For example, consider

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, int default 42) ...
```

A call `foo(10)` will fail due to the ambiguity about which function should be called.

## Notes

The full SQL type syntax is allowed for declaring a function's arguments and return value. However, parenthesized type modifiers (e.g., the precision field for type `numeric`) are discarded by `CREATE FUNCTION`. Thus for example `CREATE FUNCTION foo (varchar(10)) ...` is exactly the same as `CREATE FUNCTION foo (varchar) ....`

When replacing an existing function with `CREATE OR REPLACE FUNCTION`, there are restrictions on changing parameter names. You cannot change the name already assigned to any input parameter (although you can add names to parameters that had none before). If there is more than one output parameter, you cannot change the names of the output parameters, because that would change the column names of the anonymous composite type that describes the function's result. These restrictions are made to ensure that existing calls of the function do not stop working when it is replaced.

If a function is declared `STRICT` with a `VARIADIC` argument, the strictness check tests that the variadic array *as a whole* is non-null. The function will still be called if the array has null elements.

## Examples

Add two integers using a SQL function:

```
CREATE FUNCTION add(integer, integer) RETURNS integer
  AS 'select $1 + $2;'
  LANGUAGE SQL
  IMMUTABLE
  RETURNS NULL ON NULL INPUT;
```

Increment an integer, making use of an argument name, in PL/pgSQL:

```
CREATE OR REPLACE FUNCTION increment(i integer) RETURNS integer AS
  $$
    BEGIN
      RETURN i + 1;
    END;
  $$ LANGUAGE plpgsql;
```

Return a record containing multiple output parameters:

```
CREATE FUNCTION dup(in int, out f1 int, out f2 text)
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;
```

```
SELECT * FROM dup(42);
```

You can do the same thing more verbosely with an explicitly named composite type:

```
CREATE TYPE dup_result AS (f1 int, f2 text);

CREATE FUNCTION dup(int) RETURNS dup_result
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;

SELECT * FROM dup(42);
```

Another way to return multiple columns is to use a TABLE function:

```
CREATE FUNCTION dup(int) RETURNS TABLE(f1 int, f2 text)
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;

SELECT * FROM dup(42);
```

However, a TABLE function is different from the preceding examples, because it actually returns a *set* of records, not just one record.

## Writing SECURITY DEFINER Functions Safely

Because a SECURITY DEFINER function is executed with the privileges of the user that owns it, care is needed to ensure that the function cannot be misused. For security, search\_path should be set to exclude any schemas writable by untrusted users. This prevents malicious users from creating objects (e.g., tables, functions, and operators) that mask objects intended to be used by the function. Particularly important in this regard is the temporary-table schema, which is searched first by default, and is normally writable by anyone. A secure arrangement can be obtained by forcing the temporary schema to be searched last. To do this, write pg\_temp as the last entry in search\_path. This function illustrates safe usage:

```
CREATE FUNCTION check_password(uname TEXT, pass TEXT)
  RETURNS BOOLEAN AS $$
  DECLARE passed BOOLEAN;
  BEGIN
    SELECT (pwd = $2) INTO passed
    FROM pwds
    WHERE username = $1;

    RETURN passed;
  END;
$$ LANGUAGE plpgsql
  SECURITY DEFINER
  -- Set a secure search_path: trusted schema(s), then 'pg_temp'.
  SET search_path = admin, pg_temp;
```

This function's intention is to access a table admin.pwds. But without the SET clause, or with a SET clause mentioning only admin, the function could be subverted by creating a temporary table named pwds.

Before LightDB version 8.3, the SET clause was not available, and so older functions may contain rather complicated logic to save, set, and restore search\_path. The SET clause is far easier to use for this purpose.

Another point to keep in mind is that by default, execute privilege is granted to PUBLIC for newly created functions (see Section 5.7 for more information). Frequently you will wish to restrict use of a security definer function to only some users. To do that, you must revoke the default PUBLIC privileges and then grant execute privilege selectively. To avoid having a window where the new function is accessible to all, create it and set the privileges within a single transaction. For example:

```
BEGIN;  
CREATE FUNCTION check_password(uname TEXT, pass TEXT) ... SECURITY  
DEFINER;  
REVOKE ALL ON FUNCTION check_password(uname TEXT, pass TEXT) FROM  
PUBLIC;  
GRANT EXECUTE ON FUNCTION check_password(uname TEXT, pass TEXT) TO  
admins;  
COMMIT;
```

## Compatibility

A CREATE FUNCTION command is defined in the SQL standard. The LightDB version is similar but not fully compatible. The attributes are not portable, neither are the different available languages.

For compatibility with some other database systems, *argmode* can be written either before or after *argname*. But only the first way is standard-compliant.

For parameter defaults, the SQL standard specifies only the syntax with the DEFAULT key word. The syntax with = is used in T-SQL and Firebird.

## See Also

ALTER FUNCTION, DROP FUNCTION, GRANT, LOAD, REVOKE

---

# CREATE GROUP

CREATE GROUP — define a new database role

## Synopsis

```
CREATE GROUP name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
SUPERUSER | NOSUPERUSER  
|  
CREATEDB | NOCREATEDB  
|  
CREATEROLE | NOCREATEROLE  
|  
INHERIT | NOINHERIT  
|  
LOGIN | NOLOGIN  
|  
REPLICATION | NOREPLICATION  
|  
BYPASSRLS | NOBYPASSRLS  
|  
CONNECTION LIMIT connlimit  
|  
[ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
|  
VALID UNTIL 'timestamp'  
|  
IN ROLE role_name [, ...]  
|  
IN GROUP role_name [, ...]  
|  
ROLE role_name [, ...]  
|  
ADMIN role_name [, ...]  
|  
USER role_name [, ...]  
|  
SYSID uid
```

## Description

CREATE GROUP is now an alias for CREATE ROLE.

## Compatibility

There is no CREATE GROUP statement in the SQL standard.

## See Also

CREATE ROLE

---

# CREATE INDEX

CREATE INDEX — define a new index

## Synopsis

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ [ IF NOT EXISTS ]
[ schema_name. ] name ] ON [ ONLY ] table_name [ USING method ]
( { column_name | ( expression ) } [ COLLATE collation ]
[ opclass [ ( opclass_parameter = value [, ... ] ) ] ] [ ASC |
DESC ] [ NULLS { FIRST | LAST } ] [, ...] )
[ INCLUDE ( column_name [, ...] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ LOCAL | GLOBAL | LT_HASH_PARTITION_DEPT ]
[ LOGGING | NOLOGGING ]
[ COMPRESS | NOCOMPRESS ]
[ TABLESPACE tablespace_name ]
[ WHERE predicate ]
```

## Description

`CREATE INDEX` constructs an index on the specified column(s) of the specified relation, which can be a table or a materialized view. Indexes are primarily used to enhance database performance (though inappropriate use can result in slower performance).

The key field(s) for the index are specified as column names, or alternatively as expressions written in parentheses. Multiple fields can be specified if the index method supports multicolumn indexes.

An index field can be an expression computed from the values of one or more columns of the table row. This feature can be used to obtain fast access to data based on some transformation of the basic data. For example, an index computed on `upper(col)` would allow the clause `WHERE upper(col) = 'JIM'` to use an index.

LightDB provides the index methods B-tree, hash, GiST, GIN. Users can also define their own index methods, but that is fairly complicated.

When the `WHERE` clause is present, a *partial index* is created. A partial index is an index that contains entries for only a portion of a table, usually a portion that is more useful for indexing than the rest of the table. For example, if you have a table that contains both billed and unbilled orders where the unbilled orders take up a small fraction of the total table and yet that is an often used section, you can improve performance by creating an index on just that portion. Another possible application is to use `WHERE` with `UNIQUE` to enforce uniqueness over a subset of a table. See Section 11.8 for more discussion.

The expression used in the `WHERE` clause can refer only to columns of the underlying table, but it can use all columns, not just the ones being indexed. Presently, subqueries and aggregate expressions are also forbidden in `WHERE`. The same restrictions apply to index fields that are expressions.

All functions and operators used in an index definition must be “immutable”, that is, their results must depend only on their arguments and never on any outside influence (such as the contents of another table or the current time). This restriction ensures that the behavior of the index is well-defined. To use a user-defined function in an index expression or `WHERE` clause, remember to mark the function immutable when you create it.

LightDB supports automatic collection of statistics immediately after index creation. You can set the `lightdb_enable_indexautoanalyze` configuration variable to decide whether to automatically collect statistics.



## Parameters

### UNIQUE

Causes the system to check for duplicate values in the table when the index is created (if data already exist) and each time data is added. Attempts to insert or update data which would result in duplicate entries will generate an error.

Additional restrictions apply when unique indexes are applied to partitioned tables; see `CREATE TABLE`.

### CONCURRENTLY

When this option is used, LightDB will build the index without taking any locks that prevent concurrent inserts, updates, or deletes on the table; whereas a standard index build locks out writes (but not reads) on the table until it's done. There are several caveats to be aware of when using this option — see `Building Indexes Concurrently` below.

For temporary tables, `CREATE INDEX` is always non-concurrent, as no other session can access them, and non-concurrent index creation is cheaper.

### IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing index is anything like the one that would have been created. Index name is required when `IF NOT EXISTS` is specified.

### INCLUDE

The optional `INCLUDE` clause specifies a list of columns which will be included in the index as *non-key* columns. A non-key column cannot be used in an index scan search qualification, and it is disregarded for purposes of any uniqueness or exclusion constraint enforced by the index. However, an index-only scan can return the contents of non-key columns without having to visit the index's table, since they are available directly from the index entry. Thus, addition of non-key columns allows index-only scans to be used for queries that otherwise could not use them.

It's wise to be conservative about adding non-key columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion will fail. In any case, non-key columns duplicate data from the index's table and bloat the size of the index, thus potentially slowing searches. Furthermore, B-tree deduplication is never used with indexes that have a non-key column.

Columns listed in the `INCLUDE` clause don't need appropriate operator classes; the clause can include columns whose data types don't have operator classes defined for a given access method.

Expressions are not supported as included columns since they cannot be used in index-only scans.

Currently, the B-tree and the GiST index access methods support this feature. In B-tree and the GiST indexes, the values of columns listed in the `INCLUDE` clause are included in leaf tuples which correspond to heap tuples, but are not included in upper-level index entries used for tree navigation.

### *name*

The name of the index to be created. No schema name can be included here; the index is always created in the same schema as its parent table. If the name is omitted, LightDB chooses a suitable name based on the parent table's name and the indexed column name(s).

### ONLY

Indicates not to recurse creating indexes on partitions, if the table is partitioned. The default is to recurse.

*table\_name*

The name (possibly schema-qualified) of the table to be indexed.

*method*

The name of the index method to be used. Choices are `btree`, `hash`, `gist`, `gin`. The default method is `btree`.

*column\_name*

The name of a column of the table.

*expression*

An expression based on one or more columns of the table. The expression usually must be written with surrounding parentheses, as shown in the syntax. However, the parentheses can be omitted if the expression has the form of a function call.

*collation*

The name of the collation to use for the index. By default, the index uses the collation declared for the column to be indexed or the result collation of the expression to be indexed. Indexes with non-default collations can be useful for queries that involve expressions using non-default collations.

*opclass*

The name of an operator class. See below for details.

*opclass\_parameter*

The name of an operator class parameter. See below for details.

ASC

Specifies ascending sort order (which is the default).

DESC

Specifies descending sort order.

NULLS FIRST

Specifies that nulls sort before non-nulls. This is the default when DESC is specified.

NULLS LAST

Specifies that nulls sort after non-nulls. This is the default when DESC is not specified.

*storage\_parameter*

The name of an index-method-specific storage parameter. See Index Storage Parameters below for details.

*tablespace\_name*

The tablespace in which to create the index. If not specified, `default_tablespace` is consulted, or `temp_tablespaces` for indexes on temporary tables.

*predicate*

The constraint expression for a partial index.

*local*

Oracle compatible syntax, no function support. It is necessary to change the configuration to Oracle compatible mode.

*global*

Oracle compatible syntax, no function support. It is necessary to change the configuration to Oracle compatible mode.

*LT\_HASH\_PARTITION\_DEPT*

Oracle compatible syntax. Only global hash partition is available for the current implementation. It is necessary to change the configuration to Oracle compatible mode.

The syntax detail is as follows:

```
{ PARTITION BY HASH ( { columns } ) PARTITIONS Iconst }
```

**Note**

Iconst should be a positive integer value.

The feature is only syntax compatible for oracle, there is no implementation as that in oracle database.

## COMPRESS LOGGING

Starting from LightDB 23.2, four new non-reserved keywords COMPRESS, LOGGING, NOCOMPRESS, NOLOGGING, are added to be compatible with the syntax of Oracle Database. The four new keywords are just grammatical sugar, and do not achieve specific functions. These four keywords must be used before the TABLESPACE keyword.

## schema\_name

Starting from LightDB 23.2, the index name of the CREATE INDEX statement supports specifying the schema name to be compatible with Oracle database syntax. This function is just a syntactic sugar, there is no specific function implementation.

## Index Storage Parameters

The optional WITH clause specifies *storage parameters* for the index. Each index method has its own set of allowed storage parameters. The B-tree, hash, GiST index methods all accept this parameter:

## fillfactor (integer)

The fillfactor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (adding new largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any integer value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.

B-tree indexes additionally accept this parameter:

`deduplicate_items` (boolean)

Controls usage of the B-tree deduplication technique described in Section 60.4.2. Set to `ON` or `OFF` to enable or disable the optimization. (Alternative spellings of `ON` and `OFF` are allowed as described in Section 17.1.) The default is `ON`.

**Note**

Turning `deduplicate_items` off via `ALTER INDEX` prevents future insertions from triggering deduplication, but does not in itself make existing posting list tuples use the standard tuple representation.

GiST indexes additionally accept this parameter:

`buffering` (enum)

Determines whether the buffering build technique described in Section 61.4.1 is used to build the index. With `OFF` it is disabled, with `ON` it is enabled, and with `AUTO` it is initially disabled, but turned on on-the-fly once the index size reaches `effective_cache_size`. The default is `AUTO`.

GIN indexes accept different parameters:

`fastupdate` (boolean)

This setting controls usage of the fast update technique described in Section 62.4.1. It is a Boolean parameter: `ON` enables fast update, `OFF` disables it. The default is `ON`.

**Note**

Turning `fastupdate` off via `ALTER INDEX` prevents future insertions from going into the list of pending index entries, but does not in itself flush previous entries. You might want to `VACUUM` the table or call `gin_clean_pending_list` function afterward to ensure the pending list is emptied.

`gin_pending_list_limit` (integer)

Custom `gin_pending_list_limit` parameter. This value is specified in kilobytes.

## Building Indexes Concurrently

Creating an index can interfere with regular operation of a database. Normally LightDB locks the table to be indexed against writes and performs the entire index build with a single scan of the table. Other transactions can still read the table, but if they try to insert, update, or delete rows in the table they will block until the index build is finished. This could have a severe effect if the system is a live production database. Very large tables can take many hours to be indexed, and even for smaller tables, an index build can lock out writers for periods that are unacceptably long for a production system.

LightDB supports building indexes without locking out writes. This method is invoked by specifying the `CONCURRENTLY` option of `CREATE INDEX`. When this option is used, LightDB must perform two scans of the table, and in addition it must wait for all existing transactions that could potentially modify or use the index to terminate. Thus this method requires more total work than a standard index build and takes significantly longer to complete. However, since it allows normal operations to continue while the index is built, this method is useful for adding new indexes in a production

environment. Of course, the extra CPU and I/O load imposed by the index creation might slow other operations.

In a concurrent index build, the index is actually entered into the system catalogs in one transaction, then two table scans occur in two more transactions. Before each table scan, the index build must wait for existing transactions that have modified the table to terminate. After the second scan, the index build must wait for any transactions that have a snapshot (see Chapter 13) predating the second scan to terminate, including transactions used by any phase of concurrent index builds on other tables. Then finally the index can be marked ready for use, and the `CREATE INDEX` command terminates. Even then, however, the index may not be immediately usable for queries: in the worst case, it cannot be used as long as transactions exist that predate the start of the index build.

If a problem arises while scanning the table, such as a deadlock or a uniqueness violation in a unique index, the `CREATE INDEX` command will fail but leave behind an “invalid” index. This index will be ignored for querying purposes because it might be incomplete; however it will still consume update overhead. The `ltsql \d` command will report such an index as `INVALID`:

```
lightdb@postgres=# \d tab
          Table "public.tab"
  Column | Type   | Collation | Nullable | Default
-----+-----+-----+-----+-----
  col    | integer |           |          |
Indexes:
  "idx" btree (col) INVALID
```

The recommended recovery method in such cases is to drop the index and try again to perform `CREATE INDEX CONCURRENTLY`. (Another possibility is to rebuild the index with `REINDEX INDEX CONCURRENTLY`).

Another caveat when building a unique index concurrently is that the uniqueness constraint is already being enforced against other transactions when the second table scan begins. This means that constraint violations could be reported in other queries prior to the index becoming available for use, or even in cases where the index build eventually fails. Also, if a failure does occur in the second scan, the “invalid” index continues to enforce its uniqueness constraint afterwards.

Concurrent builds of expression indexes and partial indexes are supported. Errors occurring in the evaluation of these expressions could cause behavior similar to that described above for unique constraint violations.

Regular index builds permit other regular index builds on the same table to occur simultaneously, but only one concurrent index build can occur on a table at a time. In either case, schema modification of the table is not allowed while the index is being built. Another difference is that a regular `CREATE INDEX` command can be performed within a transaction block, but `CREATE INDEX CONCURRENTLY` cannot.

Concurrent builds for indexes on partitioned tables are currently not supported. However, you may concurrently build the index on each partition individually and then finally create the partitioned index non-concurrently in order to reduce the time where writes to the partitioned table will be locked out. In this case, building the partitioned index is a metadata only operation.

## Notes

See Chapter 11 for information about when indexes can be used, when they are not used, and in which particular situations they can be useful.

Currently, only the B-tree, GiST, GIN index methods support multicolumn indexes. Up to 32 fields can be specified by default. (This limit can be altered when building LightDB.) Only B-tree currently supports unique indexes.

An *operator class* with optional parameters can be specified for each column of an index. The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on four-byte integers would use the `int4_ops` class; this operator class includes comparison functions for four-byte integers. In practice the default operator class for the column's data type is usually sufficient. The main point of having operator classes is that for some data types, there could be more than one meaningful ordering. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when creating an index. More information about operator classes is in Section 11.10 and in Section 36.16.

When `CREATE INDEX` is invoked on a partitioned table, the default behavior is to recurse to all partitions to ensure they all have matching indexes. Each partition is first checked to determine whether an equivalent index already exists, and if so, that index will become attached as a partition index to the index being created, which will become its parent index. If no matching index exists, a new index will be created and automatically attached; the name of the new index in each partition will be determined as if no index name had been specified in the command. If the `ONLY` option is specified, no recursion is done, and the index is marked invalid. (`ALTER INDEX ... ATTACH PARTITION` marks the index valid, once all partitions acquire matching indexes.) Note, however, that any partition that is created in the future using `CREATE TABLE ... PARTITION OF` will automatically have a matching index, regardless of whether `ONLY` is specified.

For index methods that support ordered scans (currently, only B-tree), the optional clauses `ASC`, `DESC`, `NULLS FIRST`, and/or `NULLS LAST` can be specified to modify the sort ordering of the index. Since an ordered index can be scanned either forward or backward, it is not normally useful to create a single-column `DESC` index — that sort ordering is already available with a regular index. The value of these options is that multicolumn indexes can be created that match the sort ordering requested by a mixed-ordering query, such as `SELECT ... ORDER BY x ASC, y DESC`. The `NULLS` options are useful if you need to support “nulls sort low” behavior, rather than the default “nulls sort high”, in queries that depend on indexes to avoid sorting steps.

The system regularly collects statistics on all of a table's columns. Newly-created non-expression indexes can immediately use these statistics to determine an index's usefulness. For new expression indexes, it is necessary to run `ANALYZE` or wait for the autovacuum daemon to analyze the table to generate statistics for these indexes.

For most index methods, the speed of creating an index is dependent on the setting of `maintenance_work_mem`. Larger values will reduce the time needed for index creation, so long as you don't make it larger than the amount of memory really available, which would drive the machine into swapping.

LightDB can build indexes while leveraging multiple CPUs in order to process the table rows faster. This feature is known as *parallel index build*. For index methods that support building indexes in parallel (currently, only B-tree), `maintenance_work_mem` specifies the maximum amount of memory that can be used by each index build operation as a whole, regardless of how many worker processes were started. Generally, a cost model automatically determines how many worker processes should be requested, if any.

Parallel index builds may benefit from increasing `maintenance_work_mem` where an equivalent serial index build will see little or no benefit. Note that `maintenance_work_mem` may influence the number of worker processes requested, since parallel workers must have at least a 32MB share of the total `maintenance_work_mem` budget. There must also be a remaining 32MB share for the leader process. Increasing `max_parallel_maintenance_workers` may allow more workers to be used, which will reduce the time needed for index creation, so long as the index build is not already I/O bound. Of course, there should also be sufficient CPU capacity that would otherwise lie idle.

Setting a value for `parallel_workers` via `ALTER TABLE` directly controls how many parallel worker processes will be requested by a `CREATE INDEX` against the table. This bypasses the cost model completely, and prevents `maintenance_work_mem` from affecting how many parallel workers are requested. Setting `parallel_workers` to 0 via `ALTER TABLE` will disable parallel index builds on the table in all cases.

**Tip**

You might want to reset `parallel_workers` after setting it as part of tuning an index build. This avoids inadvertent changes to query plans, since `parallel_workers` affects *all* parallel table scans.

While `CREATE INDEX` with the `CONCURRENTLY` option supports parallel builds without special restrictions, only the first table scan is actually performed in parallel.

Use `DROP INDEX` to remove an index.

Like any long-running transaction, `CREATE INDEX` on a table can affect which tuples can be removed by concurrent `VACUUM` on any other table.

Prior releases of LightDB also had an R-tree index method. This method has been removed because it had no significant advantages over the GiST method. If `USING rtree` is specified, `CREATE INDEX` will interpret it as `USING gist`, to simplify conversion of old databases to GiST.

## Examples

To create a unique B-tree index on the column `title` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title);
```

To create a unique B-tree index on the column `title` with included columns `director` and `rating` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title) INCLUDE (director,
rating);
```

To create a B-Tree index with deduplication disabled:

```
CREATE INDEX title_idx ON films (title) WITH (deduplicate_items =
off);
```

To create an index on the expression `lower(title)`, allowing efficient case-insensitive searches:

```
CREATE INDEX ON films ((lower(title)));
```

(In this example we have chosen to omit the index name, so the system will choose a name, typically `films_lower_idx`.)

To create an index with non-default collation:

```
CREATE INDEX title_idx_german ON films (title COLLATE "de_DE");
```

To create an index with non-default sort ordering of nulls:

```
CREATE INDEX title_idx_nulls_low ON films (title NULLS FIRST);
```

To create an index with non-default fill factor:

---

## CREATE INDEX

---

```
CREATE UNIQUE INDEX title_idx ON films (title) WITH (fillfactor = 70);
```

To create a GIN index with fast updates disabled:

```
CREATE INDEX gin_idx ON documents_table USING GIN (locations) WITH (fastupdate = off);
```

To create an index on the column code in the table films and have the index reside in the tablespace indexespace:

```
CREATE INDEX code_idx ON films (code) TABLESPACE indexespace;
```

To create a GiST index on a point attribute so that we can efficiently use box operators on the result of the conversion function:

```
CREATE INDEX pointloc
  ON points USING gist (box(location,location));
SELECT * FROM points
  WHERE box(location,location) && '(0,0),(1,1)::box;
```

To create an index without locking out writes to the table:

```
CREATE INDEX CONCURRENTLY sales_quantity_index ON sales_table
  (quantity);
```

To create an index with local or global:

```
CREATE INDEX index_local ON sales_table (quantity) LOCAL;
CREATE INDEX index_global ON sales_table (quantity) GLOBAL;
```

To create an index with global hash partition:

```
CREATE TABLE ora_ph_t(a int,b int,c int) PARTITION BY HASH(a)
  partitions 4;
CREATE INDEX t_global_ph_idx ON ora_ph_t(a) GLOBAL PARTITION BY
  hash(a) partitions 2;
```

```
\! mkdir /tmp/tbs_test_path
create tablespace tbs_test location '/tmp/tbs_test_path';
CREATE INDEX t_global_ph_idx_with_tbs ON ora_ph_t(a ASC ,b DESC)
  TABLESPACE tbs_test GLOBAL PARTITION BY hash(a) partitions 2;
DROP INDEX t_global_ph_idx_with_tbs;
drop tablespace tbs_test;
\! rm -rf /tmp/tbs_test_path
```

Create a index with COMPRESS/NOCOMPRESS/LOGGING/NOLOGGING options.

```
create table comp_log_test(id int);
create index idx_id on comp_log_test(id) nologging compress
  tablespace pg_default;
```

Create a index with schema name.



```
create table t1(id int);
create index hahaha.index_t1_id on t1(id);
```

## Compatibility

CREATE INDEX is a LightDB language extension. There are no provisions for indexes in the SQL standard.

## See Also

ALTER INDEX, DROP INDEX, REINDEX

---

# CREATE LANGUAGE

CREATE LANGUAGE — define a new procedural language

## Synopsis

```
CREATE [ OR REPLACE ] [ TRUSTED ] [ PROCEDURAL ] LANGUAGE name
    HANDLER call_handler [ INLINE inline_handler ]
    [ VALIDATOR valfunction ]
CREATE [ OR REPLACE ] [ TRUSTED ] [ PROCEDURAL ] LANGUAGE name
```

## Description

CREATE LANGUAGE registers a new procedural language with a LightDB database. Subsequently, functions and procedures can be defined in this new language.

CREATE LANGUAGE effectively associates the language name with handler function(s) that are responsible for executing functions written in the language. Refer to Chapter 52 for more information about language handlers.

CREATE OR REPLACE LANGUAGE will either create a new language, or replace an existing definition. If the language already exists, its parameters are updated according to the command, but the language's ownership and permissions settings do not change, and any existing functions written in the language are assumed to still be valid.

One must have the LightDB superuser privilege to register a new language or change an existing language's parameters. However, once the language is created it is valid to assign ownership of it to a non-superuser, who may then drop it, change its permissions, rename it, or assign it to a new owner. (Do not, however, assign ownership of the underlying C functions to a non-superuser; that would create a privilege escalation path for that user.)

The form of CREATE LANGUAGE that does not supply any handler function is obsolete. For backwards compatibility with old dump files, it is interpreted as CREATE EXTENSION. That will work if the language has been packaged into an extension of the same name, which is the conventional way to set up procedural languages.

## Parameters

TRUSTED

TRUSTED specifies that the language does not grant access to data that the user would not otherwise have. If this key word is omitted when registering the language, only users with the LightDB superuser privilege can use this language to create new functions.

PROCEDURAL

This is a noise word.

*name*

The name of the new procedural language. The name must be unique among the languages in the database.

For backward compatibility, the name can be enclosed by single quotes.

HANDLER *call\_handler*

*call\_handler* is the name of a previously registered function that will be called to execute the procedural language's functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with LightDB as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

INLINE *inline\_handler*

*inline\_handler* is the name of a previously registered function that will be called to execute an anonymous code block (DO command) in this language. If no *inline\_handler* function is specified, the language does not support anonymous code blocks. The handler function must take one argument of type `internal`, which will be the DO command's internal representation, and it will typically return `void`. The return value of the handler is ignored.

VALIDATOR *valfunction*

*valfunction* is the name of a previously registered function that will be called when a new function in the language is created, to validate the new function. If no validator function is specified, then a new function will not be checked when it is created. The validator function must take one argument of type `oid`, which will be the OID of the to-be-created function, and will typically return `void`.

A validator function would typically inspect the function body for syntactical correctness, but it can also look at other properties of the function, for example if the language cannot handle certain argument types. To signal an error, the validator function should use the `ereport()` function. The return value of the function is ignored.

## Notes

Use `DROP LANGUAGE` to drop procedural languages.

The system catalog `pg_language` (see Section 48.37) records information about the currently installed languages. Also, the `lsql` command `\dL` lists the installed languages.

To create functions in a procedural language, a user must have the `USAGE` privilege for the language. By default, `USAGE` is granted to `PUBLIC` (i.e., everyone) for trusted languages. This can be revoked if desired.

Procedural languages are local to individual databases. However, a language can be installed into the `template1` database, which will cause it to be available automatically in all subsequently-created databases.

## Examples

A minimal sequence for creating a new procedural language is:

```
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
AS '$libdir/plsample'
LANGUAGE C;
CREATE LANGUAGE plsample
HANDLER plsample_call_handler;
```

Typically that would be written in an extension's creation script, and users would do this to install the extension:

```
CREATE EXTENSION plsample;
```

## Compatibility

CREATE LANGUAGE is a LightDB extension.

## See Also

ALTER LANGUAGE, CREATE FUNCTION, DROP LANGUAGE, GRANT, REVOKE

---

# CREATE MATERIALIZED VIEW

CREATE MATERIALIZED VIEW — define a new materialized view

## Synopsis

```
CREATE MATERIALIZED VIEW [ IF NOT EXISTS ] table_name
  [ (column_name [, ...] ) ]
  [ USING method ]
  [ WITH ( storage_parameter [= value] [, ... ] ) ]
  [ TABLESPACE tablespace_name ]
  AS query
  [ WITH [ NO ] DATA ]
```

## Description

CREATE MATERIALIZED VIEW defines a materialized view of a query. The query is executed and used to populate the view at the time the command is issued (unless WITH NO DATA is used) and may be refreshed later using REFRESH MATERIALIZED VIEW.

CREATE MATERIALIZED VIEW is similar to CREATE TABLE AS, except that it also remembers the query used to initialize the view, so that it can be refreshed later upon demand. A materialized view has many of the same properties as a table, but there is no support for temporary materialized views.

## Parameters

IF NOT EXISTS

Do not throw an error if a materialized view with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing materialized view is anything like the one that would have been created.

*table\_name*

The name (optionally schema-qualified) of the materialized view to be created.

*column\_name*

The name of a column in the new materialized view. If column names are not provided, they are taken from the output column names of the query.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new materialized view; the method needs be an access method of type TABLE. See Chapter 57 for more information. If this option is not specified, the default table access method is chosen for the new materialized view. See `default_table_access_method` for more information.

WITH ( *storage\_parameter* [= *value*] [, ... ] )

This clause specifies optional storage parameters for the new materialized view; see Storage Parameters in the CREATE TABLE documentation for more information. All parameters supported for CREATE TABLE are also supported for CREATE MATERIALIZED VIEW. See CREATE TABLE for more information.

TABLESPACE *tablespace\_name*

The *tablespace\_name* is the name of the tablespace in which the new materialized view is to be created. If not specified, `default_tablespace` is consulted.

*query*

A SELECT, TABLE, or VALUES command. This query will run within a security-restricted operation; in particular, calls to functions that themselves create temporary tables will fail.

WITH [ NO ] DATA

This clause specifies whether or not the materialized view should be populated at creation time. If not, the materialized view will be flagged as unscannable and cannot be queried until REFRESH MATERIALIZED VIEW is used.

## Compatibility

CREATE MATERIALIZED VIEW is a LightDB extension.

## See Also

ALTER MATERIALIZED VIEW, CREATE TABLE AS, CREATE VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

---

# CREATE OPERATOR

CREATE OPERATOR — define a new operator

## Synopsis

```
CREATE OPERATOR name (  
    {FUNCTION|PROCEDURE} = function_name  
    [, LEFTARG = left_type ] [, RIGHTARG = right_type ]  
    [, COMMUTATOR = com_op ] [, NEGATOR = neg_op ]  
    [, RESTRICT = res_proc ] [, JOIN = join_proc ]  
    [, HASHES ] [, MERGES ]  
)
```

## Description

CREATE OPERATOR defines a new operator, *name*. The user who defines an operator becomes its owner. If a schema name is given then the operator is created in the specified schema. Otherwise it is created in the current schema.

The operator name is a sequence of up to NAMEDATALEN-1 (63 by default) characters from the following list:

+ - \* / <> = ~ ! @ # % ^ & | ` ?

There are a few restrictions on your choice of name:

- -- and /\* cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multicharacter operator name cannot end in + or -, unless the name also contains at least one of these characters:

~ ! @ # % ^ & | ` ?

For example, @- is an allowed operator name, but \*- is not. This restriction allows LightDB to parse SQL-compliant commands without requiring spaces between tokens.

- The use of => as an operator name is deprecated. It may be disallowed altogether in a future release.

The operator != is mapped to <> on input, so these two names are always equivalent.

At least one of LEFTARG and RIGHTARG must be defined. For binary operators, both must be defined. For right unary operators, only LEFTARG should be defined, while for left unary operators only RIGHTARG should be defined.

### Note

Right unary, also called postfix, operators are deprecated and will be removed in LightDB version 14.

The *function\_name* function must have been previously defined using CREATE FUNCTION and must be defined to accept the correct number of arguments (either one or two) of the indicated types.

In the syntax of `CREATE OPERATOR`, the keywords `FUNCTION` and `PROCEDURE` are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword `PROCEDURE` here is historical and deprecated.

The other clauses specify optional operator optimization clauses. Their meaning is detailed in Section 36.15.

To be able to create an operator, you must have `USAGE` privilege on the argument types and the return type, as well as `EXECUTE` privilege on the underlying function. If a commutator or negator operator is specified, you must own these operators.

## Parameters

*name*

The name of the operator to be defined. See above for allowable characters. The name can be schema-qualified, for example `CREATE OPERATOR myschema.+ (...)`. If not, then the operator is created in the current schema. Two operators in the same schema can have the same name if they operate on different data types. This is called *overloading*.

*function\_name*

The function used to implement this operator.

*left\_type*

The data type of the operator's left operand, if any. This option would be omitted for a left-unity operator.

*right\_type*

The data type of the operator's right operand, if any. This option would be omitted for a right-unity operator.

*com\_op*

The commutator of this operator.

*neg\_op*

The negator of this operator.

*res\_proc*

The restriction selectivity estimator function for this operator.

*join\_proc*

The join selectivity estimator function for this operator.

`HASHES`

Indicates this operator can support a hash join.

`MERGES`

Indicates this operator can support a merge join.

To give a schema-qualified operator name in *com\_op* or the other optional arguments, use the `OPERATOR( )` syntax, for example:



```
COMMUTATOR = OPERATOR(myschema.===) ,
```

## Notes

Refer to Section 36.14 for further information.

It is not possible to specify an operator's lexical precedence in `CREATE OPERATOR`, because the parser's precedence behavior is hard-wired. See Section 4.1.6 for precedence details.

The obsolete options `SORT1`, `SORT2`, `LTCMP`, and `GTCMP` were formerly used to specify the names of sort operators associated with a merge-joinable operator. This is no longer necessary, since information about associated operators is found by looking at B-tree operator families instead. If one of these options is given, it is ignored except for implicitly setting `MERGES` true.

Use `DROP OPERATOR` to delete user-defined operators from a database. Use `ALTER OPERATOR` to modify operators in a database.

## Examples

The following command defines a new operator, area-equality, for the data type `box`:

```
CREATE OPERATOR === (  
    LEFTARG = box,  
    RIGHTARG = box,  
    FUNCTION = area_equal_function,  
    COMMUTATOR = ===,  
    NEGATOR = !==,  
    RESTRICT = area_restriction_function,  
    JOIN = area_join_function,  
    HASHES, MERGES  
);
```

## Compatibility

`CREATE OPERATOR` is a LightDB extension. There are no provisions for user-defined operators in the SQL standard.

## See Also

`ALTER OPERATOR`, `CREATE OPERATOR CLASS`, `DROP OPERATOR`

---

# CREATE OPERATOR CLASS

CREATE OPERATOR CLASS — define a new operator class

## Synopsis

```
CREATE OPERATOR CLASS name [ DEFAULT ] FOR TYPE data_type
  USING index_method [ FAMILY family_name ] AS
  { OPERATOR strategy_number operator_name [ ( op_type, op_type
) ] [ FOR SEARCH | FOR ORDER BY sort_family_name ]
  | FUNCTION support_number [ ( op_type [ , op_type
] ) ] function_name ( argument_type [ , ... ] )
  | STORAGE storage_type
} [ , ... ]
```

## Description

CREATE OPERATOR CLASS creates a new operator class. An operator class defines how a particular data type can be used with an index. The operator class specifies that certain operators will fill particular roles or “strategies” for this data type and this index method. The operator class also specifies the support functions to be used by the index method when the operator class is selected for an index column. All the operators and functions used by an operator class must be defined before the operator class can be created.

If a schema name is given then the operator class is created in the specified schema. Otherwise it is created in the current schema. Two operator classes in the same schema can have the same name only if they are for different index methods.

The user who defines an operator class becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator class definition could confuse or even crash the server.)

CREATE OPERATOR CLASS does not presently check whether the operator class definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator class.

Related operator classes can be grouped into *operator families*. To add a new operator class to an existing family, specify the FAMILY option in CREATE OPERATOR CLASS. Without this option, the new class is placed into a family named the same as the new class (creating that family if it doesn't already exist).

Refer to Section 36.16 for further information.

## Parameters

*name*

The name of the operator class to be created. The name can be schema-qualified.

DEFAULT

If present, the operator class will become the default operator class for its data type. At most one operator class can be the default for a specific data type and index method.

*data\_type*

The column data type that this operator class is for.

*index\_method*

The name of the index method this operator class is for.

*family\_name*

The name of the existing operator family to add this operator class to. If not specified, a family named the same as the operator class is used (creating it, if it doesn't already exist).

*strategy\_number*

The index method's strategy number for an operator associated with the operator class.

*operator\_name*

The name (optionally schema-qualified) of an operator associated with the operator class.

*op\_type*

In an OPERATOR clause, the operand data type(s) of the operator, or NONE to signify a left-unary or right-unary operator. The operand data types can be omitted in the normal case where they are the same as the operator class's data type.

In a FUNCTION clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function (for B-tree comparison functions and hash functions) or the class's data type (for B-tree sort support functions, B-tree equal image functions, and all functions in GiST, GIN operator classes). These defaults are correct, and so *op\_type* need not be specified in FUNCTION clauses, except for the case of a B-tree sort support function that is meant to support cross-data-type comparisons.

*sort\_family\_name*

The name (optionally schema-qualified) of an existing *btree* operator family that describes the sort ordering associated with an ordering operator.

If neither FOR SEARCH nor FOR ORDER BY is specified, FOR SEARCH is the default.

*support\_number*

The index method's support function number for a function associated with the operator class.

*function\_name*

The name (optionally schema-qualified) of a function that is an index method support function for the operator class.

*argument\_type*

The parameter data type(s) of the function.

*storage\_type*

The data type actually stored in the index. Normally this is the same as the column data type, but some index methods (currently GiST, GIN) allow it to be different. The STORAGE clause must be omitted unless the index method allows a different type to be used. If the column *data\_type* is specified as *anyarray*, the *storage\_type* can be declared as *anyelement* to indicate that the index entries are members of the element type belonging to the actual array type that each particular index is created for.

The OPERATOR, FUNCTION, and STORAGE clauses can appear in any order.

## Notes

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator class is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator class.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before LightDB 8.4, the OPERATOR clause could include a RECHECK option. This is no longer supported because whether an index operator is “lossy” is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

## Examples

The following example command defines a GiST index operator class for the data type `_int4` (array of `int4`). See the `intarray` module for the complete example.

```
CREATE OPERATOR CLASS gist__int_ops
  DEFAULT FOR TYPE _int4 USING gist AS
  OPERATOR          3      &&,
  OPERATOR          6      = (anyarray, anyarray),
  OPERATOR          7      @>,
  OPERATOR          8      <@,
  OPERATOR          20     @@ (_int4, query_int),
  FUNCTION          1      g_int_consistent (internal, _int4,
smallint, oid, internal),
  FUNCTION          2      g_int_union (internal, internal),
  FUNCTION          3      g_int_compress (internal),
  FUNCTION          4      g_int_decompress (internal),
  FUNCTION          5      g_int_penalty (internal, internal,
internal),
  FUNCTION          6      g_int_picksplit (internal,
internal),
  FUNCTION          7      g_int_same (_int4, _int4,
internal);
```

## Compatibility

CREATE OPERATOR CLASS is a LightDB extension. There is no CREATE OPERATOR CLASS statement in the SQL standard.

## See Also

ALTER OPERATOR CLASS, DROP OPERATOR CLASS, CREATE OPERATOR FAMILY, ALTER OPERATOR FAMILY

---

# CREATE OPERATOR FAMILY

CREATE OPERATOR FAMILY — define a new operator family

## Synopsis

```
CREATE OPERATOR FAMILY name USING index_method
```

## Description

CREATE OPERATOR FAMILY creates a new operator family. An operator family defines a collection of related operator classes, and perhaps some additional operators and support functions that are compatible with these operator classes but not essential for the functioning of any individual index. (Operators and functions that are essential to indexes should be grouped within the relevant operator class, rather than being “loose” in the operator family. Typically, single-data-type operators are bound to operator classes, while cross-data-type operators can be loose in an operator family containing operator classes for both data types.)

The new operator family is initially empty. It should be populated by issuing subsequent CREATE OPERATOR CLASS commands to add contained operator classes, and optionally ALTER OPERATOR FAMILY commands to add “loose” operators and their corresponding support functions.

If a schema name is given then the operator family is created in the specified schema. Otherwise it is created in the current schema. Two operator families in the same schema can have the same name only if they are for different index methods.

The user who defines an operator family becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

Refer to Section 36.16 for further information.

## Parameters

*name*

The name of the operator family to be created. The name can be schema-qualified.

*index\_method*

The name of the index method this operator family is for.

## Compatibility

CREATE OPERATOR FAMILY is a LightDB extension. There is no CREATE OPERATOR FAMILY statement in the SQL standard.

## See Also

ALTER OPERATOR FAMILY, DROP OPERATOR FAMILY, CREATE OPERATOR CLASS, ALTER OPERATOR CLASS, DROP OPERATOR CLASS

---

# CREATE POLICY

CREATE POLICY — define a new row level security policy for a table

## Synopsis

```
CREATE POLICY name ON table_name
  [ AS { PERMISSIVE | RESTRICTIVE } ]
  [ FOR { ALL | SELECT | INSERT | UPDATE | DELETE } ]
  [ TO { role_name | PUBLIC | CURRENT_USER | SESSION_USER }
  [, ...] ]
  [ USING ( using_expression ) ]
  [ WITH CHECK ( check_expression ) ]
```

## Description

The CREATE POLICY command defines a new row-level security policy for a table. Note that row-level security must be enabled on the table (using ALTER TABLE ... ENABLE ROW LEVEL SECURITY) in order for created policies to be applied.

A policy grants the permission to select, insert, update, or delete rows that match the relevant policy expression. Existing table rows are checked against the expression specified in USING, while new rows that would be created via INSERT or UPDATE are checked against the expression specified in WITH CHECK. When a USING expression returns true for a given row then that row is visible to the user, while if false or null is returned then the row is not visible. When a WITH CHECK expression returns true for a row then that row is inserted or updated, while if false or null is returned then an error occurs.

For INSERT and UPDATE statements, WITH CHECK expressions are enforced after BEFORE triggers are fired, and before any actual data modifications are made. Thus a BEFORE ROW trigger may modify the data to be inserted, affecting the result of the security policy check. WITH CHECK expressions are enforced before any other constraints.

Policy names are per-table. Therefore, one policy name can be used for many different tables and have a definition for each table which is appropriate to that table.

Policies can be applied for specific commands or for specific roles. The default for newly created policies is that they apply for all commands and roles, unless otherwise specified. Multiple policies may apply to a single command; see below for more details. Table 271 summarizes how the different types of policy apply to specific commands.

For policies that can have both USING and WITH CHECK expressions (ALL and UPDATE), if no WITH CHECK expression is defined, then the USING expression will be used both to determine which rows are visible (normal USING case) and which new rows will be allowed to be added (WITH CHECK case).

If row-level security is enabled for a table, but no applicable policies exist, a “default deny” policy is assumed, so that no rows will be visible or updatable.

## Parameters

*name*

The name of the policy to be created. This must be distinct from the name of any other policy for the table.

*table\_name*

The name (optionally schema-qualified) of the table the policy applies to.

PERMISSIVE

Specify that the policy is to be created as a permissive policy. All permissive policies which are applicable to a given query will be combined together using the Boolean “OR” operator. By creating permissive policies, administrators can add to the set of records which can be accessed. Policies are permissive by default.

RESTRICTIVE

Specify that the policy is to be created as a restrictive policy. All restrictive policies which are applicable to a given query will be combined together using the Boolean “AND” operator. By creating restrictive policies, administrators can reduce the set of records which can be accessed as all restrictive policies must be passed for each record.

Note that there needs to be at least one permissive policy to grant access to records before restrictive policies can be usefully used to reduce that access. If only restrictive policies exist, then no records will be accessible. When a mix of permissive and restrictive policies are present, a record is only accessible if at least one of the permissive policies passes, in addition to all the restrictive policies.

*command*

The command to which the policy applies. Valid options are ALL, SELECT, INSERT, UPDATE, and DELETE. ALL is the default. See below for specifics regarding how these are applied.

*role\_name*

The role(s) to which the policy is to be applied. The default is PUBLIC, which will apply the policy to all roles.

*using\_expression*

Any SQL conditional expression (returning boolean). The conditional expression cannot contain any aggregate or window functions. This expression will be added to queries that refer to the table if row level security is enabled. Rows for which the expression returns true will be visible. Any rows for which the expression returns false or null will not be visible to the user (in a SELECT), and will not be available for modification (in an UPDATE or DELETE). Such rows are silently suppressed; no error is reported.

*check\_expression*

Any SQL conditional expression (returning boolean). The conditional expression cannot contain any aggregate or window functions. This expression will be used in INSERT and UPDATE queries against the table if row level security is enabled. Only rows for which the expression evaluates to true will be allowed. An error will be thrown if the expression evaluates to false or null for any of the records inserted or any of the records that result from the update. Note that the *check\_expression* is evaluated against the proposed new contents of the row, not the original contents.

## Per-Command Policies

ALL

Using ALL for a policy means that it will apply to all commands, regardless of the type of command. If an ALL policy exists and more specific policies exist, then both the ALL policy and the more specific policy (or policies) will be applied. Additionally, ALL policies will be applied

to both the selection side of a query and the modification side, using the `USING` expression for both cases if only a `USING` expression has been defined.

As an example, if an `UPDATE` is issued, then the `ALL` policy will be applicable both to what the `UPDATE` will be able to select as rows to be updated (applying the `USING` expression), and to the resulting updated rows, to check if they are permitted to be added to the table (applying the `WITH CHECK` expression, if defined, and the `USING` expression otherwise). If an `INSERT` or `UPDATE` command attempts to add rows to the table that do not pass the `ALL` policy's `WITH CHECK` expression, the entire command will be aborted.

#### SELECT

Using `SELECT` for a policy means that it will apply to `SELECT` queries and whenever `SELECT` permissions are required on the relation the policy is defined for. The result is that only those records from the relation that pass the `SELECT` policy will be returned during a `SELECT` query, and that queries that require `SELECT` permissions, such as `UPDATE`, will also only see those records that are allowed by the `SELECT` policy. A `SELECT` policy cannot have a `WITH CHECK` expression, as it only applies in cases where records are being retrieved from the relation.

#### INSERT

Using `INSERT` for a policy means that it will apply to `INSERT` commands. Rows being inserted that do not pass this policy will result in a policy violation error, and the entire `INSERT` command will be aborted. An `INSERT` policy cannot have a `USING` expression, as it only applies in cases where records are being added to the relation.

Note that `INSERT` with `ON CONFLICT DO UPDATE` checks `INSERT` policies' `WITH CHECK` expressions only for rows appended to the relation by the `INSERT` path.

#### UPDATE

Using `UPDATE` for a policy means that it will apply to `UPDATE`, `SELECT FOR UPDATE` and `SELECT FOR SHARE` commands, as well as auxiliary `ON CONFLICT DO UPDATE` clauses of `INSERT` commands. Since `UPDATE` involves pulling an existing record and replacing it with a new modified record, `UPDATE` policies accept both a `USING` expression and a `WITH CHECK` expression. The `USING` expression determines which records the `UPDATE` command will see to operate against, while the `WITH CHECK` expression defines which modified rows are allowed to be stored back into the relation.

Any rows whose updated values do not pass the `WITH CHECK` expression will cause an error, and the entire command will be aborted. If only a `USING` clause is specified, then that clause will be used for both `USING` and `WITH CHECK` cases.

Typically an `UPDATE` command also needs to read data from columns in the relation being updated (e.g., in a `WHERE` clause or a `RETURNING` clause, or in an expression on the right hand side of the `SET` clause). In this case, `SELECT` rights are also required on the relation being updated, and the appropriate `SELECT` or `ALL` policies will be applied in addition to the `UPDATE` policies. Thus the user must have access to the row(s) being updated through a `SELECT` or `ALL` policy in addition to being granted permission to update the row(s) via an `UPDATE` or `ALL` policy.

When an `INSERT` command has an auxiliary `ON CONFLICT DO UPDATE` clause, if the `UPDATE` path is taken, the row to be updated is first checked against the `USING` expressions of any `UPDATE` policies, and then the new updated row is checked against the `WITH CHECK` expressions. Note, however, that unlike a standalone `UPDATE` command, if the existing row does not pass the `USING` expressions, an error will be thrown (the `UPDATE` path will *never* be silently avoided).

#### DELETE

Using `DELETE` for a policy means that it will apply to `DELETE` commands. Only rows that pass this policy will be seen by a `DELETE` command. There can be rows that are visible through a



SELECT that are not available for deletion, if they do not pass the USING expression for the DELETE policy.

In most cases a DELETE command also needs to read data from columns in the relation that it is deleting from (e.g., in a WHERE clause or a RETURNING clause). In this case, SELECT rights are also required on the relation, and the appropriate SELECT or ALL policies will be applied in addition to the DELETE policies. Thus the user must have access to the row(s) being deleted through a SELECT or ALL policy in addition to being granted permission to delete the row(s) via a DELETE or ALL policy.

A DELETE policy cannot have a WITH CHECK expression, as it only applies in cases where records are being deleted from the relation, so that there is no new row to check.

**Table 271. Policies Applied by Command Type**

Command	SELECT/ALL policy	INSERT/ALL policy	UPDATE/ALL policy		DELETE/ALL policy
	USING expression	WITH CHECK expression	USING expression	WITH CHECK expression	USING expression
SELECT	Existing row	—	—	—	—
SELECT FOR UPDATE / SHARE	Existing row	—	Existing row	—	—
INSERT	—	New row	—	—	—
INSERT . . . RETURNING	New row <sup>a</sup>	New row	—	—	—
UPDATE	Existing & new rows <sup>a</sup>	—	Existing row	New row	—
DELETE	Existing row <sup>a</sup>	—	—	—	Existing row
ON CONFLICT DO UPDATE	Existing & new rows	—	Existing row	New row	—

<sup>a</sup> If read access is required to the existing or new row (for example, a WHERE or RETURNING clause that refers to columns from the relation).

## Application of Multiple Policies

When multiple policies of different command types apply to the same command (for example, SELECT and UPDATE policies applied to an UPDATE command), then the user must have both types of permissions (for example, permission to select rows from the relation as well as permission to update them). Thus the expressions for one type of policy are combined with the expressions for the other type of policy using the AND operator.

When multiple policies of the same command type apply to the same command, then there must be at least one PERMISSIVE policy granting access to the relation, and all of the RESTRICTIVE policies must pass. Thus all the PERMISSIVE policy expressions are combined using OR, all the RESTRICTIVE policy expressions are combined using AND, and the results are combined using AND. If there are no PERMISSIVE policies, then access is denied.

Note that, for the purposes of combining multiple policies, ALL policies are treated as having the same type as whichever other type of policy is being applied.

For example, in an UPDATE command requiring both SELECT and UPDATE permissions, if there are multiple applicable policies of each type, they will be combined as follows:

```
expression from RESTRICTIVE SELECT/ALL policy 1
AND
expression from RESTRICTIVE SELECT/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE SELECT/ALL policy 1
  OR
  expression from PERMISSIVE SELECT/ALL policy 2
  OR
  ...
)
AND
expression from RESTRICTIVE UPDATE/ALL policy 1
AND
expression from RESTRICTIVE UPDATE/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE UPDATE/ALL policy 1
  OR
  expression from PERMISSIVE UPDATE/ALL policy 2
  OR
  ...
)
```

## Notes

You must be the owner of a table to create or change policies for it.

While policies will be applied for explicit queries against tables in the database, they are not applied when the system is performing internal referential integrity checks or validating constraints. This means there are indirect ways to determine that a given value exists. An example of this is attempting to insert a duplicate value into a column that is a primary key or has a unique constraint. If the insert fails then the user can infer that the value already exists. (This example assumes that the user is permitted by policy to insert records which they are not allowed to see.) Another example is where a user is allowed to insert into a table which references another, otherwise hidden table. Existence can be determined by the user inserting values into the referencing table, where success would indicate that the value exists in the referenced table. These issues can be addressed by carefully crafting policies to prevent users from being able to insert, delete, or update records at all which might possibly indicate a value they are not otherwise able to see, or by using generated values (e.g., surrogate keys) instead of keys with external meanings.

Generally, the system will enforce filter conditions imposed using security policies prior to qualifications that appear in user queries, in order to prevent inadvertent exposure of the protected data to user-defined functions which might not be trustworthy. However, functions and operators marked by the system (or the system administrator) as LEAKPROOF may be evaluated before policy expressions, as they are assumed to be trustworthy.

Since policy expressions are added to the user's query directly, they will be run with the rights of the user running the overall query. Therefore, users who are using a given policy must be able to access any tables or functions referenced in the expression or they will simply receive a permission denied error when attempting to query the table that has row-level security enabled. This does not change how views work, however. As with normal queries and views, permission checks and policies for the tables which are referenced by a view will use the view owner's rights and any policies which apply to the view owner.

Additional discussion and practical examples can be found in Section 5.8.

## Compatibility

CREATE POLICY is a LightDB extension.

## See Also

ALTER POLICY, DROP POLICY, ALTER TABLE

---

# CREATE PROCEDURE

CREATE PROCEDURE — define a new procedure

## Synopsis

```
CREATE [ OR REPLACE ] PROCEDURE
  name ( [ [ argmode ] [ argname ] argtype [ { DEFAULT |
= } default_expr ] [, ...] ] )
  { LANGUAGE lang_name
  | TRANSFORM { FOR TYPE type_name } [, ... ]
  | [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
  | SET configuration_parameter { TO value | = value | FROM
CURRENT }
  | AS 'definition'
  | AS 'obj_file', 'link_symbol'
  } ...
```

## Description

CREATE PROCEDURE defines a new procedure. CREATE OR REPLACE PROCEDURE will either create a new procedure, or replace an existing definition. To be able to define a procedure, the user must have the USAGE privilege on the language.

If a schema name is included, then the procedure is created in the specified schema. Otherwise it is created in the current schema. The name of the new procedure must not match any existing procedure or function with the same input argument types in the same schema. However, procedures and functions of different argument types can share a name (this is called *overloading*).

To replace the current definition of an existing procedure, use CREATE OR REPLACE PROCEDURE. It is not possible to change the name or argument types of a procedure this way (if you tried, you would actually be creating a new, distinct procedure).

When CREATE OR REPLACE PROCEDURE is used to replace an existing procedure, the ownership and permissions of the procedure do not change. All other procedure properties are assigned the values specified or implied in the command. You must own the procedure to replace it (this includes being a member of the owning role).

The user that creates the procedure becomes the owner of the procedure.

To be able to create a procedure, you must have USAGE privilege on the argument types.

Refer to Section 36.4 for further information on writing procedures.

## Parameters

*name*

The name (optionally schema-qualified) of the procedure to create.

*argmode*

The mode of an argument: IN, INOUT, or VARIADIC. If omitted, the default is IN. (OUT arguments are currently not supported for procedures. Use INOUT instead.)

*argname*

The name of an argument.

*argtype*

The data type(s) of the procedure's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. Pseudo-types indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a procedure independent of changes to the definition of a table.

*default\_expr*

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. All input parameters following a parameter with a default value must have default values as well.

*lang\_name*

The name of the language that the procedure is implemented in. It can be `sql`, `c`, `internal`, or the name of a user-defined procedural language, e.g., `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

`TRANSFORM { FOR TYPE type_name } [ , ... ] }`

Lists which transforms a call to the procedure should apply. Transforms convert between SQL types and language-specific data types; see `CREATE TRANSFORM`. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

`[EXTERNAL] SECURITY INVOKER`

`[EXTERNAL] SECURITY DEFINER`

`SECURITY INVOKER` indicates that the procedure is to be executed with the privileges of the user that calls it. That is the default. `SECURITY DEFINER` specifies that the procedure is to be executed with the privileges of the user that owns it.

The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all procedures not only external ones.

A `SECURITY DEFINER` procedure cannot execute transaction control statements (for example, `COMMIT` and `ROLLBACK`, depending on the language).

*configuration\_parameter*

*value*

The `SET` clause causes the specified configuration parameter to be set to the specified value when the procedure is entered, and then restored to its prior value when the procedure exits. `SET FROM CURRENT` saves the value of the parameter that is current when `CREATE PROCEDURE` is executed as the value to be applied when the procedure is entered.

If a `SET` clause is attached to a procedure, then the effects of a `SET LOCAL` command executed inside the procedure for the same variable are restricted to the procedure: the configuration parameter's prior value is still restored at procedure exit. However, an ordinary `SET` command

(without `LOCAL`) overrides the `SET` clause, much as it would do for a previous `SET LOCAL` command: the effects of such a command will persist after procedure exit, unless the current transaction is rolled back.

If a `SET` clause is attached to a procedure, then that procedure cannot execute transaction control statements (for example, `COMMIT` and `ROLLBACK`, depending on the language).

See `SET` and Chapter 17 for more information about allowed parameter names and values.

#### *definition*

A string constant defining the procedure; the meaning depends on the language. It can be an internal procedure name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the procedure definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the procedure definition must be escaped by doubling them.

#### *obj\_file, link\_symbol*

This form of the `AS` clause is used for dynamically loadable C language procedures when the procedure name in the C language source code is not the same as the name of the SQL procedure. The string *obj\_file* is the name of the shared library file containing the compiled C procedure, and is interpreted as for the `LOAD` command. The string *link\_symbol* is the procedure's link symbol, that is, the name of the procedure in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL procedure being defined.

When repeated `CREATE PROCEDURE` calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

## Notes

See `CREATE FUNCTION` for more details on function creation that also apply to procedures.

Use `CALL` to execute a procedure.

## Examples

```
CREATE PROCEDURE insert_data(a integer, b integer)
LANGUAGE SQL
AS $$
INSERT INTO tbl VALUES (a);
INSERT INTO tbl VALUES (b);
$$;

CALL insert_data(1, 2);
```

## Compatibility

A `CREATE PROCEDURE` command is defined in the SQL standard. The LightDB version is similar but not fully compatible. For details see also `CREATE FUNCTION`.

## See Also

`ALTER PROCEDURE`, `DROP PROCEDURE`, `CALL`, `CREATE FUNCTION`

---

# CREATE PUBLICATION

CREATE PUBLICATION — define a new publication

## Synopsis

```
CREATE PUBLICATION name
  [ FOR TABLE [ ONLY ] table_name [ * ] [, ...]
  | FOR ALL TABLES ]
  [ WITH ( publication_parameter [= value] [, ... ] ) ]
```

## Description

CREATE PUBLICATION adds a new publication into the current database. The publication name must be distinct from the name of any existing publication in the current database.

A publication is essentially a group of tables whose data changes are intended to be replicated through logical replication. See Section 28.1 for details about how publications fit into the logical replication setup.

## Parameters

*name*

The name of the new publication.

FOR TABLE

Specifies a list of tables to add to the publication. If ONLY is specified before the table name, only that table is added to the publication. If ONLY is not specified, the table and all its descendant tables (if any) are added. Optionally, \* can be specified after the table name to explicitly indicate that descendant tables are included. This does not apply to a partitioned table, however. The partitions of a partitioned table are always implicitly considered part of the publication, so they are never explicitly added to the publication.

Only persistent base tables and partitioned tables can be part of a publication. Temporary tables, unlogged tables, foreign tables, materialized views, and regular views cannot be part of a publication.

When a partitioned table is added to a publication, all of its existing and future partitions are implicitly considered to be part of the publication. So, even operations that are performed directly on a partition are also published via publications that its ancestors are part of.

FOR ALL TABLES

Marks the publication as one that replicates changes for all tables in the database, including tables created in the future.

WITH ( *publication\_parameter* [= *value*] [, ... ] )

This clause specifies optional parameters for a publication. The following parameters are supported:

publish(*string*)

This parameter determines which DML operations will be published by the new publication to the subscribers. The value is comma-separated list of operations. The allowed operations

are insert, update, delete, and truncate. The default is to publish all actions, and so the default value for this option is 'insert, update, delete, truncate'.

`publish_via_partition_root` (boolean)

This parameter determines whether changes in a partitioned table (or on its partitions) contained in the publication will be published using the identity and schema of the partitioned table rather than that of the individual partitions that are actually changed; the latter is the default. Enabling this allows the changes to be replicated into a non-partitioned table or a partitioned table consisting of a different set of partitions.

If this is enabled, TRUNCATE operations performed directly on partitions are not replicated.

## Notes

If neither FOR TABLE nor FOR ALL TABLES is specified, then the publication starts out with an empty set of tables. That is useful if tables are to be added later.

The creation of a publication does not start replication. It only defines a grouping and filtering logic for future subscribers.

To create a publication, the invoking user must have the CREATE privilege for the current database. (Of course, superusers bypass this check.)

To add a table to a publication, the invoking user must have ownership rights on the table. The FOR ALL TABLES clause requires the invoking user to be a superuser.

The tables added to a publication that publishes UPDATE and/or DELETE operations must have REPLICA IDENTITY defined. Otherwise those operations will be disallowed on those tables.

For an INSERT ... ON CONFLICT command, the publication will publish the operation that actually results from the command. So depending of the outcome, it may be published as either INSERT or UPDATE, or it may not be published at all.

ATTACHing a table into a partition tree whose root is published using a publication with `publish_via_partition_root` set to true does not result in the table's existing contents being replicated.

COPY ... FROM commands are published as INSERT operations.

DDL operations are not published.

## Examples

Create a publication that publishes all changes in two tables:

```
CREATE PUBLICATION mypublication FOR TABLE users, departments;
```

Create a publication that publishes all changes in all tables:

```
CREATE PUBLICATION alltables FOR ALL TABLES;
```

Create a publication that only publishes INSERT operations in one table:

```
CREATE PUBLICATION insert_only FOR TABLE mydata
WITH (publish = 'insert');
```



## Compatibility

CREATE PUBLICATION is a LightDB extension.

## See Also

ALTER PUBLICATION, DROP PUBLICATION, CREATE SUBSCRIPTION, ALTER SUBSCRIPTION

---

# CREATE ROLE

CREATE ROLE — define a new database role

## Synopsis

```
CREATE ROLE name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER  
    | CREATEDB | NOCREATEDB  
    | CREATEROLE | NOCREATEROLE  
    | INHERIT | NOINHERIT  
    | LOGIN | NOLOGIN  
    | REPLICATION | NOREPLICATION  
    | BYPASSRLS | NOBYPASSRLS  
    | CONNECTION LIMIT conlimit  
    | [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
    | VALID UNTIL 'timestamp'  
    | IN ROLE role_name [ , ... ]  
    | IN GROUP role_name [ , ... ]  
    | ROLE role_name [ , ... ]  
    | ADMIN role_name [ , ... ]  
    | USER role_name [ , ... ]  
    | SYSID uid
```

## Description

CREATE ROLE adds a new role to a LightDB database cluster. A role is an entity that can own database objects and have database privileges; a role can be considered a “user”, a “group”, or both depending on how it is used. Refer to Chapter 19 and Chapter 18 for information about managing users and authentication. You must have CREATEROLE privilege or be a database superuser to use this command.

Note that roles are defined at the database cluster level, and so are valid in all databases in the cluster.

## Parameters

*name*

The name of the new role.

SUPERUSER  
NOSUPERUSER

These clauses determine whether the new role is a “superuser”, who can override all access restrictions within the database. Superuser status is dangerous and should be used only when really needed. You must yourself be a superuser to create a new superuser. If not specified, NOSUPERUSER is the default.

CREATEDB  
NOCREATEDB

These clauses define a role's ability to create databases. If `CREATEDB` is specified, the role being defined will be allowed to create new databases. Specifying `NOCREATEDB` will deny a role the ability to create databases. If not specified, `NOCREATEDB` is the default.

CREATEROLE  
NOCREATEROLE

These clauses determine whether a role will be permitted to create new roles (that is, execute `CREATE ROLE`). A role with `CREATEROLE` privilege can also alter and drop other roles. If not specified, `NOCREATEROLE` is the default.

INHERIT  
NOINHERIT

These clauses determine whether a role “inherits” the privileges of roles it is a member of. A role with the `INHERIT` attribute can automatically use whatever database privileges have been granted to all roles it is directly or indirectly a member of. Without `INHERIT`, membership in another role only grants the ability to `SET ROLE` to that other role; the privileges of the other role are only available after having done so. If not specified, `INHERIT` is the default.

LOGIN  
NOLOGIN

These clauses determine whether a role is allowed to log in; that is, whether the role can be given as the initial session authorization name during client connection. A role having the `LOGIN` attribute can be thought of as a user. Roles without this attribute are useful for managing database privileges, but are not users in the usual sense of the word. If not specified, `NOLOGIN` is the default, except when `CREATE ROLE` is invoked through its alternative spelling `CREATE USER`.

REPLICATION  
NOREPLICATION

These clauses determine whether a role is a replication role. A role must have this attribute (or be a superuser) in order to be able to connect to the server in replication mode (physical or logical replication) and in order to be able to create or drop replication slots. A role having the `REPLICATION` attribute is a very highly privileged role, and should only be used on roles actually used for replication. If not specified, `NOREPLICATION` is the default. You must be a superuser to create a new role having the `REPLICATION` attribute.

BYPASSRLS  
NOBYPASSRLS

These clauses determine whether a role bypasses every row-level security (RLS) policy. `NOBYPASSRLS` is the default. You must be a superuser to create a new role having the `BYPASSRLS` attribute.

Note that `lt_dump` will set `row_security` to `OFF` by default, to ensure all contents of a table are dumped out. If the user running `lt_dump` does not have appropriate permissions, an error will be returned. However, superusers and the owner of the table being dumped always bypass RLS.

`CONNECTION LIMIT conlimit`

If role can log in, this specifies how many concurrent connections the role can make. `-1` (the default) means no limit. Note that only normal connections are counted towards this limit. Neither prepared transactions nor background worker connections are counted towards this limit.

```
[ ENCRYPTED ] PASSWORD 'password'  
PASSWORD NULL
```

Sets the role's password. (A password is only of use for roles having the LOGIN attribute, but you can nonetheless define one for roles without it.) If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as PASSWORD NULL.

### Note

Specifying an empty string will also set the password to null, but that was not the case before LightDB version 10. In earlier versions, an empty string could be used, or not, depending on the authentication method and the exact version, and libpq would refuse to use it in any case. To avoid the ambiguity, specifying an empty string should be avoided.

The password is always stored encrypted in the system catalogs. The ENCRYPTED keyword has no effect, but is accepted for backwards compatibility. The method of encryption is determined by the configuration parameter password\_encryption. If the presented password string is already in MD5-encrypted or SCRAM-encrypted format, then it is stored as-is regardless of password\_encryption (since the system cannot decrypt the specified encrypted password string, to encrypt it in a different format). This allows reloading of encrypted passwords during dump/restore.

```
VALID UNTIL 'timestamp'
```

The VALID UNTIL clause sets a date and time after which the role's password is no longer valid. If this clause is omitted the password will be valid for all time.

```
IN ROLE role_name
```

The IN ROLE clause lists one or more existing roles to which the new role will be immediately added as a new member. (Note that there is no option to add the new role as an administrator; use a separate GRANT command to do that.)

```
IN GROUP role_name
```

IN GROUP is an obsolete spelling of IN ROLE.

```
ROLE role_name
```

The ROLE clause lists one or more existing roles which are automatically added as members of the new role. (This in effect makes the new role a “group”.)

```
ADMIN role_name
```

The ADMIN clause is like ROLE, but the named roles are added to the new role WITH ADMIN OPTION, giving them the right to grant membership in this role to others.

```
USER role_name
```

The USER clause is an obsolete spelling of the ROLE clause.

```
SYSID uid
```

The SYSID clause is ignored, but is accepted for backwards compatibility.

## Notes

Use `ALTER ROLE` to change the attributes of a role, and `DROP ROLE` to remove a role. All the attributes specified by `CREATE ROLE` can be modified by later `ALTER ROLE` commands.

The preferred way to add and remove members of roles that are being used as groups is to use `GRANT` and `REVOKE`.

The `VALID UNTIL` clause defines an expiration time for a password only, not for the role *per se*. In particular, the expiration time is not enforced when logging in using a non-password-based authentication method.

The `INHERIT` attribute governs inheritance of grantable privileges (that is, access privileges for database objects and role memberships). It does not apply to the special role attributes set by `CREATE ROLE` and `ALTER ROLE`. For example, being a member of a role with `CREATEDB` privilege does not immediately grant the ability to create databases, even if `INHERIT` is set; it would be necessary to become that role via `SET ROLE` before creating a database.

The `INHERIT` attribute is the default for reasons of backwards compatibility: in prior releases of LightDB, users always had access to all privileges of groups they were members of. However, `NOINHERIT` provides a closer match to the semantics specified in the SQL standard.

Be careful with the `CREATEROLE` privilege. There is no concept of inheritance for the privileges of a `CREATEROLE`-role. That means that even if a role does not have a certain privilege but is allowed to create other roles, it can easily create another role with different privileges than its own (except for creating roles with superuser privileges). For example, if the role “user” has the `CREATEROLE` privilege but not the `CREATEDB` privilege, nonetheless it can create a new role with the `CREATEDB` privilege. Therefore, regard roles that have the `CREATEROLE` privilege as almost-superuser-roles.

LightDB includes a program `createuser` that has the same functionality as `CREATE ROLE` (in fact, it calls this command) but can be run from the command shell.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection “slot” remains for the role, it is possible that both will fail. Also, the limit is never enforced for superusers.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. The command `createuser`, however, transmits the password encrypted. Also, `Itsql` contains a command `\password` that can be used to safely change the password later.

## Examples

Create a role that can log in, but don't give it a password:

```
CREATE ROLE jonathan LOGIN;
```

Create a role with a password:

```
CREATE USER davide WITH PASSWORD 'jw8s0F4';
```

(`CREATE USER` is the same as `CREATE ROLE` except that it implies `LOGIN`.)

Create a role with a password that is valid until the end of 2004. After one second has ticked in 2005, the password is no longer valid.

```
CREATE ROLE miriam WITH LOGIN PASSWORD 'jw8s0F4' VALID UNTIL
'2005-01-01';
```

Create a role that can create databases and manage roles:

```
CREATE ROLE admin WITH CREATEDB CREATEROLE;
```

## Compatibility

The `CREATE ROLE` statement is in the SQL standard, but the standard only requires the syntax

```
CREATE ROLE name [ WITH ADMIN role_name ]
```

Multiple initial administrators, and all the other options of `CREATE ROLE`, are LightDB extensions.

The SQL standard defines the concepts of users and roles, but it regards them as distinct concepts and leaves all commands defining users to be specified by each database implementation. In LightDB we have chosen to unify users and roles into a single kind of entity. Roles therefore have many more optional attributes than they do in the standard.

The behavior specified by the SQL standard is most closely approximated by giving users the `NOINHERIT` attribute, while roles are given the `INHERIT` attribute.

## See Also

`SET ROLE`, `ALTER ROLE`, `DROP ROLE`, `GRANT`, `REVOKE`, `createuser`

---

# CREATE RULE

CREATE RULE — define a new rewrite rule

## Synopsis

```
CREATE [ OR REPLACE ] RULE name AS ON event
  TO table_name [ WHERE condition ]
  DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command
  ... ) }
```

where *event* can be one of:

```
SELECT | INSERT | UPDATE | DELETE
```

## Description

CREATE RULE defines a new rule applying to a specified table or view. CREATE OR REPLACE RULE will either create a new rule, or replace an existing rule of the same name for the same table.

The LightDB rule system allows one to define an alternative action to be performed on insertions, updates, or deletions in database tables. Roughly speaking, a rule causes additional commands to be executed when a given command on a given table is executed. Alternatively, an INSTEAD rule can replace a given command by another, or cause a command not to be executed at all. Rules are used to implement SQL views as well. It is important to realize that a rule is really a command transformation mechanism, or command macro. The transformation happens before the execution of the command starts. If you actually want an operation that fires independently for each physical row, you probably want to use a trigger, not a rule. More information about the rules system is in Chapter 39.

Presently, ON SELECT rules must be unconditional INSTEAD rules and must have actions that consist of a single SELECT command. Thus, an ON SELECT rule effectively turns the table into a view, whose visible contents are the rows returned by the rule's SELECT command rather than whatever had been stored in the table (if anything). It is considered better style to write a CREATE VIEW command than to create a real table and define an ON SELECT rule for it.

You can create the illusion of an updatable view by defining ON INSERT, ON UPDATE, and ON DELETE rules (or any subset of those that's sufficient for your purposes) to replace update actions on the view with appropriate updates on other tables. If you want to support INSERT RETURNING and so on, then be sure to put a suitable RETURNING clause into each of these rules.

There is a catch if you try to use conditional rules for complex view updates: there *must* be an unconditional INSTEAD rule for each action you wish to allow on the view. If the rule is conditional, or is not INSTEAD, then the system will still reject attempts to perform the update action, because it thinks it might end up trying to perform the action on the dummy table of the view in some cases. If you want to handle all the useful cases in conditional rules, add an unconditional DO INSTEAD NOTHING rule to ensure that the system understands it will never be called on to update the dummy table. Then make the conditional rules non-INSTEAD; in the cases where they are applied, they add to the default INSTEAD NOTHING action. (This method does not currently work to support RETURNING queries, however.)

### Note

A view that is simple enough to be automatically updatable (see CREATE VIEW) does not require a user-created rule in order to be updatable. While you can create an

explicit rule anyway, the automatic update transformation will generally outperform an explicit rule.

Another alternative worth considering is to use `INSTEAD OF` triggers (see `CREATE TRIGGER`) in place of rules.

## Parameters

### *name*

The name of a rule to create. This must be distinct from the name of any other rule for the same table. Multiple rules on the same table and same event type are applied in alphabetical name order.

### *event*

The event is one of `SELECT`, `INSERT`, `UPDATE`, or `DELETE`. Note that an `INSERT` containing an `ON CONFLICT` clause cannot be used on tables that have either `INSERT` or `UPDATE` rules. Consider using an updatable view instead.

### *table\_name*

The name (optionally schema-qualified) of the table or view the rule applies to.

### *condition*

Any SQL conditional expression (returning `boolean`). The condition expression cannot refer to any tables except `NEW` and `OLD`, and cannot contain aggregate functions.

### `INSTEAD`

`INSTEAD` indicates that the commands should be executed *instead of* the original command.

### `ALSO`

`ALSO` indicates that the commands should be executed *in addition to* the original command.

If neither `ALSO` nor `INSTEAD` is specified, `ALSO` is the default.

### *command*

The command or commands that make up the rule action. Valid commands are `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `NOTIFY`.

Within *condition* and *command*, the special table names `NEW` and `OLD` can be used to refer to values in the referenced table. `NEW` is valid in `ON INSERT` and `ON UPDATE` rules to refer to the new row being inserted or updated. `OLD` is valid in `ON UPDATE` and `ON DELETE` rules to refer to the existing row being updated or deleted.

## Notes

You must be the owner of a table to create or change rules for it.

In a rule for `INSERT`, `UPDATE`, or `DELETE` on a view, you can add a `RETURNING` clause that emits the view's columns. This clause will be used to compute the outputs if the rule is triggered by an `INSERT RETURNING`, `UPDATE RETURNING`, or `DELETE RETURNING` command respectively. When the rule is triggered by a command without `RETURNING`, the rule's `RETURNING` clause will be ignored. The current implementation allows only unconditional `INSTEAD` rules to contain `RETURNING`; furthermore there can be at most one `RETURNING` clause among all the rules for the same event. (This ensures that there is only one candidate `RETURNING` clause to be used to compute



the results.) RETURNING queries on the view will be rejected if there is no RETURNING clause in any available rule.

It is very important to take care to avoid circular rules. For example, though each of the following two rule definitions are accepted by LightDB, the SELECT command would cause LightDB to report an error because of recursive expansion of a rule:

```
CREATE RULE "_RETURN" AS
  ON SELECT TO t1
  DO INSTEAD
    SELECT * FROM t2;
```

```
CREATE RULE "_RETURN" AS
  ON SELECT TO t2
  DO INSTEAD
    SELECT * FROM t1;
```

```
SELECT * FROM t1;
```

Presently, if a rule action contains a NOTIFY command, the NOTIFY command will be executed unconditionally, that is, the NOTIFY will be issued even if there are not any rows that the rule should apply to. For example, in:

```
CREATE RULE notify_me AS ON UPDATE TO mytable DO ALSO NOTIFY
  mytable;
```

```
UPDATE mytable SET name = 'foo' WHERE id = 42;
```

one NOTIFY event will be sent during the UPDATE, whether or not there are any rows that match the condition `id = 42`. This is an implementation restriction that might be fixed in future releases.

## Compatibility

CREATE RULE is a LightDB language extension, as is the entire query rewrite system.

## See Also

ALTER RULE, DROP RULE

---

# CREATE SCHEMA

CREATE SCHEMA — define a new schema

## Synopsis

```
CREATE SCHEMA schema_name [ AUTHORIZATION role_specification ]
  [ schema_element [ ... ] ]
CREATE SCHEMA AUTHORIZATION role_specification [ schema_element
  [ ... ] ]
CREATE SCHEMA IF NOT EXISTS schema_name
  [ AUTHORIZATION role_specification ]
CREATE SCHEMA IF NOT EXISTS AUTHORIZATION role_specification
```

where *role\_specification* can be:

```
    user_name
  | CURRENT_USER
  | SESSION_USER
```

## Description

CREATE SCHEMA enters a new schema into the current database. The schema name must be distinct from the name of any existing schema in the current database.

A schema is essentially a namespace: it contains named objects (tables, data types, functions, and operators) whose names can duplicate those of other objects existing in other schemas. Named objects are accessed either by “qualifying” their names with the schema name as a prefix, or by setting a search path that includes the desired schema(s). A CREATE command specifying an unqualified object name creates the object in the current schema (the one at the front of the search path, which can be determined with the function `current_schema`).

Optionally, CREATE SCHEMA can include subcommands to create objects within the new schema. The subcommands are treated essentially the same as separate commands issued after creating the schema, except that if the AUTHORIZATION clause is used, all the created objects will be owned by that user.

## Parameters

*schema\_name*

The name of a schema to be created. If this is omitted, the *user\_name* is used as the schema name. The name cannot begin with `pg_`, as such names are reserved for system schemas.

*user\_name*

The role name of the user who will own the new schema. If omitted, defaults to the user executing the command. To create a schema owned by another role, you must be a direct or indirect member of that role, or be a superuser.

*schema\_element*

An SQL statement defining an object to be created within the schema. Currently, only CREATE TABLE, CREATE VIEW, CREATE INDEX, CREATE SEQUENCE, CREATE TRIGGER and

GRANT are accepted as clauses within CREATE SCHEMA. Other kinds of objects may be created in separate commands after the schema is created.

IF NOT EXISTS

Do nothing (except issuing a notice) if a schema with the same name already exists. *schema\_element* subcommands cannot be included when this option is used.

## Notes

To create a schema, the invoking user must have the CREATE privilege for the current database. (Of course, superusers bypass this check.)

## Examples

Create a schema:

```
CREATE SCHEMA myschema;
```

Create a schema for user joe; the schema will also be named joe:

```
CREATE SCHEMA AUTHORIZATION joe;
```

Create a schema named test that will be owned by user joe, unless there already is a schema named test. (It does not matter whether joe owns the pre-existing schema.)

```
CREATE SCHEMA IF NOT EXISTS test AUTHORIZATION joe;
```

Create a schema and create a table and view within it:

```
CREATE SCHEMA hollywood
  CREATE TABLE films (title text, release date, awards text[])
  CREATE VIEW winners AS
    SELECT title, release FROM films WHERE awards IS NOT NULL;
```

Notice that the individual subcommands do not end with semicolons.

The following is an equivalent way of accomplishing the same result:

```
CREATE SCHEMA hollywood;
CREATE TABLE hollywood.films (title text, release date, awards
  text[]);
CREATE VIEW hollywood.winners AS
  SELECT title, release FROM hollywood.films WHERE awards IS NOT
  NULL;
```

## Compatibility

The SQL standard allows a DEFAULT CHARACTER SET clause in CREATE SCHEMA, as well as more subcommand types than are presently accepted by LightDB.

The SQL standard specifies that the subcommands in CREATE SCHEMA can appear in any order. The present LightDB implementation does not handle all cases of forward references in subcommands; it might sometimes be necessary to reorder the subcommands in order to avoid forward references.

According to the SQL standard, the owner of a schema always owns all objects within it. LightDB allows schemas to contain objects owned by users other than the schema owner. This can happen only if the schema owner grants the `CREATE` privilege on their schema to someone else, or a superuser chooses to create objects in it.

The `IF NOT EXISTS` option is a LightDB extension.

### **See Also**

`ALTER SCHEMA`, `DROP SCHEMA`

---

# CREATE SEQUENCE

CREATE SEQUENCE — define a new sequence generator

## Synopsis

```
CREATE [ TEMPORARY | TEMP ] SEQUENCE [ IF NOT EXISTS ] name
  [ AS data_type ]
  [ INCREMENT [ BY ] increment ]
  [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO
MAXVALUE ]
  [ START [ WITH ] start ] [ CACHE cache ] [ [ NO ] CYCLE ]
  [ OWNED BY { table_name.column_name | NONE } ]
  [ NOORDER ]
  [ ORDER ]
  [ NOCACHE ]
  [ NOCYCLE ]
  [ NOMAXVALUE ]
```

## Description

CREATE SEQUENCE creates a new sequence number generator. This involves creating and initializing a new special single-row table with the name *name*. The generator will be owned by the user issuing the command.

If a schema name is given then the sequence is created in the specified schema. Otherwise it is created in the current schema. Temporary sequences exist in a special schema, so a schema name cannot be given when creating a temporary sequence. The sequence name must be distinct from the name of any other sequence, table, index, view, or foreign table in the same schema.

After a sequence is created, you use the functions `nextval`, `currval`, and `setval` to operate on the sequence. These functions are documented in Section 9.17.

Although you cannot update a sequence directly, you can use a query like:

```
SELECT * FROM name;
```

to examine the parameters and current state of a sequence. In particular, the `last_value` field of the sequence shows the last value allocated by any session. (Of course, this value might be obsolete by the time it's printed, if other sessions are actively doing `nextval` calls.)

## Parameters

TEMPORARY or TEMP

If specified, the sequence object is created only for this session, and is automatically dropped on session exit. Existing permanent sequences with the same name are not visible (in this session) while the temporary sequence exists, unless they are referenced with schema-qualified names.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the sequence that would have been created — it might not even be a sequence.

*name*

The name (optionally schema-qualified) of the sequence to be created.

*data\_type*

The optional clause `AS data_type` specifies the data type of the sequence. Valid types are `smallint`, `integer`, and `bigint`. `bigint` is the default. The data type determines the default minimum and maximum values of the sequence.

*increment*

The optional clause `INCREMENT BY increment` specifies which value is added to the current sequence value to create a new value. A positive value will make an ascending sequence, a negative one a descending sequence. The default value is 1.

*minvalue*

`NO MINVALUE`

The optional clause `MINVALUE minvalue` determines the minimum value a sequence can generate. If this clause is not supplied or `NO MINVALUE` is specified, then defaults will be used. The default for an ascending sequence is 1. The default for a descending sequence is the minimum value of the data type.

*maxvalue*

`NO MAXVALUE`

The optional clause `MAXVALUE maxvalue` determines the maximum value for the sequence. If this clause is not supplied or `NO MAXVALUE` is specified, then default values will be used. The default for an ascending sequence is the maximum value of the data type. The default for a descending sequence is -1.

If the value of *maxvalue* is greater than `INT64_MAX(9223372036854775807)`, set *maxvalue* to the maximum value corresponding to the sequence type.

*start*

The optional clause `START WITH start` allows the sequence to begin anywhere. The default starting value is *minvalue* for ascending sequences and *maxvalue* for descending ones.

*cache*

The optional clause `CACHE cache` specifies how many sequence numbers are to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache), and this is also the default.

`CYCLE`

`NO CYCLE`

The `CYCLE` option allows the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

If `NO CYCLE` is specified, any calls to `nextval` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, `NO CYCLE` is the default.

`OWNED BY table_name.column_name`

`OWNED BY NONE`

The `OWNED BY` option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as

well. The specified table must have the same owner and be in the same schema as the sequence. OWNED BY NONE, the default, specifies that there is no such association.

NOORDER  
ORDER  
NOCACHE  
NOCYCLE

The CREATE SEQUENCE statement supports the NOORDER/ORDER/NOCACHE/NOCYCLE keywords, which are intended to fit the syntax of Oracle databases. In the LightDB implementation, these keywords are just syntactic sugar.

NOMAXVALUE

For compatibility with Oracle database syntax, the CREATE SEQUENCE statement supports the NOMAXVALUE keyword. The internal logic is the same as NO MAXVALUE.

## Notes

Use DROP SEQUENCE to remove a sequence.

Sequences are based on bigint arithmetic, so the range cannot exceed the range of an eight-byte integer (-9223372036854775808 to 9223372036854775807).

Because nextval and setval calls are never rolled back, sequence objects cannot be used if “gapless” assignment of sequence numbers is needed. It is possible to build gapless assignment by using exclusive locking of a table containing a counter; but this solution is much more expensive than sequence objects, especially if many transactions need sequence numbers concurrently.

Unexpected results might be obtained if a cache setting greater than one is used for a sequence object that will be used concurrently by multiple sessions. Each session will allocate and cache successive sequence values during one access to the sequence object and increase the sequence object's last\_value accordingly. Then, the next cache-1 uses of nextval within that session simply return the preallocated values without touching the sequence object. So, any numbers allocated but not used within a session will be lost when that session ends, resulting in “holes” in the sequence.

Furthermore, although multiple sessions are guaranteed to allocate distinct sequence values, the values might be generated out of sequence when all the sessions are considered. For example, with a cache setting of 10, session A might reserve values 1..10 and return nextval=1, then session B might reserve values 11..20 and return nextval=11 before session A has generated nextval=2. Thus, with a cache setting of one it is safe to assume that nextval values are generated sequentially; with a cache setting greater than one you should only assume that the nextval values are all distinct, not that they are generated purely sequentially. Also, last\_value will reflect the latest value reserved by any session, whether or not it has yet been returned by nextval.

Another consideration is that a setval executed on such a sequence will not be noticed by other sessions until they have used up any preallocated values they have cached.

## Examples

Create an ascending sequence called serial, starting at 101:

```
CREATE SEQUENCE serial START 101;
```

Select the next number from this sequence:

```
SELECT nextval('serial');
```

```
nextval
-----
      101
```

Select the next number from this sequence:

```
SELECT nextval('serial');
```

```
nextval
-----
      102
```

Use this sequence in an INSERT command:

```
INSERT INTO distributors VALUES (nextval('serial'), 'nothing');
```

Update the sequence value after a COPY FROM:

```
BEGIN;
COPY distributors FROM 'input_file';
SELECT setval('serial', max(id)) FROM distributors;
END;
```

Create sequence with ORDER/NOORDER/NOCACHE/NOCYCLE options;

```
create sequence lt_seq_test5 start 100 ORDER nocache NOCYCLE;
create sequence lt_seq_test6 start 100 NOCACHE NOORDER nocycle;
```

## Compatibility

CREATE SEQUENCE conforms to the SQL standard, with the following exceptions:

- Obtaining the next value is done using the `nextval()` function instead of the standard's `NEXT VALUE FOR` expression.
- The `OWNED BY` clause is a LightDB extension.

## See Also

ALTER SEQUENCE, DROP SEQUENCE



---

# CREATE SERVER

CREATE SERVER — define a new foreign server

## Synopsis

```
CREATE SERVER [ IF NOT EXISTS ] server_name [ TYPE 'server_type' ]  
  [ VERSION 'server_version' ]  
  FOREIGN DATA WRAPPER fdw_name  
  [ OPTIONS ( option 'value' [, ... ] ) ]
```

## Description

CREATE SERVER defines a new foreign server. The user who defines the server becomes its owner.

A foreign server typically encapsulates connection information that a foreign-data wrapper uses to access an external data resource. Additional user-specific connection information may be specified by means of user mappings.

The server name must be unique within the database.

Creating a server requires USAGE privilege on the foreign-data wrapper being used.

## Parameters

IF NOT EXISTS

Do not throw an error if a server with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing server is anything like the one that would have been created.

*server\_name*

The name of the foreign server to be created.

*server\_type*

Optional server type, potentially useful to foreign-data wrappers.

*server\_version*

Optional server version, potentially useful to foreign-data wrappers.

*fdw\_name*

The name of the foreign-data wrapper that manages the server.

OPTIONS ( *option* '*value*' [, ... ] )

This clause specifies the options for the server. The options typically define the connection details of the server, but the actual names and values are dependent on the server's foreign-data wrapper.

## Notes

When using the dblink module, a foreign server's name can be used as an argument of the dblink\_connect function to indicate the connection parameters. It is necessary to have the USAGE privilege on the foreign server to be able to use it in this way.

## Examples

Create a server `myserver` that uses the foreign-data wrapper `postgres_fdw`:

```
CREATE SERVER myservers FOREIGN DATA WRAPPER postgres_fdw OPTIONS
(host 'foo', dbname 'foodb', port '5432');
```

See `postgres_fdw` for more details.

## Compatibility

`CREATE SERVER` conforms to ISO/IEC 9075-9 (SQL/MED).

## See Also

`ALTER SERVER`, `DROP SERVER`, `CREATE FOREIGN DATA WRAPPER`, `CREATE FOREIGN TABLE`, `CREATE USER MAPPING`

---

# CREATE STATISTICS

CREATE STATISTICS — define extended statistics

## Synopsis

```
CREATE STATISTICS [ IF NOT EXISTS ] statistics_name
  [ ( statistics_kind [, ... ] ) ]
  ON column_name, column_name [, ...]
  FROM table_name
```

## Description

CREATE STATISTICS will create a new extended statistics object tracking data about the specified table, foreign table or materialized view. The statistics object will be created in the current database and will be owned by the user issuing the command.

If a schema name is given (for example, CREATE STATISTICS myschema.mystat ...) then the statistics object is created in the specified schema. Otherwise it is created in the current schema. The name of the statistics object must be distinct from the name of any other statistics object in the same schema.

## Parameters

IF NOT EXISTS

Do not throw an error if a statistics object with the same name already exists. A notice is issued in this case. Note that only the name of the statistics object is considered here, not the details of its definition.

*statistics\_name*

The name (optionally schema-qualified) of the statistics object to be created.

*statistics\_kind*

A statistics kind to be computed in this statistics object. Currently supported kinds are `ndistinct`, which enables n-distinct statistics, `dependencies`, which enables functional dependency statistics, and `mcv` which enables most-common values lists. If this clause is omitted, all supported statistics kinds are included in the statistics object. For more information, see Section 14.2.2 and Section 66.2.

*column\_name*

The name of a table column to be covered by the computed statistics. At least two column names must be given; the order of the column names is insignificant.

*table\_name*

The name (optionally schema-qualified) of the table containing the column(s) the statistics are computed on.

## Notes

You must be the owner of a table to create a statistics object reading it. Once created, however, the ownership of the statistics object is independent of the underlying table(s).

## Examples

Create table `t1` with two functionally dependent columns, i.e., knowledge of a value in the first column is sufficient for determining the value in the other column. Then functional dependency statistics are built on those columns:

```
CREATE TABLE t1 (  
    a    int,  
    b    int  
);  
  
INSERT INTO t1 SELECT i/100, i/500  
    FROM generate_series(1,1000000) s(i);  
  
ANALYZE t1;  
  
-- the number of matching rows will be drastically underestimated:  
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);  
  
CREATE STATISTICS s1 (dependencies) ON a, b FROM t1;  
  
ANALYZE t1;  
  
-- now the row count estimate is more accurate:  
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);
```

Without functional-dependency statistics, the planner would assume that the two `WHERE` conditions are independent, and would multiply their selectivities together to arrive at a much-too-small row count estimate. With such statistics, the planner recognizes that the `WHERE` conditions are redundant and does not underestimate the row count.

Create table `t2` with two perfectly correlated columns (containing identical data), and a MCV list on those columns:

```
CREATE TABLE t2 (  
    a    int,  
    b    int  
);  
  
INSERT INTO t2 SELECT mod(i,100), mod(i,100)  
    FROM generate_series(1,1000000) s(i);  
  
CREATE STATISTICS s2 (mcv) ON a, b FROM t2;  
  
ANALYZE t2;  
  
-- valid combination (found in MCV)  
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 1);  
  
-- invalid combination (not found in MCV)  
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 2);
```

The MCV list gives the planner more detailed information about the specific values that commonly appear in the table, as well as an upper bound on the selectivities of combinations of values that do not appear in the table, allowing it to generate better estimates in both cases.

## Compatibility

There is no `CREATE STATISTICS` command in the SQL standard.

## See Also

`ALTER STATISTICS`, `DROP STATISTICS`

---

# CREATE SUBSCRIPTION

CREATE SUBSCRIPTION — define a new subscription

## Synopsis

```
CREATE SUBSCRIPTION subscription_name
  CONNECTION 'conninfo'
  PUBLICATION publication_name [, ...]
  [ WITH ( subscription_parameter [= value] [, ... ] ) ]
```

## Description

CREATE SUBSCRIPTION adds a new subscription for the current database. The subscription name must be distinct from the name of any existing subscription in the database.

The subscription represents a replication connection to the publisher. As such this command does not only add definitions in the local catalogs but also creates a replication slot on the publisher.

A logical replication worker will be started to replicate data for the new subscription at the commit of the transaction where this command is run.

Additional information about subscriptions and logical replication as a whole is available at Section 28.2 and Chapter 28.

## Parameters

*subscription\_name*

The name of the new subscription.

CONNECTION '*conninfo*'

The connection string to the publisher. For details see Section 32.1.1.

PUBLICATION *publication\_name*

Names of the publications on the publisher to subscribe to.

WITH ( *subscription\_parameter* [= *value*] [, ... ] )

This clause specifies optional parameters for a subscription. The following parameters are supported:

*copy\_data* (boolean)

Specifies whether the existing data in the publications that are being subscribed to should be copied once the replication starts. The default is `true`.

*create\_slot* (boolean)

Specifies whether the command should create the replication slot on the publisher. The default is `true`.

*enabled* (boolean)

Specifies whether the subscription should be actively replicating, or whether it should be just setup but not started yet. The default is `true`.

`slot_name` (string)

Name of the replication slot to use. The default behavior is to use the name of the subscription for the slot name.

When `slot_name` is set to `NONE`, there will be no replication slot associated with the subscription. This can be used if the replication slot will be created later manually. Such subscriptions must also have both `enabled` and `create_slot` set to `false`.

`synchronous_commit` (enum)

The value of this parameter overrides the `synchronous_commit` setting. The default value is `off`.

It is safe to use `off` for logical replication: If the subscriber loses transactions because of missing synchronization, the data will be sent again from the publisher.

A different setting might be appropriate when doing synchronous logical replication. The logical replication workers report the positions of writes and flushes to the publisher, and when using synchronous replication, the publisher will wait for the actual flush. This means that setting `synchronous_commit` for the subscriber to `off` when the subscription is used for synchronous replication might increase the latency for `COMMIT` on the publisher. In this scenario, it can be advantageous to set `synchronous_commit` to `local` or higher.

`connect` (boolean)

Specifies whether the `CREATE SUBSCRIPTION` should connect to the publisher at all. Setting this to `false` will change default values of `enabled`, `create_slot` and `copy_data` to `false`.

It is not allowed to combine `connect` set to `false` and `enabled`, `create_slot`, or `copy_data` set to `true`.

Since no connection is made when this option is set to `false`, the tables are not subscribed, and so after you enable the subscription nothing will be replicated. It is required to run `ALTER SUBSCRIPTION ... REFRESH PUBLICATION` in order for tables to be subscribed.

## Notes

See Section 28.7 for details on how to configure access control between the subscription and the publication instance.

When creating a replication slot (the default behavior), `CREATE SUBSCRIPTION` cannot be executed inside a transaction block.

Creating a subscription that connects to the same database cluster (for example, to replicate between databases in the same cluster or to replicate within the same database) will only succeed if the replication slot is not created as part of the same command. Otherwise, the `CREATE SUBSCRIPTION` call will hang. To make this work, create the replication slot separately (using the function `pg_create_logical_replication_slot` with the plugin name `ltoutput`) and create the subscription using the parameter `create_slot = false`. This is an implementation restriction that might be lifted in a future release.

## Examples

Create a subscription to a remote server that replicates tables in the publications `mypublication` and `insert_only` and starts replicating immediately on commit:

```
CREATE SUBSCRIPTION mysub
```

```
        CONNECTION 'host=192.168.1.50 port=5432 user=foo
dbname=foodb'
        PUBLICATION mypublication, insert_only;
```

Create a subscription to a remote server that replicates tables in the `insert_only` publication and does not start replicating until enabled at a later time.

```
CREATE SUBSCRIPTION mysub
        CONNECTION 'host=192.168.1.50 port=5432 user=foo
dbname=foodb'
        PUBLICATION insert_only
        WITH (enabled = false);
```

## Compatibility

`CREATE SUBSCRIPTION` is a LightDB extension.

## See Also

`ALTER SUBSCRIPTION`, `DROP SUBSCRIPTION`, `CREATE PUBLICATION`, `ALTER PUBLICATION`



---

# CREATE TABLE

CREATE TABLE — define a new table

## Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED |
IMMUTABLE ] TABLE [ IF NOT EXISTS ] table_name ( [
  { column_name data_type [ COLLATE collation ] [ column_constraint
[enable|disable] [ ... ] ] [ COMMENT column_comment ]
  | table_constraint
  | LIKE source_table [ like_option ... ] }
[ , ... ]
] ) [ INHERITS ( parent_table [ , ... ] ) ]
[ lt_partition_option ]
[ USING method ]
[ WITH ( storage_parameter [= value] [ , ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ lt_table_options ]
[NO DELETE][NO UPDATE][NO DROP][NO TRUNCATE ]
```

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED |
IMMUTABLE ] TABLE [ IF NOT EXISTS ] table_name
  OF type_name [ (
  { column_name [ WITH OPTIONS ] [ column_constraint [enable|
disable] [ ... ] ]
  | table_constraint }
  [ , ... ]
) ]
[ lt_partition_options ]
[ USING method ]
[ WITH ( storage_parameter [= value] [ , ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]
[NO DELETE][NO UPDATE][NO DROP][NO TRUNCATE ]
```

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED |
IMMUTABLE ] TABLE [ IF NOT EXISTS ] table_name
  PARTITION OF parent_table [ (
  { column_name [ WITH OPTIONS ] [ column_constraint [enable|
disable] [ ... ] ]
  | table_constraint }
  [ , ... ]
) ] { FOR VALUES partition_bound_spec | DEFAULT }
[ PARTITION BY { RANGE | LIST | HASH } ( { column_name |
( expression ) } [ COLLATE collation ] [ opclass ] [ , ... ] ) ]
[ PARTITIONS partitions_value ]
[ INTERVAL interval_value ]
[ USING method ]
[ WITH ( storage_parameter [= value] [ , ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]
[NO DELETE][NO UPDATE][NO DROP][NO TRUNCATE ]
```

where *lt\_partition\_option* is:

```
{
  PARTITION BY { RANGE | LIST | HASH } ( { column_name |
  ( expression ) } [ COLLATE collation ] [ opclass ] [, ... ] )
  [ PARTITIONS partitions_value ]
  [ INTERVAL interval_value ] |
  PARTITION BY partition_type (column)
    [ SUBPARTITION BY partition_type (column) ]
    [ SUBPARTITIONS subpartitions_value ]
    [ SUBPARTITION TEMPLATE ( template_spec ) ]
    [...]
  ( partition_spec )
    | [ SUBPARTITION BY partition_type (column) ]
    [...]
  ( partition_spec
    [ ( subpartition_spec
      [(...)]
    ) ]
  )
}
```

and *lt\_table\_options* is:

```
{ TABLESPACE tablespace_name |
  WITH UPDATE CURRENT_TIMESTAMP |
  WITH PRIMRAY KEY [ smallserial | serial | bigserial ] |
  { DISTRIBUTED BY [HASH | APPEND](column) [ distribute_option
  ... ] | DISTRIBUTED REPLICATED } |
  COMMENT = table_comment |
  { COMPRESS | NOCOMPRESS } |
  { LOGGING | NOLOGGING } |
  STORAGE(value) |
  ENGINE = { INNODB | MYISAM } |
  DEFAULT CHARSET = value |
  COLLATE = value |
  NESTED TABLE column_name STORE AS nested_table_name [...]
}
```

and *column\_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  CHECK ( expression ) [ NO INHERIT ] |
  DEFAULT default_expr |
  ON UPDATE CURRENT_TIMESTAMP |
  AUTO_INCREMENT |
  GENERATED ALWAYS AS ( generation_expr ) STORED |
  GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
  [ ( sequence_options ) ] |
  UNIQUE index_parameters |
  PRIMARY KEY index_parameters |
  REFERENCES reftable [ ( refcolumn ) ] [ MATCH FULL | MATCH
  PARTIAL | MATCH SIMPLE ]
  [ ON DELETE referential_action ] [ ON UPDATE referential_action
  ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

and *table\_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ CHECK ( expression ) [ NO INHERIT ] |
  UNIQUE ( column_name [, ... ] ) index_parameters |
  PRIMARY KEY ( column_name [, ... ] ) index_parameters |
  EXCLUDE [ USING index_method ] ( exclude_element WITH operator
  [, ... ] ) index_parameters [ WHERE ( predicate ) ] |
  FOREIGN KEY ( column_name [, ... ] ) REFERENCES reftable
  [ ( refcolumn [, ... ] ) ]
  [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON
  DELETE referential_action ] [ ON UPDATE referential_action ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

and *like\_option* is:

```
{ INCLUDING | EXCLUDING } { COMMENTS | CONSTRAINTS | DEFAULTS |
GENERATED | IDENTITY | INDEXES | STATISTICS | STORAGE | SEQUENCES
| ALL }
```

and *partition\_bound\_spec* is:

```
IN ( partition_bound_expr [, ...] ) |
FROM ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] )
  TO ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS numeric_literal, REMAINDER numeric_literal )
```

*index\_parameters* in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

```
[ INCLUDE ( column_name [, ... ] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ USING INDEX TABLESPACE tablespace_name ]
```

*exclude\_element* in an EXCLUDE constraint is:

```
{ column_name | ( expression ) } [ opclass ] [ ASC | DESC ] [ NULLS
{ FIRST | LAST } ]
```

where *partition\_type* is:

```
LIST
| RANGE
| HASH
```

where *partition\_spec* is:

*partition\_element* [, ...]

and *partition\_element* is:

```
DEFAULT PARTITION name
| [PARTITION name] VALUES ( list_value [,...] )
| [PARTITION name]
  START ([datatype] start_value ) [INCLUSIVE | EXCLUSIVE]
  [ END ([datatype] end_value ) [INCLUSIVE | EXCLUSIVE] ]
  [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [PARTITION name]
  END ([datatype] end_value ) [INCLUSIVE | EXCLUSIVE]
  [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [PARTITION name]
  FROM ([datatype] from_value ) [INCLUSIVE | EXCLUSIVE]
```

```

    [ TO ([datatype] to_value ) [INCLUSIVE | EXCLUSIVE] ]
    [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [PARTITION name]
    TO ([datatype] to_value ) [INCLUSIVE | EXCLUSIVE]
    [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [PARTITION name] VALUES WITH ( MODULUS numeric_literal,
REMAINDER numeric_literal )
| [PARTITION name] VALUES LESS THAN ( { partition_value |
MAXVALUE } )
| [PARTITION name]
[ TABLESPACE tablespace ]
[ NOCOMPRESS | COMPRESS ]
where subpartition_spec or template_spec is:
subpartition_element [, ...]
and subpartition_element is:
    DEFAULT SUBPARTITION name
| [SUBPARTITION name] VALUES ( list_value [,...] )
| [SUBPARTITION name]
    START ([datatype] start_value ) [INCLUSIVE | EXCLUSIVE]
    [ END ([datatype] end_value ) [INCLUSIVE | EXCLUSIVE] ]
    [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [SUBPARTITION name]
    END ([datatype] end_value ) [INCLUSIVE | EXCLUSIVE]
    [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [SUBPARTITION name]
    FROM ([datatype] from_value ) [INCLUSIVE | EXCLUSIVE]
    [ TO ([datatype] to_value ) [INCLUSIVE | EXCLUSIVE] ]
    [ EVERY ([datatype] [number | INTERVAL] interval_value) ]
| [SUBPARTITION name]
    TO ([datatype] to_value ) [INCLUSIVE | EXCLUSIVE]
    [ EVERY ([datatype] [number | INTERVAL] interval_value ) ]
| [SUBPARTITION name] VALUES WITH ( MODULUS numeric_literal,
REMAINDER numeric_literal )
[ NOCOMPRESS | COMPRESS ]
where distribute_option is:
    SHARD_COUNT(int_value)
| COLOCATE_WITH('string_value')

```

## Description

CREATE TABLE will create a new, initially empty table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, CREATE TABLE myschema.mytable ...) then the table is created in the specified schema. Otherwise it is created in the current schema. Temporary tables exist in a special schema, so a schema name cannot be given when creating a temporary table. The name of the table must be distinct from the name of any other table, sequence, index, view, or foreign table in the same schema.

CREATE TABLE also automatically creates a data type that represents the composite type corresponding to one row of the table. Therefore, tables cannot have the same name as any existing data type in the same schema.

Any option in *lt\_table\_options* can be specified in any order.

The optional constraint clauses specify constraints (tests) that new or updated rows must satisfy for an insert or update operation to succeed. A constraint is an SQL object that helps define the set of valid values in the table in various ways.

There are two ways to define constraints: table constraints and column constraints. A column constraint is defined as part of a column definition. A table constraint definition is not tied to a particular column, and it can encompass more than one column. Every column constraint can also be written as a table constraint; a column constraint is only a notational convenience for use when the constraint only affects one column.

When the `column_comment` is specified then it would create comment on that column. Likewise, specifying the `table_comment` following the end of table definition made the table comment for it.

To be able to create a table, you must have `USAGE` privilege on all column types or the type in the `OF` clause, respectively.

## Parameters

`TEMPORARY` or `TEMP`

If specified, the table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see `ON COMMIT` below). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

The autovacuum daemon cannot access and therefore cannot vacuum or analyze temporary tables. For this reason, appropriate vacuum and analyze operations should be performed via session SQL commands. For example, if a temporary table is going to be used in complex queries, it is wise to run `ANALYZE` on the temporary table after it is populated.

Optionally, `LOCAL` can be written before `TEMPORARY` or `TEMP`. This presently makes no difference in LightDB and is deprecated; see Compatibility below.

`UNLOGGED`

If specified, the table is created as an unlogged table. Data written to unlogged tables is not written to the write-ahead log (see Chapter 27), which makes them considerably faster than ordinary tables. However, they are not crash-safe: an unlogged table is automatically truncated after a crash or unclean shutdown. The contents of an unlogged table are also not replicated to standby servers. Any indexes created on an unlogged table are automatically unlogged as well.

`IF NOT EXISTS`

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

*table\_name*

The name (optionally schema-qualified) of the table to be created. Please note that the table name is limited to a maximum of 31 characters in length when creating a partition table in oracle mode.

*table\_comment*

The contents of comment for the table to be created.

`OF` *type\_name*

Creates a *typed table*, which takes its structure from the specified composite type (name optionally schema-qualified). A typed table is tied to its type; for example the table will be dropped if the type is dropped (with `DROP TYPE . . . CASCADE`).

When a typed table is created, then the data types of the columns are determined by the underlying composite type and are not specified by the `CREATE TABLE` command. But the `CREATE TABLE` command can add defaults and constraints to the table and can specify storage parameters.

*column\_name*

The name of a column to be created in the new table.

Significantly, if the current database which was initated by mysql mode accompanied with setting 'lightdb\_sql\_mode' to 'uppercase\_identifier' on the lightdb.conf in the meanwhile then the *column\_name* couldn't occur more than once even if they were in different case. This feature is considered to kept the same with mysql but differ from traditional lightdb which allows *column\_name* case sensitive that is to say only prohibited equaled absolutely to them.

Considering similar situation in oracle mode that is slightly different to mysql mode. If the guc parameter 'lightdb\_oracle\_sql\_mode' is setted to 'show\_identifier\_uppercase' on oracle session then the label of executing a select statement which would display on screen is always in uppercase by default even if using alias. So the only way to keep case invariant is wrapped with double-quote that column name. Setting 'lightdb\_oracle\_sql\_mode' to " could disable this function and recovery the default state.

*column\_comment*

The contents of comment for the column to be created in the new table.

*data\_type*

The data type of the column. This can include array specifiers. For more information on the data types supported by LightDB, refer to Chapter 8.

COLLATE *collation*

The COLLATE clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

INHERITS ( *parent\_table* [, ... ] )

The optional INHERITS clause specifies a list of tables from which the new table automatically inherits all columns. Parent tables can be plain tables or foreign tables.

Use of INHERITS creates a persistent relationship between the new child table and its parent table(s). Schema modifications to the parent(s) normally propagate to children as well, and by default the data of the child table is included in scans of the parent(s).

If the same column name exists in more than one parent table, an error is reported unless the data types of the columns match in each of the parent tables. If there is no conflict, then the duplicate columns are merged to form a single column in the new table. If the column name list of the new table contains a column name that is also inherited, the data type must likewise match the inherited column(s), and the column definitions are merged into one. If the new table explicitly specifies a default value for the column, this default overrides any defaults from inherited declarations of the column. Otherwise, any parents that specify default values for the column must all specify the same default, or an error will be reported.

CHECK constraints are merged in essentially the same way as columns: if multiple parent tables and/or the new table definition contain identically-named CHECK constraints, these constraints must all have the same check expression, or an error will be reported. Constraints having the same name and expression will be merged into one copy. A constraint marked NO INHERIT in a parent will not be considered. Notice that an unnamed CHECK constraint in the new table will never be merged, since a unique name will always be chosen for it.

Column STORAGE settings are also copied from parent tables.

If a column in the parent table is an identity column, that property is not inherited. A column in the child table can be declared identity column if desired.

---

```
PARTITION BY { RANGE | LIST | HASH } ( { column_name | ( expression ) } [ opclass ] [, ...] )
```

The optional `PARTITION BY` clause specifies a strategy of partitioning the table. The table thus created is called a *partitioned* table. The parenthesized list of columns or expressions forms the *partition key* for the table. When using range or hash partitioning, the partition key can include multiple columns or expressions (up to 32, but this limit can be altered when building LightDB), but for list partitioning, the partition key must consist of a single column or expression.

Range and list partitioning require a btree operator class, while hash partitioning requires a hash operator class. If no operator class is specified explicitly, the default operator class of the appropriate type will be used; if no default operator class exists, an error will be raised. When hash partitioning is used, the operator class used must implement support function 2 (see Section 36.16.3 for details).

A partitioned table is divided into sub-tables (called partitions), which are created using separate `CREATE TABLE` commands. The partitioned table is itself empty. A data row inserted into the table is routed to a partition based on the value of columns or expressions in the partition key. If no existing partition matches the values in the new row, an error will be reported.

Partitioned tables do not support `EXCLUDE` constraints; however, you can define these constraints on individual partitions.

See Section 5.11 for more discussion on table partitioning.

Both partition name and subpartition name is limited to a maximum of 31 characters in length when creating a partitioned table in oracle compatible syntax in oracle mode.

```
PARTITION OF parent_table { FOR VALUES partition_bound_spec | DEFAULT }
```

Creates the table as a *partition* of the specified parent table. The table can be created either as a partition for specific values using `FOR VALUES` or as a default partition using `DEFAULT`. Any indexes, constraints and user-defined row-level triggers that exist in the parent table are cloned on the new partition.

The *partition\_bound\_spec* must correspond to the partitioning method and partition key of the parent table, and must not overlap with any existing partition of that parent. The form with `IN` is used for list partitioning, the form with `FROM` and `TO` is used for range partitioning, the form with `WITH` is used for hash partitioning and the form with `LESS THAN` is used for range partitioning(Oracle compatible syntax).

*partition\_bound\_expr* is any variable-free expression (subqueries, window functions, aggregate functions, and set-returning functions are not allowed). Its data type must match the data type of the corresponding partition key column. The expression is evaluated once at table creation time, so it can even contain volatile expressions such as `CURRENT_TIMESTAMP`.

When creating a list partition, `NULL` can be specified to signify that the partition allows the partition key column to be null. However, there cannot be more than one such list partition for a given parent table. `NULL` cannot be specified for range partitions.

When creating a range partition, the lower bound specified with `FROM` is an inclusive bound, whereas the upper bound specified with `TO` is an exclusive bound. That is, the values specified in the `FROM` list are valid values of the corresponding partition key columns for this partition, whereas those in the `TO` list are not. Note that this statement must be understood according to the rules of row-wise comparison (Section 9.24.5). For example, given `PARTITION BY RANGE (x, y)`, a partition bound `FROM (1, 2) TO (3, 4)` allows `x=1` with any `y>=2`, `x=2` with any non-null `y`, and `x=3` with any `y<4`.

The special values `MINVALUE` and `MAXVALUE` may be used when creating a range partition to indicate that there is no lower or upper bound on the column's value. For example, a partition

defined using `FROM (MINVALUE) TO (10)` allows any values less than 10, and a partition defined using `FROM (10) TO (MAXVALUE)` allows any values greater than or equal to 10.

When creating a range partition involving more than one column, it can also make sense to use `MAXVALUE` as part of the lower bound, and `MINVALUE` as part of the upper bound. For example, a partition defined using `FROM (0, MAXVALUE) TO (10, MAXVALUE)` allows any rows where the first partition key column is greater than 0 and less than or equal to 10. Similarly, a partition defined using `FROM ('a', MINVALUE) TO ('b', MINVALUE)` allows any rows where the first partition key column starts with "a".

Note that if `MINVALUE` or `MAXVALUE` is used for one column of a partitioning bound, the same value must be used for all subsequent columns. For example, `(10, MINVALUE, 0)` is not a valid bound; you should write `(10, MINVALUE, MINVALUE)`.

Also note that some element types, such as `timestamp`, have a notion of "infinity", which is just another value that can be stored. This is different from `MINVALUE` and `MAXVALUE`, which are not real values that can be stored, but rather they are ways of saying that the value is unbounded. `MAXVALUE` can be thought of as being greater than any other value, including "infinity" and `MINVALUE` as being less than any other value, including "minus infinity". Thus the range `FROM ('infinity') TO (MAXVALUE)` is not an empty range; it allows precisely one value to be stored — "infinity".

If `DEFAULT` is specified, the table will be created as the default partition of the parent table. This option either be a list or range or hash partitioned table. A partition key value not fitting into any other partition of the given parent will be routed to the default partition. There can be only one default partition for a given parent table.

When a table has an existing `DEFAULT` partition and a new partition is added to it, the default partition must be scanned to verify that it does not contain any rows which properly belong in the new partition. If the default partition contains a large number of rows, this may be slow. The scan will be skipped if the default partition is a foreign table or if it has a constraint which proves that it cannot contain rows which should be placed in the new partition.

When creating a hash partition, a modulus and remainder must be specified. The modulus must be a positive integer, and the remainder must be a non-negative integer less than the modulus. Typically, when initially setting up a hash-partitioned table, you should choose a modulus equal to the number of partitions and assign every table the same modulus and a different remainder (see examples, below). However, it is not required that every partition have the same modulus, only that every modulus which occurs among the partitions of a hash-partitioned table is a factor of the next larger modulus. This allows the number of partitions to be increased incrementally without needing to move all the data at once. For example, suppose you have a hash-partitioned table with 8 partitions, each of which has modulus 8, but find it necessary to increase the number of partitions to 16. You can detach one of the modulus-8 partitions, create two new modulus-16 partitions covering the same portion of the key space (one with a remainder equal to the remainder of the detached partition, and the other with a remainder equal to that value plus 8), and repopulate them with data. You can then repeat this -- perhaps at a later time -- for each modulus-8 partition until none remain. While this may still involve a large amount of data movement at each step, it is still better than having to create a whole new table and move all the data at once.

A partition must have the same column names and types as the partitioned table to which it belongs. Modifications to the column names or types of a partitioned table will automatically propagate to all partitions. `CHECK` constraints will be inherited automatically by every partition, but an individual partition may specify additional `CHECK` constraints; additional constraints with the same name and condition as in the parent will be merged with the parent constraint. Defaults may be specified separately for each partition. But note that a partition's default value is not applied when inserting a tuple through a partitioned table.

Rows inserted into a partitioned table will be automatically routed to the correct partition. If no suitable partition exists, an error will occur.



Operations such as TRUNCATE which normally affect a table and all of its inheritance children will cascade to all partitions, but may also be performed on an individual partition. Note that dropping a partition with DROP TABLE requires taking an ACCESS EXCLUSIVE lock on the parent table.

LIKE *source\_table* [ *like\_option* ... ]

The LIKE clause specifies a table from which the new table automatically copies all column names, their data types, and their not-null constraints.

Unlike INHERITS, the new table and original table are completely decoupled after creation is complete. Changes to the original table will not be applied to the new table, and it is not possible to include data of the new table in scans of the original table.

Also unlike INHERITS, columns and constraints copied by LIKE are not merged with similarly named columns and constraints. If the same name is specified explicitly or in another LIKE clause, an error is signaled.

The optional *like\_option* clauses specify which additional properties of the original table to copy. Specifying INCLUDING copies the property, specifying EXCLUDING omits the property. EXCLUDING is the default. If multiple specifications are made for the same kind of object, the last one is used. The available options are:

INCLUDING COMMENTS

Comments for the copied columns, constraints, and indexes will be copied. The default behavior is to exclude comments, resulting in the copied columns and constraints in the new table having no comments.

INCLUDING CONSTRAINTS

CHECK constraints will be copied. No distinction is made between column constraints and table constraints. Not-null constraints are always copied to the new table.

INCLUDING DEFAULTS

Default expressions for the copied column definitions will be copied. Otherwise, default expressions are not copied, resulting in the copied columns in the new table having null defaults. Note that copying defaults that call database-modification functions, such as nextval, may create a functional linkage between the original and new tables.

INCLUDING GENERATED

Any generation expressions of copied column definitions will be copied. By default, new columns will be regular base columns.

INCLUDING IDENTITY

Any identity specifications of copied column definitions will be copied. A new sequence is created for each identity column of the new table, separate from the sequences associated with the old table.

INCLUDING INDEXES

Indexes, PRIMARY KEY, UNIQUE, and EXCLUDE constraints on the original table will be created on the new table. Names for the new indexes and constraints are chosen according to the default rules, regardless of how the originals were named. (This behavior avoids possible duplicate-name failures for the new indexes.)

INCLUDING STATISTICS

Extended statistics are copied to the new table.

INCLUDING STORAGE

STORAGE settings for the copied column definitions will be copied. The default behavior is to exclude STORAGE settings, resulting in the copied columns in the new table having type-specific default settings. For more on STORAGE settings, see Section 64.2.

INCLUDING SEQUENCES

Work with INCLUDING DEFAULTS. When columns of the old table are created using one of the serial types (*serial*, *smallserial*, *bigserial*), a new sequence is created for each serial column of the new table, separate from the sequences associated with the old table.

INCLUDING ALL

INCLUDING ALL is an abbreviated form selecting all the available individual options. (It could be useful to write individual EXCLUDING clauses after INCLUDING ALL to select all but some specific options.)

The LIKE clause can also be used to copy column definitions from views, foreign tables, or composite types. Inapplicable options (e.g., INCLUDING INDEXES from a view) are ignored.

CONSTRAINT *constraint\_name*

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

NOT NULL

The column is not allowed to contain null values.

NULL

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

CHECK ( *expression* ) [ NO INHERIT ]

The CHECK clause specifies an expression producing a Boolean result which new or updated rows must satisfy for an insert or update operation to succeed. Expressions evaluating to TRUE or UNKNOWN succeed. Should any row of an insert or update operation produce a FALSE result, an error exception is raised and the insert or update does not alter the database. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, CHECK expressions cannot contain subqueries nor refer to variables other than columns of the current row (see Section 5.4.1). The system column `tableoid` may be referenced, but not any other system column.

A constraint marked with NO INHERIT will not propagate to child tables.

When a table has multiple CHECK constraints, they will be tested for each row in alphabetical order by name, after checking NOT NULL constraints. (LightDB versions before 9.5 did not honor any particular firing order for CHECK constraints.)

[NO DELETE] | [NO UPDATE] | [NO DROP] | [NO TRUNCATE ]

[NO DELETE] | [NO UPDATE] | [NO DROP] | [NO TRUNCATE ] this operation is only support in oracle mode and table is a immutable table.

NO DELETE if a IMMUTABLE table with NO DELETE, this table is not allowed for DELETE.

NO UPDATE if a IMMUTABLE table with NO UPDATE, this table is not allowed for UPDATE.

NO DROP if a IMMUTABLE table with NO DROP, this table is not allowed for DROP.

NO TRUNCATE if a IMMUTABLE table with NO TRUNCATE, this table is not allowed for TRUNCATE.

DEFAULT *default\_expr*

The DEFAULT clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (in particular, cross-references to other columns in the current table are not allowed). Subqueries are not allowed either. The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

ON UPDATE CURRENT\_TIMESTAMP

TIMESTAMP ON UPDATE CURRENT\_TIMESTAMP columns can be automatically initialized and updated to the current timestamp. For any TIMESTAMP column in a table, you can assign the current timestamp as the default value, the ON UPDATE CURRENT\_TIMESTAMP, or both. But not suggest use both default value and on update current\_timestamp, because on update current\_timestamp ready contains the default current\_timestamp semantics.

ON UPDATE CURRENT\_TIMESTAMP decorate only with TIMESTAMP type, other types are not allowed.

AUTO\_INCREMENT

The clause creates the column as an auto increment column. The column cannot be written to. It will have an implicit sequence attached to it and the column in new rows will automatically have value from the sequence assigned to it. Such a column is implicitly NOT NULL.

The clause is equal to GENERATED ALWAYS AS IDENTITY.

GENERATED ALWAYS AS ( *generation\_expr* ) STORED

This clause creates the column as a *generated column*. The column cannot be written to, and when read the result of the specified expression will be returned.

The keyword STORED is required to signify that the column will be computed on write and will be stored on disk.

The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [ ( *sequence\_options* ) ]

This clause creates the column as an *identity column*. It will have an implicit sequence attached to it and the column in new rows will automatically have values from the sequence assigned to it. Such a column is implicitly NOT NULL.

The clauses ALWAYS and BY DEFAULT determine how explicitly user-specified values are handled in INSERT and UPDATE commands.

In an INSERT command, if ALWAYS is selected, a user-specified value is only accepted if the INSERT statement specifies OVERRIDING SYSTEM VALUE. If BY DEFAULT is selected, then the user-specified value takes precedence. See INSERT for details. (In the COPY command, user-specified values are always used regardless of this setting.)

In an UPDATE command, if ALWAYS is selected, any update of the column to any value other than DEFAULT will be rejected. If BY DEFAULT is selected, the column can be updated normally. (There is no OVERRIDING clause for the UPDATE command.)

The optional *sequence\_options* clause can be used to override the options of the sequence. See CREATE SEQUENCE for details.

UNIQUE (column constraint)  
UNIQUE ( *column\_name* [, ... ] ) [ INCLUDE ( *column\_name* [, ...] ) ]  
(table constraint)

The UNIQUE constraint specifies that a group of one or more columns of a table can contain only unique values. The behavior of a unique table constraint is the same as that of a unique column constraint, with the additional capability to span multiple columns. The constraint therefore enforces that any two rows must differ in at least one of these columns.

For the purpose of a unique constraint, null values are not considered equal.

Each unique constraint should name a set of columns that is different from the set of columns named by any other unique or primary key constraint defined for the table. (Otherwise, redundant unique constraints will be discarded.)

When establishing a unique constraint for a multi-level partition hierarchy, all the columns in the partition key of the target partitioned table, as well as those of all its descendant partitioned tables, must be included in the constraint definition.

Adding a unique constraint will automatically create a unique btree index on the column or group of columns used in the constraint.

The optional INCLUDE clause adds to that index one or more columns that are simply “payload”: uniqueness is not enforced on them, and the index cannot be searched on the basis of those columns. However they can be retrieved by an index-only scan. Note that although the constraint is not enforced on included columns, it still depends on them. Consequently, some operations on such columns (e.g., DROP COLUMN) can cause cascaded constraint and index deletion.

PRIMARY KEY (column constraint)  
PRIMARY KEY ( *column\_name* [, ... ] ) [ INCLUDE ( *column\_name* [, ...] ) ]  
(table constraint)

The PRIMARY KEY constraint specifies that a column or columns of a table can contain only unique (non-duplicate), nonnull values. Only one primary key can be specified for a table, whether as a column constraint or a table constraint.

The primary key constraint should name a set of columns that is different from the set of columns named by any unique constraint defined for the same table. (Otherwise, the unique constraint is redundant and will be discarded.)

PRIMARY KEY enforces the same data constraints as a combination of UNIQUE and NOT NULL. However, identifying a set of columns as the primary key also provides metadata about the design of the schema, since a primary key implies that other tables can rely on this set of columns as a unique identifier for rows.

When placed on a partitioned table, PRIMARY KEY constraints share the restrictions previously described for UNIQUE constraints.

Adding a PRIMARY KEY constraint will automatically create a unique btree index on the column or group of columns used in the constraint.

The optional INCLUDE clause adds to that index one or more columns that are simply “payload”: uniqueness is not enforced on them, and the index cannot be searched on the basis of those columns. However they can be retrieved by an index-only scan. Note that although the constraint

is not enforced on included columns, it still depends on them. Consequently, some operations on such columns (e.g., `DROP COLUMN`) can cause cascaded constraint and index deletion.

```
EXCLUDE [ USING index_method ] ( exclude_element WITH operator
[ , ... ] ) index_parameters [ WHERE ( predicate ) ]
```

The `EXCLUDE` clause defines an exclusion constraint, which guarantees that if any two rows are compared on the specified column(s) or expression(s) using the specified operator(s), not all of these comparisons will return `TRUE`. If all of the specified operators test for equality, this is equivalent to a `UNIQUE` constraint, although an ordinary unique constraint will be faster. However, exclusion constraints can specify constraints that are more general than simple equality. For example, you can specify a constraint that no two rows in the table contain overlapping circles (see Section 8.8) by using the `&&` operator.

Exclusion constraints are implemented using an index, so each specified operator must be associated with an appropriate operator class (see Section 11.10) for the index access method *index\_method*. The operators are required to be commutative. Each *exclude\_element* can optionally specify an operator class and/or ordering options; these are described fully under `CREATE INDEX`.

The access method must support `amgettuple` (see Chapter 58); at present this means `GIN` cannot be used. Although it's allowed, there is little point in using `B-tree` or `hash` indexes with an exclusion constraint, because this does nothing that an ordinary unique constraint doesn't do better. So in practice the access method will always be `GiST`.

The *predicate* allows you to specify an exclusion constraint on a subset of the table; internally this creates a partial index. Note that parentheses are required around the predicate.

```
REFERENCES reftable [ ( refcolumn ) ] [ MATCH matchtype ] [ ON DELETE
referential_action ] [ ON UPDATE referential_action ] (column constraint)
FOREIGN KEY ( column_name [ , ... ] ) REFERENCES reftable [ ( refcolumn
[ , ... ] ) ] [ MATCH matchtype ] [ ON DELETE referential_action ]
[ ON UPDATE referential_action ] (table constraint)
```

These clauses specify a foreign key constraint, which requires that a group of one or more columns of the new table must only contain values that match values in the referenced column(s) of some row of the referenced table. If the *refcolumn* list is omitted, the primary key of the *reftable* is used. The referenced columns must be the columns of a non-deferrable unique or primary key constraint in the referenced table. The user must have `REFERENCES` permission on the referenced table (either the whole table, or the specific referenced columns). The addition of a foreign key constraint requires a `SHARE ROW EXCLUSIVE` lock on the referenced table. Note that foreign key constraints cannot be defined between temporary tables and permanent tables.

A value inserted into the referencing column(s) is matched against the values of the referenced table and referenced columns using the given match type. There are three match types: `MATCH FULL`, `MATCH PARTIAL`, and `MATCH SIMPLE` (which is the default). `MATCH FULL` will not allow one column of a multicolumn foreign key to be null unless all foreign key columns are null; if they are all null, the row is not required to have a match in the referenced table. `MATCH SIMPLE` allows any of the foreign key columns to be null; if any of them are null, the row is not required to have a match in the referenced table. `MATCH PARTIAL` is not yet implemented. (Of course, `NOT NULL` constraints can be applied to the referencing column(s) to prevent these cases from arising.)

In addition, when the data in the referenced columns is changed, certain actions are performed on the data in this table's columns. The `ON DELETE` clause specifies the action to perform when a referenced row in the referenced table is being deleted. Likewise, the `ON UPDATE` clause specifies the action to perform when a referenced column in the referenced table is being updated to a new value. If the row is updated, but the referenced column is not actually changed, no action is done. Referential actions other than the `NO ACTION` check cannot be deferred, even if the constraint is declared deferrable. There are the following possible actions for each clause:

NO ACTION

Produce an error indicating that the deletion or update would create a foreign key constraint violation. If the constraint is deferred, this error will be produced at constraint check time if there still exist any referencing rows. This is the default action.

RESTRICT

Produce an error indicating that the deletion or update would create a foreign key constraint violation. This is the same as NO ACTION except that the check is not deferrable.

CASCADE

Delete any rows referencing the deleted row, or update the values of the referencing column(s) to the new values of the referenced columns, respectively.

SET NULL

Set the referencing column(s) to null.

SET DEFAULT

Set the referencing column(s) to their default values. (There must be a row in the referenced table matching the default values, if they are not null, or the operation will fail.)

If the referenced column(s) are changed frequently, it might be wise to add an index to the referencing column(s) so that referential actions associated with the foreign key constraint can be performed more efficiently.

DEFERRABLE

NOT DEFERRABLE

This controls whether the constraint can be deferred. A constraint that is not deferrable will be checked immediately after every command. Checking of constraints that are deferrable can be postponed until the end of the transaction (using the SET CONSTRAINTS command). NOT DEFERRABLE is the default. Currently, only UNIQUE, PRIMARY KEY, EXCLUDE, and REFERENCES (foreign key) constraints accept this clause. NOT NULL and CHECK constraints are not deferrable. Note that deferrable constraints cannot be used as conflict arbitrators in an INSERT statement that includes an ON CONFLICT DO UPDATE clause.

INITIALLY IMMEDIATE

INITIALLY DEFERRED

If a constraint is deferrable, this clause specifies the default time to check the constraint. If the constraint is INITIALLY IMMEDIATE, it is checked after each statement. This is the default. If the constraint is INITIALLY DEFERRED, it is checked only at the end of the transaction. The constraint check time can be altered with the SET CONSTRAINTS command.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new table; the method needs be an access method of type TABLE. See Chapter 57 for more information. If this option is not specified, the default table access method is chosen for the new table. See default\_table\_access\_method for more information.

WITH UPDATE CURRENT\_TIMESTAMP

This clause specifies an optional implicit "ltaut" column for a table. The "ltaut" column can be automatically initialized and updated to the current timestamp, similar to TIMESTAMP ON UPDATE CURRENT\_TIMESTAMP columns. It can be automatically initialized and updated to the current timestamp. If you use WITH UPDATE CURRENT\_TIMESTAMP, ON UPDATE CURRENT\_TIMESTAMP is not allowed, and vice versa.

Notice that `WITH UPDATE CURRENT_TIMESTAMP` is not supported for creating distributed tables.

`WITH PRIMARY KEY [ smallserial | serial | bigserial ]`

This clause specifies optional implicate "Itapk" column for a table. "Itapk" column can be automatically incremented and be specified the primary key constrain. If tables already have a primary key, `WITH PRIMARY KEY` is not allowed.

When creating a table via `CREATE TABLE`, `CREATE TABLE AS` or `SELECT INTO`, "Itapk" is not allowed to be an explicit column name of the new table. (unless `INDEXES` and `DEFAULTS` are included in *like\_option* when used in `CREATE TABLE`)

Notice `WITH PRIMARY KEY` is not support create distributed table.

`DISTRIBUTED REPLICATED`

The clause create reference table, make sure canopy extension is ready.

Notice read only table and temporary table is not support. If you create distributed table impose primary key constraint only if the distribution column is a part of the primary key, and only hash distribute type is support.

`DISTRIBUTED BY [HASH | APPEND](column) [ distribute_option ... ]`

The clause create a distributed table, make sure canopy extension is ready. The distribution column is "column", and distributed type is "hash" or "append", default is "hash".

The `distribute_option` can specify `shard_count` option or `colocate_with` option. `shard_count` is optional, to choose a shard consulted for a table you wish to distribute. `colocate_with` is optional, is a table that the current distributed table will be colocated with. Possible values are "default", "none" to start a new colocation group, or the name of another table with which to colocate.

Notice read only table and temporary table is not support. If you create distributed table impose primary key constraint only if the distribution column is a part of the primary key, and only hash distribute type is support.

`WITH ( storage_parameter [= value] [, ... ] )`

This clause specifies optional storage parameters for a table or index; see Storage Parameters below for more information. For backward-compatibility the `WITH` clause for a table can also include `OIDS=FALSE` to specify that rows of the new table should not contain OIDs (object identifiers), `OIDS=TRUE` is not supported anymore.

`WITHOUT OIDS`

This is backward-compatible syntax for declaring a table `WITHOUT OIDS`, creating a table `WITH OIDS` is not supported anymore.

`ON COMMIT`

The behavior of temporary tables at the end of a transaction block can be controlled using `ON COMMIT`. The three options are:

`PRESERVE ROWS`

No special action is taken at the ends of transactions. This is the default behavior.

`DELETE ROWS`

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic `TRUNCATE` is done at each commit. When used on a partitioned table, this is not cascaded to its partitions.

DROP

The temporary table will be dropped at the end of the current transaction block. When used on a partitioned table, this action drops its partitions and when used on tables with inheritance children, it drops the dependent children.

COMPRESS  
LOGGING

Starting from LightDB 23.2, four new non-reserved keywords COMPRESS, LOGGING, NOCOMPRESS, NOLOGGING, are added to be compatible with the syntax of Oracle Database. The four new keywords are just grammatical sugar, and do not achieve specific functions. These four keywords must be used before the TABLESPACE keyword.

STORAGE

Starting from LightDB 23.2, the CREATE TABLE statement supports the STORAGE keyword for syntactic compatibility with ORACLE database. The content inside the parentheses of the STORAGE keyword is ignored. The STORAGE keyword must be used between the COMPRESS LOGGING keyword and the TABLESPACE keyword.

ENGINE

The keyword ENGINE is simply used for compatibility with MYSQL databases in terms of syntax. The two options are:

INNODB

Case insensitive

MYISAM

Case insensitive

DEFAULT CHARSET = ...

The keywords DEFAULT CHARSET are simply used for compatibility with MYSQL database in terms of syntax. NOTE: DEFAULT CHARACTER SET is not yet supported by lightdb.

COLLATE = ...

The keyword COLLATE is simply used for compatibility with MYSQL database in terms of syntax.

TABLESPACE *tablespace\_name*

The *tablespace\_name* is the name of the tablespace in which the new table is to be created. If not specified, default\_tablespace is consulted, or temp\_tablespaces if the table is temporary. For partitioned tables, since no storage is required for the table itself, the tablespace specified overrides default\_tablespace as the default tablespace to use for any newly created partitions when no other tablespace is explicitly specified.

USING INDEX TABLESPACE *tablespace\_name*

This clause allows selection of the tablespace in which the index associated with a UNIQUE, PRIMARY KEY, or EXCLUDE constraint will be created. If not specified, default\_tablespace is consulted, or temp\_tablespaces if the table is temporary.

PARTITIONS *partitions\_value*

Oracle partition compatible syntax for creating hash partitions. It is necessary to change the configuration to Oracle compatible mode.



SUBPARTITIONS *subpartitions\_value*

Oracle partition compatible syntax for creating hash sub partitions. Currently, only range is supported as the primary partition, list as the sub partition and hash as the sub partition. It is necessary to change the configuration to Oracle compatible mode.

INTERVAL *interval\_value*

Oracle partition compatible syntax for creating range partitions. Two time conversion functions are supported: NUMTOYMINTERVAL() and NUMTODSINTERVAL(). Currently, only time interval partitions are supported. It is necessary to change the configuration to Oracle compatible mode.

NESTED TABLE *column\_name* STORE AS *nested\_table\_name*

Oracle partition compatible syntax for creating a table with nested table types. Currently, it is only grammar compatible, and functional support may be provided in the future.

enable  
disable

In order to be compatible with the syntax of Oracle databases, the column constraint supports the enable/disable keyword when creating a table. This feature is just grammatical sugar.

## Storage Parameters

The WITH clause can specify *storage parameters* for tables, and for indexes associated with a UNIQUE, PRIMARY KEY, or EXCLUDE constraint. Storage parameters for indexes are documented in CREATE INDEX. The storage parameters currently available for tables are listed below. For many of these parameters, as shown, there is an additional parameter with the same name prefixed with *toast .*, which controls the behavior of the table's secondary TOAST table, if any (see Section 64.2 for more information about TOAST). If a table parameter value is set and the equivalent *toast .* parameter is not, the TOAST table will use the table's parameter value. Specifying these parameters for partitioned tables is not supported, but you may specify them for individual leaf partitions.

*fillfactor* (*integer*)

The *fillfactor* for a table is a percentage between 10 and 100. 100 (complete packing) is the default. When a smaller *fillfactor* is specified, INSERT operations pack table pages only to the indicated percentage; the remaining space on each page is reserved for updating rows on that page. This gives UPDATE a chance to place the updated copy of a row on the same page as the original, which is more efficient than placing it on a different page. For a table whose entries are never updated, complete packing is the best choice, but in heavily updated tables smaller *fillfactors* are appropriate. This parameter cannot be set for TOAST tables.

*toast\_tuple\_target* (*integer*)

The *toast\_tuple\_target* specifies the minimum tuple length required before we try to compress and/or move long column values into TOAST tables, and is also the target length we try to reduce the length below once toasting begins. This affects columns marked as External (for move), Main (for compression), or Extended (for both) and applies only to new tuples. There is no effect on existing rows. By default this parameter is set to allow at least 4 tuples per block, which with the default block size will be 2040 bytes. Valid values are between 128 bytes and the (block size - header), by default 8160 bytes. Changing this value may not be useful for very short or very long rows. Note that the default setting is often close to optimal, and it is possible that setting this parameter could have negative effects in some cases. This parameter cannot be set for TOAST tables.

*parallel\_workers* (*integer*)

This sets the number of workers that should be used to assist a parallel scan of this table. If not set, the system will determine a value based on the relation size. The actual number of workers

chosen by the planner or by utility statements that use parallel scans may be less, for example due to the setting of `max_worker_processes`.

`autovacuum_enabled`, `toast.autovacuum_enabled` (boolean)

Enables or disables the autovacuum daemon for a particular table. If true, the autovacuum daemon will perform automatic `VACUUM` and/or `ANALYZE` operations on this table following the rules discussed in Section 22.1.6. If false, this table will not be autovacuumed, except to prevent transaction ID wraparound. See Section 22.1.5 for more about wraparound prevention. Note that the autovacuum daemon does not run at all (except to prevent transaction ID wraparound) if the autovacuum parameter is false; setting individual tables' storage parameters does not override that. Therefore there is seldom much point in explicitly setting this storage parameter to true, only to false.

`vacuum_index_cleanup`, `toast.vacuum_index_cleanup` (boolean)

Enables or disables index cleanup when `VACUUM` is run on this table. The default value is true. Disabling index cleanup can speed up `VACUUM` very significantly, but may also lead to severely bloated indexes if table modifications are frequent. The `INDEX_CLEANUP` parameter of `VACUUM`, if specified, overrides the value of this option.

`vacuum_truncate`, `toast.vacuum_truncate` (boolean)

Enables or disables vacuum to try to truncate off any empty pages at the end of this table. The default value is true. If true, `VACUUM` and autovacuum do the truncation and the disk space for the truncated pages is returned to the operating system. Note that the truncation requires `ACCESS EXCLUSIVE` lock on the table. The `TRUNCATE` parameter of `VACUUM`, if specified, overrides the value of this option.

`autovacuum_vacuum_threshold`, `toast.autovacuum_vacuum_threshold` (integer)

Per-table value for `autovacuum_vacuum_threshold` parameter.

`autovacuum_vacuum_scale_factor`, `toast.autovacuum_vacuum_scale_factor` (floating point)

Per-table value for `autovacuum_vacuum_scale_factor` parameter.

`autovacuum_vacuum_insert_threshold`,  
`toast.autovacuum_vacuum_insert_threshold` (integer)

Per-table value for `autovacuum_vacuum_insert_threshold` parameter. The special value of -1 may be used to disable insert vacuums on the table.

`autovacuum_vacuum_insert_scale_factor`,  
`toast.autovacuum_vacuum_insert_scale_factor` (floating point)

Per-table value for `autovacuum_vacuum_insert_scale_factor` parameter.

`autovacuum_analyze_threshold` (integer)

Per-table value for `autovacuum_analyze_threshold` parameter.

`autovacuum_analyze_scale_factor` (floating point)

Per-table value for `autovacuum_analyze_scale_factor` parameter.

`autovacuum_vacuum_cost_delay`, `toast.autovacuum_vacuum_cost_delay` (floating point)

Per-table value for `autovacuum_vacuum_cost_delay` parameter.

---

```
autovacuum_vacuum_cost_limit,      toast.autovacuum_vacuum_cost_limit
(integer)
```

Per-table value for `autovacuum_vacuum_cost_limit` parameter.

```
autovacuum_freeze_min_age, toast.autovacuum_freeze_min_age (integer)
```

Per-table value for `vacuum_freeze_min_age` parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_min_age` parameters that are larger than half the system-wide `autovacuum_freeze_max_age` setting.

```
autovacuum_freeze_max_age, toast.autovacuum_freeze_max_age (integer)
```

Per-table value for `autovacuum_freeze_max_age` parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

```
autovacuum_freeze_table_age,      toast.autovacuum_freeze_table_age
(integer)
```

Per-table value for `vacuum_freeze_table_age` parameter.

```
autovacuum_multixact_freeze_min_age,
toast.autovacuum_multixact_freeze_min_age (integer)
```

Per-table value for `vacuum_multixact_freeze_min_age` parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_min_age` parameters that are larger than half the system-wide `autovacuum_multixact_freeze_max_age` setting.

```
autovacuum_multixact_freeze_max_age,
toast.autovacuum_multixact_freeze_max_age (integer)
```

Per-table value for `autovacuum_multixact_freeze_max_age` parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

```
autovacuum_multixact_freeze_table_age,
toast.autovacuum_multixact_freeze_table_age (integer)
```

Per-table value for `vacuum_multixact_freeze_table_age` parameter.

```
log_autovacuum_min_duration,      toast.log_autovacuum_min_duration
(integer)
```

Per-table value for `log_autovacuum_min_duration` parameter.

```
user_catalog_table (boolean)
```

Declare the table as an additional catalog table for purposes of logical replication. See Section 45.6.2 for details. This parameter cannot be set for TOAST tables.

## Notes

LightDB automatically creates an index for each unique constraint and primary key constraint to enforce uniqueness. Thus, it is not necessary to create an index explicitly for primary key columns. (See `CREATE INDEX` for more information.)

Unique constraints and primary keys are not inherited in the current implementation. This makes the combination of inheritance and unique constraints rather dysfunctional.

A table cannot have more than 1600 columns. (In practice, the effective limit is usually lower because of tuple-length constraints.)

## Examples

Create table `films` and table `distributors`:

```
CREATE TABLE films (  
    code          char(5) CONSTRAINT firstkey PRIMARY KEY,  
    title         varchar(40) NOT NULL,  
    did           integer NOT NULL,  
    date_prod     date,  
    kind          varchar(10),  
    len           interval hour to minute  
);  
  
CREATE TABLE distributors (  
    did           integer PRIMARY KEY GENERATED BY DEFAULT AS IDENTITY,  
    name          varchar(40) NOT NULL CHECK (name <> '')  
);
```

Create a table with a 2-dimensional array:

```
CREATE TABLE array_int (  
    vector        int[][]  
);
```

Define a unique table constraint for the table `films`. Unique table constraints can be defined on one or more columns of the table:

```
CREATE TABLE films (  
    code          char(5),  
    title         varchar(40),  
    did           integer,  
    date_prod     date,  
    kind          varchar(10),  
    len           interval hour to minute,  
    CONSTRAINT production UNIQUE(date_prod)  
);
```

Define a check column constraint:

```
CREATE TABLE distributors (  
    did           integer CHECK (did > 100),  
    name          varchar(40)  
);
```

Define comments for some columns and table:

```
CREATE TABLE films (  
    code          char(5) COMMENT 'code of films',  
    title         varchar(40),  
    did           integer CHECK (did > 100) COMMENT 'comment for  
did',
```

---

## CREATE TABLE

---

```
    date_prod    date,
    kind         varchar(10),
    len         interval hour to minute COMMENT 'length of the
films',
    CONSTRAINT production UNIQUE(date_prod)
) COMMENT = 'films table';
```

Define a check table constraint:

```
CREATE TABLE distributors (
    did         integer,
    name       varchar(40),
    CONSTRAINT con1 CHECK (did > 100 AND name <> '')
);
```

Define a primary key table constraint for the table films:

```
CREATE TABLE films (
    code        char(5),
    title       varchar(40),
    did         integer,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute,
    CONSTRAINT code_title PRIMARY KEY(code,title)
);
```

Define a primary key constraint for table distributors. The following two examples are equivalent, the first using the table constraint syntax, the second the column constraint syntax:

```
CREATE TABLE distributors (
    did         integer,
    name       varchar(40),
    PRIMARY KEY(did)
);
```

```
CREATE TABLE distributors (
    did         integer PRIMARY KEY,
    name       varchar(40)
);
```

Assign a literal constant default value for the column name, arrange for the default value of column did to be generated by selecting the next value of a sequence object, and make the default value of modtime be the time at which the row is inserted:

```
CREATE TABLE distributors (
    name       varchar(40) DEFAULT 'Luso Films',
    did        integer DEFAULT nextval('distributors_serial'),
    modtime    timestamp DEFAULT current_timestamp
);
```

Define two NOT NULL column constraints on the table distributors, one of which is explicitly given a name:

```
CREATE TABLE distributors (
```

---

---

## CREATE TABLE

---

```
    did      integer CONSTRAINT no_null NOT NULL,  
    name     varchar(40) NOT NULL  
);
```

Define ON UPDATE CURRENT\_TIMESTAMP column on the table distributors, one of which is explicitly given a name:

```
CREATE TABLE distributors (  
    did      int,  
    modtime timestamp ON UPDATE CURRENT_TIMESTAMP  
);
```

Create table distributors WITH UPDATE CURRENT\_TIMESTAMP.

```
CREATE TABLE distributors (  
    did      int,  
) WITH UPDATE CURRENT_TIMESTAMP;
```

Define AUTO\_INCREMENT column constraints on the table distributors, one of which is explicitly given a name:

```
CREATE TABLE distributors (  
    did      int AUTO_INCREMENT,  
    name     varchar(40) NOT NULL  
);
```

Define a unique constraint for the name column:

```
CREATE TABLE distributors (  
    did      integer,  
    name     varchar(40) UNIQUE  
);
```

The same, specified as a table constraint:

```
CREATE TABLE distributors (  
    did      integer,  
    name     varchar(40),  
    UNIQUE(name)  
);
```

Create the same table, specifying 70% fill factor for both the table and its unique index:

```
CREATE TABLE distributors (  
    did      integer,  
    name     varchar(40),  
    UNIQUE(name) WITH (fillfactor=70)  
)  
WITH (fillfactor=70);
```

Create table circles with an exclusion constraint that prevents any two circles from overlapping:

```
CREATE TABLE circles (  
    c circle,
```

---

## CREATE TABLE

---

```
        EXCLUDE USING gist (c WITH &&)
    );
```

Create table cinemas in tablespace diskvoll:

```
CREATE TABLE cinemas (
    id serial,
    name text,
    location text
) TABLESPACE diskvoll;
```

Create a composite type and a typed table:

```
CREATE TYPE employee_type AS (name text, salary numeric);

CREATE TABLE employees OF employee_type (
    PRIMARY KEY (name),
    salary WITH OPTIONS DEFAULT 1000
);
```

Create a range partitioned table:

```
CREATE TABLE measurement (
    logdate          date not null,
    peaktemp         int,
    unitsales        int
) PARTITION BY RANGE (logdate);
```

Create a range partitioned table with multiple columns in the partition key:

```
CREATE TABLE measurement_year_month (
    logdate          date not null,
    peaktemp         int,
    unitsales        int
) PARTITION BY RANGE (EXTRACT(YEAR FROM logdate), EXTRACT(MONTH
FROM logdate));
```

Create a list partitioned table:

```
CREATE TABLE cities (
    city_id          bigserial not null,
    name             text not null,
    population       bigint
) PARTITION BY LIST (left(lower(name), 1));
```

Create a hash partitioned table:

```
CREATE TABLE orders (
    order_id         bigint not null,
    cust_id          bigint not null,
    status           text
) PARTITION BY HASH (order_id);
```

Create partition of a range partitioned table:

---

## CREATE TABLE

---

```
CREATE TABLE measurement_y2016m07
  PARTITION OF measurement (
    unitsales DEFAULT 0
  ) FOR VALUES FROM ('2016-07-01') TO ('2016-08-01');
```

Create a few partitions of a range partitioned table with multiple columns in the partition key:

```
CREATE TABLE measurement_ym_older
  PARTITION OF measurement_year_month
  FOR VALUES FROM (MINVALUE, MINVALUE) TO (2016, 11);
```

```
CREATE TABLE measurement_ym_y2016m11
  PARTITION OF measurement_year_month
  FOR VALUES FROM (2016, 11) TO (2016, 12);
```

```
CREATE TABLE measurement_ym_y2016m12
  PARTITION OF measurement_year_month
  FOR VALUES FROM (2016, 12) TO (2017, 01);
```

```
CREATE TABLE measurement_ym_y2017m01
  PARTITION OF measurement_year_month
  FOR VALUES FROM (2017, 01) TO (2017, 02);
```

Create partition of a list partitioned table:

```
CREATE TABLE cities_ab
  PARTITION OF cities (
    CONSTRAINT city_id_nonzero CHECK (city_id != 0)
  ) FOR VALUES IN ('a', 'b');
```

Create partition of a list partitioned table that is itself further partitioned and then add a partition to it:

```
CREATE TABLE cities_ab
  PARTITION OF cities (
    CONSTRAINT city_id_nonzero CHECK (city_id != 0)
  ) FOR VALUES IN ('a', 'b') PARTITION BY RANGE (population);
```

```
CREATE TABLE cities_ab_10000_to_100000
  PARTITION OF cities_ab FOR VALUES FROM (10000) TO (100000);
```

Create partitions of a hash partitioned table:

```
CREATE TABLE orders_p1 PARTITION OF orders
  FOR VALUES WITH (MODULUS 4, REMAINDER 0);
CREATE TABLE orders_p2 PARTITION OF orders
  FOR VALUES WITH (MODULUS 4, REMAINDER 1);
CREATE TABLE orders_p3 PARTITION OF orders
  FOR VALUES WITH (MODULUS 4, REMAINDER 2);
CREATE TABLE orders_p4 PARTITION OF orders
  FOR VALUES WITH (MODULUS 4, REMAINDER 3);
```

Create a default partition:

```
CREATE TABLE cities_partdef
```



PARTITION OF cities DEFAULT;

Create range partitioned tables:

```
CREATE TABLE sales (  
    id int,  
    date date  
) PARTITION BY RANGE (date)  
(  
    START (date '2020-01-01') INCLUSIVE  
    END (date '2021-01-01') EXCLUSIVE  
    EVERY (INTERVAL '1 day')  
);
```

Create range partitioned tables(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
CREATE TABLE oracle_partition_range  
(  
    a int,  
    b float,  
    c date,  
    d timestamp  
)PARTITION BY RANGE (c)  
(  
    PARTITION p1 VALUES LESS THAN(to_date('2022-01-01', 'yyyy-mm-dd')),  
    PARTITION p2 VALUES LESS THAN(to_date('2022-02-01', 'yyyy-mm-dd')),  
    PARTITION p3 VALUES LESS THAN(to_date('2022-03-01', 'yyyy-mm-dd'))  
);
```

Create list partitioned tables:

```
CREATE TABLE rank (  
    id int,  
    gender char(1)  
) PARTITION BY LIST (gender)  
(  
    PARTITION girls VALUES ('F'),  
    PARTITION boys VALUES ('M'),  
    DEFAULT PARTITION other  
);
```

Create a list partitioned table with a list default partition(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
CREATE TABLE l(a int) partition by list(a) (  
    partition l_1 values(1),  
    partition l_def values(default)  
);
```

Create hash partitioned tables:

```
CREATE TABLE thash (  

```

---

## CREATE TABLE

---

```
    a int,
    b int,
    c text
) PARTITION BY HASH(a,b)
(
    PARTITION p1 VALUES WITH (MODULUS 3, REMAINDER 0),
    PARTITION p2 VALUES WITH (MODULUS 3, REMAINDER 1),
    PARTITION p3 VALUES WITH (MODULUS 3, REMAINDER 2)
);
```

Create hash partitioned tables(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
CREATE TABLE oracle_hash1
(
    a int,
    b float,
    c VARCHAR(20),
    d DATE,
    e timestamp
) PARTITION BY HASH (a)
(
    PARTITION p1,
    PARTITION p2,
    PARTITION p3
);
```

```
CREATE TABLE oracle_hash2
(
    a int,
    b float,
    c VARCHAR(20),
    d DATE,
    e timestamp
) PARTITION BY HASH (a) PARTITIONS 3;
```

Create range interval partitioned tables(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
CREATE TABLE lt_oracle_intervall1
(
    a int,
    b float,
    c date,
    d timestamp,
    e varchar(20)
)PARTITION BY RANGE (c) INTERVAL (numtoyminterval(3, 'month'))
(
    PARTITION p1 VALUES LESS THAN(to_date('2022-01-01', 'yyyy-mm-dd'))
);
CREATE TABLE lt_oracle_interval2
(
    a int,
    b float,
    c date,
    d timestamp,
    e varchar(20)
)PARTITION BY RANGE (c) INTERVAL (numtodsinterval(3, 'day'))
```

---

## CREATE TABLE

---

```
(
  PARTITION p1 VALUES LESS THAN(to_date('2022-01-01', 'yyyy-mm-dd'))
);
```

Create sub-partition:

```
CREATE TABLE sub_partition_list (a text) PARTITION BY LIST(a)
(PARTITION p1 VALUES ('1','2','3'));
CREATE TABLE sub_partition_range (a int) PARTITION BY RANGE(a)
(PARTITION p1 FROM (0) TO (10));
CREATE TABLE sub_partition_range2 (a int) PARTITION BY RANGE(a)
(PARTITION p1 START (0) END (10));
CREATE TABLE sub_partition_hash (a int) PARTITION BY HASH(a)
(
  PARTITION p1 VALUES WITH (MODULUS 3, REMAINDER 0),
  PARTITION p2 VALUES WITH (MODULUS 3, REMAINDER 1),
  PARTITION p3 VALUES WITH (MODULUS 3, REMAINDER 2)
);
CREATE TABLE sub_partition_sp (
  a int, b int, c text
) PARTITION BY RANGE(a)
SUBPARTITION BY LIST (c)
SUBPARTITION TEMPLATE (
  VALUES ('0000', '0001', '0002'),
  VALUES ('0003')
)
(
  PARTITION p1 FROM (0) TO (12),
  PARTITION p2 FROM (12) TO (20)
);
```

Create sub-partition(Oracle compatible syntax):

```
CREATE TABLE lt_oracle_partition_rh
(
  transaction_id number,
  item_id number(8) not null,
  item_description VARCHAR(300),
  transaction_date DATE
)
PARTITION BY RANGE(transaction_date)
SUBPARTITION BY HASH(transaction_id)
SUBPARTITIONS 10
(
  PARTITION P1 VALUES LESS THAN(to_date('2020-01-01', 'yyyy-mm-dd')),
  PARTITION P2 VALUES LESS THAN(to_date('2021-01-01', 'yyyy-mm-dd')),
  PARTITION P3 VALUES LESS THAN(to_date('2022-01-01', 'yyyy-mm-dd'))
);
```

Create a composite range-list partitioned table with a list default partition(Oracle compatible syntax):  
It is necessary to change the configuration to Oracle compatible mode.

```
CREATE TABLE RL(a int, b int) PARTITION BY RANGE(a)
SUBPARTITION BY LIST(b)
SUBPARTITION TEMPLATE
(
```

---

## CREATE TABLE

---

```
    SUBPARTITION 10 VALUES(0,1,2,3,4,5,6,7,8,9),
    SUBPARTITION 11 VALUES(10,11,12,13,14,15,16,17,18,19),
    SUBPARTITION 1_default VALUES(DEFAULT) tablespace pg_default
  )
(
  PARTITION r_lt10 VALUES less than(10)
);
```

Create a composite list-hash partitioned table without set a subpartitions count(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
create table LH(a int, b int)
partition by list(a)
subpartition by hash(b)
(
  partition l_1 values(1),
  partition l_2 values(2)
);
```

Create a composite list-hash partitioned table with subpartitions count(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
create table LH(a int, b int)
partition by list(a)
subpartition by hash(b) subpartitions 4
(
  partition l_1 values(1),
  partition l_2 values(2)
);
```

Create a composite list-hash partitioned table with subpartition template(Oracle compatible syntax): It is necessary to change the configuration to Oracle compatible mode.

```
create table LH(a int, b int)
partition by list(a)
subpartition by hash(b)
subpartition template
(
  subpartition h_0,
  subpartition h_1
)
(
  partition l_1 values(1),
  partition l_2 values(2)
);
```

Create reference tables:

```
CREATE TABLE dist_reference_table(a int, b text) DISTRIBUTED
REPLICATED;
```

Create distributed hash tables:

```
CREATE TABLE dist_table(a int, b text) DISTRIBUTED BY(a);
```

## CREATE TABLE

---

```
CREATE TABLE dist_hash_table(a int, b text) DISTRIBUTED BY HASH(a);
```

Create distributed append tables:

```
CREATE TABLE dist_append_table(a int, b text) DISTRIBUTED BY  
APPEND(a);
```

Create distributed tables, specify 4 shard count:

```
CREATE TABLE dist_shard_table(a int, b text) DISTRIBUTED BY(a)  
shard_count(4);
```

Create distributed tables, specify colocate with dist\_table.

```
CREATE TABLE dist_colocate_table(a int, b text) DISTRIBUTED BY (a)  
colocate_with('dist_table');
```

Create a session-level global temporary table.

```
CREATE GLOBAL TEMPORARY TABLE gtt_session(id number,ename  
varchar(15)) ON COMMIT PRESERVE ROWS;
```

Create a transaction-level global temporary table.

```
CREATE GLOBAL TEMPORARY TABLE gtt_transaction(id number,ename  
varchar(15)) ON COMMIT DELETE ROWS;
```

Create a table with COMPRESS/NOCOMPRESS/LOGGING/NOLOGGING options.

```
CREATE TABLE comp_log1(id int) COMPRESS;  
CREATE TABLE comp_log2(id int) NOCOMPRESS;  
CREATE TABLE comp_log3(id int) LOGGING;  
CREATE TABLE comp_log4(id int) NOLOGGING;  
CREATE TABLE comp_log5(id int) COMPRESS LOGGING;  
CREATE TABLE comp_log6(id int) COMPRESS NOLOGGING;  
CREATE TABLE comp_log7(id int) NOCOMPRESS LOGGING;  
CREATE TABLE comp_log8(id int) NOCOMPRESS NOLOGGING;  
CREATE TABLE comp_log9(id int) LOGGING COMPRESS;  
CREATE TABLE comp_log10(id int) LOGGING NOCOMPRESS;  
CREATE TABLE comp_log11(id int) NOLOGGING COMPRESS;  
CREATE TABLE comp_log12(id int) NOLOGGING NOCOMPRESS;
```

Create a table with STORAGE option.

```
create table comp_log1(id int) storage(INITIAL 65536 NEXT 1048576  
MINEXTENTS 1 MAXEXTENTS 2147483645 PCTINCREASE 0 FREELISTS 1
```

```
FREELIST GROUPS 1 BUFFER_POOL DEFAULT FLASH_CACHE DEFAULT
CELL_FLASH_CACHE DEFAULT);
create table comp_log2(id int) storage(464 131 fw f31 fe31);
create table comp_log3(id int) storage(dfa fdsa fdasf fdsa fdsa
fads dfsa 1234 454);
create table comp_log4(id int) storage(abcd);
create table comp_log5(id int) storage(654123);
```

Create a table with nested table types.

```
create type nt_type is table of int;
create table nt_table (col nt_type);
```

## Compatibility

The `CREATE TABLE` command conforms to the SQL standard, with exceptions listed below.

### Temporary Tables

Although the syntax of `CREATE TEMPORARY TABLE` resembles that of the SQL standard, the effect is not the same. In the standard, temporary tables are defined just once and automatically exist (starting with empty contents) in every session that needs them. LightDB instead requires each session to issue its own `CREATE TEMPORARY TABLE` command for each temporary table to be used. This allows different sessions to use the same temporary table name for different purposes, whereas the standard's approach constrains all instances of a given temporary table name to have the same table structure.

The standard's definition of the behavior of temporary tables is widely ignored. LightDB's behavior on this point is similar to that of several other SQL databases.

The SQL standard also distinguishes between global and local temporary tables, where a local temporary table has a separate set of contents for each SQL module within each session, though its definition is still shared across sessions. Since LightDB does not support SQL modules, this distinction is not relevant in LightDB.

For compatibility's sake, LightDB will accept the `LOCAL` keyword in a temporary table declaration, but it currently has no effect. Use of the keyword is discouraged, since future versions of LightDB might adopt a more standard-compliant interpretation of their meaning.

LightDB currently supports the `global` temporary table feature. Support session-level temporary tables and transaction-level temporary tables. Partitioning is temporarily not supported for global temporary tables. Global temporary tables support distributed.

The `ON COMMIT` clause for temporary tables also resembles the SQL standard, but has some differences. If the `ON COMMIT` clause is omitted, SQL specifies that the default behavior is `ON COMMIT DELETE ROWS`. However, the default behavior in LightDB is `ON COMMIT PRESERVE ROWS`. The `ON COMMIT DROP` option does not exist in SQL.

### Local Tables

The syntax of `CREATE LOCAL TABLE` resembles that of the SQL standard, the effect is the same as `CREATE TABLE`, when `lightdb_arch_mode` is `dist`, create a normal local table instead of distributed table.

The `lightdb_arch_mode` has two values. `dist` means current is a distributed architecture mode. `classic` means current database system is not a distributed architecture mode. This configuration is in develop, not suggest user to use. When in `dist` mode, while change the create table syntax. When

in dist mode, if create table has primary key, will create a distributed table distributed by primary key column, this is also in develop, not suggest user to use.

## Non-Deferred Uniqueness Constraints

When a `UNIQUE` or `PRIMARY KEY` constraint is not deferrable, LightDB checks for uniqueness immediately whenever a row is inserted or modified. The SQL standard says that uniqueness should be enforced only at the end of the statement; this makes a difference when, for example, a single command updates multiple key values. To obtain standard-compliant behavior, declare the constraint as `DEFERRABLE` but not deferred (i.e., `INITIALLY IMMEDIATE`). Be aware that this can be significantly slower than immediate uniqueness checking.

## Column Check Constraints

The SQL standard says that `CHECK` column constraints can only refer to the column they apply to; only `CHECK` table constraints can refer to multiple columns. LightDB does not enforce this restriction; it treats column and table check constraints alike.

## EXCLUDE Constraint

The `EXCLUDE` constraint type is a LightDB extension.

## NULL “Constraint”

The NULL “constraint” (actually a non-constraint) is a LightDB extension to the SQL standard that is included for compatibility with some other database systems (and for symmetry with the `NOT NULL` constraint). Since it is the default for any column, its presence is simply noise.

## Constraint Naming

The SQL standard says that table and domain constraints must have names that are unique across the schema containing the table or domain. LightDB is laxer: it only requires constraint names to be unique across the constraints attached to a particular table or domain. However, this extra freedom does not exist for index-based constraints (`UNIQUE`, `PRIMARY KEY`, and `EXCLUDE` constraints), because the associated index is named the same as the constraint, and index names must be unique across all relations within the same schema.

Currently, LightDB does not record names for `NOT NULL` constraints at all, so they are not subject to the uniqueness restriction. This might change in a future release.

## Inheritance

Multiple inheritance via the `INHERITS` clause is a LightDB language extension. SQL:1999 and later define single inheritance using a different syntax and different semantics. SQL:1999-style inheritance is not yet supported by LightDB.

## Zero-Column Tables

LightDB allows a table of no columns to be created (for example, `CREATE TABLE foo( ) ;`). This is an extension from the SQL standard, which does not allow zero-column tables. Zero-column tables are not in themselves very useful, but disallowing them creates odd special cases for `ALTER TABLE DROP COLUMN`, so it seems cleaner to ignore this spec restriction.

## Multiple Identity Columns

LightDB allows a table to have more than one identity column. The standard specifies that a table can have at most one identity column. This is relaxed mainly to give more flexibility for doing

schema changes or migrations. Note that the `INSERT` command supports only one override clause that applies to the entire statement, so having multiple identity columns with different behaviors is not well supported.

## Generated Columns

The option `STORED` is not standard but is also used by other SQL implementations. The SQL standard does not specify the storage of generated columns.

## LIKE Clause

While a `LIKE` clause exists in the SQL standard, many of the options that LightDB accepts for it are not in the standard, and some of the standard's options are not implemented by LightDB.

## WITH Clause

The `WITH` clause is a LightDB extension; storage parameters are not in the standard.

## Tablespaces

The LightDB concept of tablespaces is not part of the standard. Hence, the clauses `TABLESPACE` and `USING INDEX TABLESPACE` are extensions.

## Typed Tables

Typed tables implement a subset of the SQL standard. According to the standard, a typed table has columns corresponding to the underlying composite type as well as one other column that is the “self-referencing column”. LightDB does not support self-referencing columns explicitly.

## PARTITION BY Clause

The `PARTITION BY` clause is a LightDB extension.

## PARTITION OF Clause

The `PARTITION OF` clause is a LightDB extension.

## See Also

`ALTER TABLE`, `DROP TABLE`, `CREATE TABLE AS`, `CREATE TABLESPACE`, `CREATE TYPE`



---

# CREATE TABLE AS

CREATE TABLE AS — define a new table from the results of a query

## Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE
 [ IF NOT EXISTS ] table_name
   [ ( column_name [, ...] ) ]
   [ USING method ]
   [ WITH ( storage_parameter [= value] [, ...] ) | WITHOUT
 OIDS ]
   [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
   [ COMPRESS | NOCOMPRESS | LOGGING | NOLOGGING | COMPRESS
 LOGGING | COMPRESS NOLOGGING | NOCOMPRESS LOGGING | NOCOMPRESS
 NOLOGGING | LOGGING COMPRESS | LOGGING NOCOMPRESS | NOLOGGING
 COMPRESS | NOLOGGING NOCOMPRESS ]
   [ STORAGE(...) ]
   [ TABLESPACE tablespace_name ]
 AS query
 [ WITH [ NO ] DATA ]
```

## Description

CREATE TABLE AS creates a table and fills it with data computed by a SELECT command. The table columns have the names and data types associated with the output columns of the SELECT (except that you can override the column names by giving an explicit list of new column names).

CREATE TABLE AS bears some resemblance to creating a view, but it is really quite different: it creates a new table and evaluates the query just once to fill the new table initially. The new table will not track subsequent changes to the source tables of the query. In contrast, a view re-evaluates its defining SELECT statement whenever it is queried.

## Parameters

GLOBAL or LOCAL

Ignored for compatibility. Use of these keywords is deprecated; refer to CREATE TABLE for details.

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Refer to CREATE TABLE for details.

*table\_name*

The name (optionally schema-qualified) of the table to be created.

*column\_name*

The name of a column in the new table. If column names are not provided, they are taken from the output column names of the query.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new table; the method needs be an access method of type TABLE. See Chapter 57 for more information. If this option is not specified, the default table access method is chosen for the new table. See `default_table_access_method` for more information.

WITH ( *storage\_parameter* [= *value*] [, ... ] )

This clause specifies optional storage parameters for the new table; see Storage Parameters in the CREATE TABLE documentation for more information. For backward-compatibility the WITH clause for a table can also include `OIDS=FALSE` to specify that rows of the new table should contain no OIDs (object identifiers), `OIDS=TRUE` is not supported anymore.

WITHOUT OIDS

This is backward-compatible syntax for declaring a table WITHOUT OIDS, creating a table WITH OIDS is not supported anymore.

ON COMMIT

The behavior of temporary tables at the end of a transaction block can be controlled using ON COMMIT. The three options are:

PRESERVE ROWS

No special action is taken at the ends of transactions. This is the default behavior.

DELETE ROWS

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

DROP

The temporary table will be dropped at the end of the current transaction block.

COMPRESS LOGGING

Starting from LightDB 23.2, four new non-reserved keywords COMPRESS, LOGGING, NOCOMPRESS, NOLOGGING, are added to be compatible with the syntax of Oracle Database. The four new keywords are just grammatical sugar, and do not achieve specific functions. These four keywords must be used before the TABLESPACE keyword.

STORAGE

Starting from LightDB 23.2, the CREATE TABLE AS statement supports the STORAGE keyword for syntactic compatibility with ORACLE database. The content inside the parentheses of the STORAGE keyword is ignored. The STORAGE keyword must be used between the COMPRESS LOGGING keyword and the TABLESPACE keyword.

TABLESPACE *tablespace\_name*

The *tablespace\_name* is the name of the tablespace in which the new table is to be created. If not specified, `default_tablespace` is consulted, or `temp_tablespaces` if the table is temporary.

*query*

A SELECT, TABLE, or VALUES command, or an EXECUTE command that runs a prepared SELECT, TABLE, or VALUES query.

WITH [ NO ] DATA

This clause specifies whether or not the data produced by the query should be copied into the new table. If not, only the table structure is copied. The default is to copy the data.

## Notes

This command is functionally similar to SELECT INTO, but it is preferred since it is less likely to be confused with other uses of the SELECT INTO syntax. Furthermore, CREATE TABLE AS offers a superset of the functionality offered by SELECT INTO.

## Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
CREATE TABLE films_recent AS
  SELECT * FROM films WHERE date_prod >= '2002-01-01';
```

To copy a table completely, the short form using the TABLE command can also be used:

```
CREATE TABLE films2 AS
  TABLE films;
```

Create a new temporary table `films_recent`, consisting of only recent entries from the table `films`, using a prepared statement. The new table will be dropped at commit:

```
PREPARE recentfilms(date) AS
  SELECT * FROM films WHERE date_prod > $1;
CREATE TEMP TABLE films_recent ON COMMIT DROP AS
  EXECUTE recentfilms('2002-01-01');
```

Create a table with COMPRESS/NOCOMPRESS/LOGGING/NOLOGGING options.

```
CREATE TABLE films_recent compress logging tablespace pg_default AS
  SELECT 10 age, 'xiaohong' name, 123456 id;
```

Create a table with STORAGE options.

```
CREATE TABLE films_recent compress logging storage(INITIAL 65536
  NEXT 1048576 MINEXTENTS 1 MAXEXTENTS 2147483645 PCTINCREASE 0
  FREELISTS 1
  FREELIST GROUPS 1 BUFFER_POOL DEFAULT FLASH_CACHE DEFAULT
  CELL_FLASH_CACHE DEFAULT) tablespace pg_default AS SELECT 10 age,
  'xiaohong' name, 123456 id;
```

## Compatibility

CREATE TABLE AS conforms to the SQL standard. The following are nonstandard extensions:

- The standard requires parentheses around the subquery clause; in LightDB, these parentheses are optional.
- In the standard, the `WITH [ NO ] DATA` clause is required; in LightDB it is optional.
- LightDB handles temporary tables in a way rather different from the standard; see `CREATE TABLE` for details.
- The `WITH` clause is a LightDB extension; storage parameters are not in the standard.
- The LightDB concept of tablespaces is not part of the standard. Hence, the clause `TABLESPACE` is an extension.

## See Also

`CREATE MATERIALIZED VIEW`, `CREATE TABLE`, `EXECUTE`, `SELECT`, `SELECT INTO`, `VALUES`

---

# CREATE TABLESPACE

CREATE TABLESPACE — define a new tablespace

## Synopsis

```
CREATE TABLESPACE tablespace_name
  [ OWNER { new_owner | CURRENT_USER | SESSION_USER } ]
  LOCATION 'directory'
  [ WITH ( tablespace_option = value [ , ... ] ) ]
```

## Description

CREATE TABLESPACE registers a new cluster-wide tablespace. The tablespace name must be distinct from the name of any existing tablespace in the database cluster.

A tablespace allows superusers to define an alternative location on the file system where the data files containing database objects (such as tables and indexes) can reside.

A user with appropriate privileges can pass *tablespace\_name* to CREATE DATABASE, CREATE TABLE, CREATE INDEX or ADD CONSTRAINT to have the data files for these objects stored within the specified tablespace.

### Warning

A tablespace cannot be used independently of the cluster in which it is defined; see Section 20.6.

## Parameters

*tablespace\_name*

The name of a tablespace to be created. The name cannot begin with `pg_`, as such names are reserved for system tablespaces.

*user\_name*

The name of the user who will own the tablespace. If omitted, defaults to the user executing the command. Only superusers can create tablespaces, but they can assign ownership of tablespaces to non-superusers.

*directory*

The directory that will be used for the tablespace. The directory must exist (CREATE TABLESPACE will not create it), should be empty, and must be owned by the LightDB system user. The directory must be specified by an absolute path name.

*tablespace\_option*

A tablespace parameter to be set or reset. Currently, the only available parameters are `seq_page_cost`, `random_page_cost`, `effective_io_concurrency` and `maintenance_io_concurrency`. Setting these values for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that

tablespace, and the executor's prefetching behavior, as established by the configuration parameters of the same name (see `seq_page_cost`, `random_page_cost`, `effective_io_concurrency`, `maintenance_io_concurrency`). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

## Notes

Tablespaces are only supported on systems that support symbolic links.

`CREATE TABLESPACE` cannot be executed inside a transaction block.

## Examples

To create a tablespace `dbspace` at file system location `/data/dbs`, first create the directory using operating system facilities and set the correct ownership:

```
mkdir /data/dbs
chown lightdb:lightdb /data/dbs
```

Then issue the tablespace creation command inside LightDB:

```
CREATE TABLESPACE dbspace LOCATION '/data/dbs';
```

To create a tablespace owned by a different database user, use a command like this:

```
CREATE TABLESPACE indexspace OWNER genevieve LOCATION '/data/
indexes';
```

## Compatibility

`CREATE TABLESPACE` is a LightDB extension.

## See Also

`CREATE DATABASE`, `CREATE TABLE`, `CREATE INDEX`, `DROP TABLESPACE`, `ALTER TABLESPACE`

---

# CREATE TEXT SEARCH CONFIGURATION

CREATE TEXT SEARCH CONFIGURATION — define a new text search configuration

## Synopsis

```
CREATE TEXT SEARCH CONFIGURATION name (  
    PARSER = parser_name |  
    COPY = source_config  
)
```

## Description

CREATE TEXT SEARCH CONFIGURATION creates a new text search configuration. A text search configuration specifies a text search parser that can divide a string into tokens, plus dictionaries that can be used to determine which tokens are of interest for searching.

If only the parser is specified, then the new text search configuration initially has no mappings from token types to dictionaries, and therefore will ignore all words. Subsequent ALTER TEXT SEARCH CONFIGURATION commands must be used to create mappings to make the configuration useful. Alternatively, an existing text search configuration can be copied.

If a schema name is given then the text search configuration is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search configuration becomes its owner.

Refer to Chapter 12 for further information.

## Parameters

*name*

The name of the text search configuration to be created. The name can be schema-qualified.

*parser\_name*

The name of the text search parser to use for this configuration.

*source\_config*

The name of an existing text search configuration to copy.

## Notes

The PARSER and COPY options are mutually exclusive, because when an existing configuration is copied, its parser selection is copied too.

## Compatibility

There is no CREATE TEXT SEARCH CONFIGURATION statement in the SQL standard.

## See Also

ALTER TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

---

# CREATE TEXT SEARCH DICTIONARY

CREATE TEXT SEARCH DICTIONARY — define a new text search dictionary

## Synopsis

```
CREATE TEXT SEARCH DICTIONARY name (  
    TEMPLATE = template  
    [, option = value [, ... ]]  
)
```

## Description

CREATE TEXT SEARCH DICTIONARY creates a new text search dictionary. A text search dictionary specifies a way of recognizing interesting or uninteresting words for searching. A dictionary depends on a text search template, which specifies the functions that actually perform the work. Typically the dictionary provides some options that control the detailed behavior of the template's functions.

If a schema name is given then the text search dictionary is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search dictionary becomes its owner.

Refer to Chapter 12 for further information.

## Parameters

*name*

The name of the text search dictionary to be created. The name can be schema-qualified.

*template*

The name of the text search template that will define the basic behavior of this dictionary.

*option*

The name of a template-specific option to be set for this dictionary.

*value*

The value to use for a template-specific option. If the value is not a simple identifier or number, it must be quoted (but you can always quote it, if you wish).

The options can appear in any order.

## Examples

The following example command creates a Snowball-based dictionary with a nonstandard list of stop words.

```
CREATE TEXT SEARCH DICTIONARY my_russian (  
    template = snowball,
```



## CREATE TEXT SEARCH DICTIONARY

---

```
language = russian,  
stopwords = myrussian  
);
```

### Compatibility

There is no `CREATE TEXT SEARCH DICTIONARY` statement in the SQL standard.

### See Also

`ALTER TEXT SEARCH DICTIONARY`, `DROP TEXT SEARCH DICTIONARY`

---

# CREATE TEXT SEARCH PARSER

CREATE TEXT SEARCH PARSER — define a new text search parser

## Synopsis

```
CREATE TEXT SEARCH PARSER name (  
    START = start_function ,  
    GETTOKEN = gettoken_function ,  
    END = end_function ,  
    LEXTYPES = lextypes_function  
    [, HEADLINE = headline_function ]  
)
```

## Description

CREATE TEXT SEARCH PARSER creates a new text search parser. A text search parser defines a method for splitting a text string into tokens and assigning types (categories) to the tokens. A parser is not particularly useful by itself, but must be bound into a text search configuration along with some text search dictionaries to be used for searching.

If a schema name is given then the text search parser is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH PARSER. (This restriction is made because an erroneous text search parser definition could confuse or even crash the server.)

Refer to Chapter 12 for further information.

## Parameters

*name*

The name of the text search parser to be created. The name can be schema-qualified.

*start\_function*

The name of the start function for the parser.

*gettoken\_function*

The name of the get-next-token function for the parser.

*end\_function*

The name of the end function for the parser.

*lextypes\_function*

The name of the lextypes function for the parser (a function that returns information about the set of token types it produces).

*headline\_function*

The name of the headline function for the parser (a function that summarizes a set of tokens).

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. All except the headline function are required.

The arguments can appear in any order, not only the one shown above.

## Compatibility

There is no `CREATE TEXT SEARCH PARSER` statement in the SQL standard.

## See Also

`ALTER TEXT SEARCH PARSER`, `DROP TEXT SEARCH PARSER`

---

# CREATE TEXT SEARCH TEMPLATE

CREATE TEXT SEARCH TEMPLATE — define a new text search template

## Synopsis

```
CREATE TEXT SEARCH TEMPLATE name (  
    [ INIT = init_function , ]  
    LEXIZE = lexize_function  
)
```

## Description

CREATE TEXT SEARCH TEMPLATE creates a new text search template. Text search templates define the functions that implement text search dictionaries. A template is not useful by itself, but must be instantiated as a dictionary to be used. The dictionary typically specifies parameters to be given to the template functions.

If a schema name is given then the text search template is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH TEMPLATE. This restriction is made because an erroneous text search template definition could confuse or even crash the server. The reason for separating templates from dictionaries is that a template encapsulates the “unsafe” aspects of defining a dictionary. The parameters that can be set when defining a dictionary are safe for unprivileged users to set, and so creating a dictionary need not be a privileged operation.

Refer to Chapter 12 for further information.

## Parameters

*name*

The name of the text search template to be created. The name can be schema-qualified.

*init\_function*

The name of the init function for the template.

*lexize\_function*

The name of the lexize function for the template.

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. The lexize function is required, but the init function is optional.

The arguments can appear in any order, not only the one shown above.

## Compatibility

There is no CREATE TEXT SEARCH TEMPLATE statement in the SQL standard.

## See Also

ALTER TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

---

# CREATE TRANSFORM

CREATE TRANSFORM — define a new transform

## Synopsis

```
CREATE [ OR REPLACE ] TRANSFORM FOR type_name LANGUAGE lang_name (  
    FROM SQL WITH FUNCTION from_sql_function_name [ (argument_type  
    [, ...]) ],  
    TO SQL WITH FUNCTION to_sql_function_name [ (argument_type  
    [, ...]) ]  
);
```

## Description

CREATE TRANSFORM defines a new transform. CREATE OR REPLACE TRANSFORM will either create a new transform, or replace an existing definition.

A transform specifies two functions:

- A “from SQL” function that converts the type from the SQL environment to the language. This function will be invoked on the arguments of a function written in the language.
- A “to SQL” function that converts the type from the language to the SQL environment. This function will be invoked on the return value of a function written in the language.

It is not necessary to provide both of these functions. If one is not specified, the language-specific default behavior will be used if necessary. (To prevent a transformation in a certain direction from happening at all, you could also write a transform function that always errors out.)

To be able to create a transform, you must own and have USAGE privilege on the type, have USAGE privilege on the language, and own and have EXECUTE privilege on the from-SQL and to-SQL functions, if specified.

## Parameters

*type\_name*

The name of the data type of the transform.

*lang\_name*

The name of the language of the transform.

*from\_sql\_function\_name*[(*argument\_type* [, ...])]

The name of the function for converting the type from the SQL environment to the language. It must take one argument of type *internal* and return type *internal*. The actual argument will be of the type for the transform, and the function should be coded as if it were. (But it is not allowed to declare an SQL-level function returning *internal* without at least one argument of type *internal*.) The actual return value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

*to\_sql\_function\_name*[(*argument\_type* [, ...])]

The name of the function for converting the type from the language to the SQL environment. It must take one argument of type *internal* and return the type that is the type for the transform.

The actual argument value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

## Notes

Use `DROP TRANSFORM` to remove transforms.

## Examples

To create a transform for type `hstore` and language `plpythonu`, first set up the type and the language:

```
CREATE TYPE hstore ...;
```

```
CREATE EXTENSION plpythonu;
```

Then create the necessary functions:

```
CREATE FUNCTION hstore_to_plpython(val internal) RETURNS internal
LANGUAGE C STRICT IMMUTABLE
AS ...;
```

```
CREATE FUNCTION plpython_to_hstore(val internal) RETURNS hstore
LANGUAGE C STRICT IMMUTABLE
AS ...;
```

And finally create the transform to connect them all together:

```
CREATE TRANSFORM FOR hstore LANGUAGE plpythonu (
    FROM SQL WITH FUNCTION hstore_to_plpython(internal),
    TO SQL WITH FUNCTION plpython_to_hstore(internal)
);
```

In practice, these commands would be wrapped up in an extension.

The `contrib` section contains a number of extensions that provide transforms, which can serve as real-world examples.

## Compatibility

This form of `CREATE TRANSFORM` is a LightDB extension. There is a `CREATE TRANSFORM` command in the SQL standard, but it is for adapting data types to client languages. That usage is not supported by LightDB.

## See Also

`CREATE FUNCTION`, `CREATE LANGUAGE`, `CREATE TYPE`, `DROP TRANSFORM`

---

# CREATE TRIGGER

CREATE TRIGGER — define a new trigger

## Synopsis

```
CREATE [ CONSTRAINT ] TRIGGER name { BEFORE | AFTER | INSTEAD OF }
  { event [ OR ... ] }
  ON table_name
  [ FROM referenced_table_name ]
  [ NOT DEFERRABLE | [ DEFERRABLE ] [ INITIALLY IMMEDIATE |
INITIALLY DEFERRED ] ]
  [ REFERENCING { { OLD | NEW } TABLE
[ AS ] transition_relation_name } [ ... ] ]
  [ FOR [ EACH ] { ROW | STATEMENT } ]
  [ WHEN ( condition ) ]
  EXECUTE { FUNCTION | PROCEDURE } function_name ( arguments )
```

where *event* can be one of:

```
INSERT
UPDATE [ OF column_name [, ... ] ]
DELETE
TRUNCATE
```

## Description

CREATE TRIGGER creates a new trigger. The trigger will be associated with the specified table, view, or foreign table and will execute the specified function *function\_name* when certain operations are performed on that table.

The trigger can be specified to fire before the operation is attempted on a row (before constraints are checked and the INSERT, UPDATE, or DELETE is attempted); or after the operation has completed (after constraints are checked and the INSERT, UPDATE, or DELETE has completed); or instead of the operation (in the case of inserts, updates or deletes on a view). If the trigger fires before or instead of the event, the trigger can skip the operation for the current row, or change the row being inserted (for INSERT and UPDATE operations only). If the trigger fires after the event, all changes, including the effects of other triggers, are “visible” to the trigger.

A trigger that is marked FOR EACH ROW is called once for every row that the operation modifies. For example, a DELETE that affects 10 rows will cause any ON DELETE triggers on the target relation to be called 10 separate times, once for each deleted row. In contrast, a trigger that is marked FOR EACH STATEMENT only executes once for any given operation, regardless of how many rows it modifies (in particular, an operation that modifies zero rows will still result in the execution of any applicable FOR EACH STATEMENT triggers).

Triggers that are specified to fire INSTEAD OF the trigger event must be marked FOR EACH ROW, and can only be defined on views. BEFORE and AFTER triggers on a view must be marked as FOR EACH STATEMENT.

In addition, triggers may be defined to fire for TRUNCATE, though only FOR EACH STATEMENT.

The following table summarizes which types of triggers may be used on tables, views, and foreign tables:

When	Event	Row-level	Statement-level
BEFORE	INSERT/ UPDATE/DELETE	Tables and foreign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
AFTER	INSERT/ UPDATE/DELETE	Tables and foreign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
INSTEAD OF	INSERT/ UPDATE/DELETE	Views	—
	TRUNCATE	—	—

Also, a trigger definition can specify a Boolean `WHEN` condition, which will be tested to see whether the trigger should be fired. In row-level triggers the `WHEN` condition can examine the old and/or new values of columns of the row. Statement-level triggers can also have `WHEN` conditions, although the feature is not so useful for them since the condition cannot refer to any values in the table.

If multiple triggers of the same kind are defined for the same event, they will be fired in alphabetical order by name.

When the `CONSTRAINT` option is specified, this command creates a *constraint trigger*. This is the same as a regular trigger except that the timing of the trigger firing can be adjusted using `SET CONSTRAINTS`. Constraint triggers must be `AFTER ROW` triggers on plain tables (not foreign tables). They can be fired either at the end of the statement causing the triggering event, or at the end of the containing transaction; in the latter case they are said to be *deferred*. A pending deferred-trigger firing can also be forced to happen immediately by using `SET CONSTRAINTS`. Constraint triggers are expected to raise an exception when the constraints they implement are violated.

The `REFERENCING` option enables collection of *transition relations*, which are row sets that include all of the rows inserted, deleted, or modified by the current SQL statement. This feature lets the trigger see a global view of what the statement did, not just one row at a time. This option is only allowed for an `AFTER` trigger that is not a constraint trigger; also, if the trigger is an `UPDATE` trigger, it must not specify a `column_name` list. `OLD TABLE` may only be specified once, and only for a trigger that can fire on `UPDATE` or `DELETE`; it creates a transition relation containing the *before-images* of all rows updated or deleted by the statement. Similarly, `NEW TABLE` may only be specified once, and only for a trigger that can fire on `UPDATE` or `INSERT`; it creates a transition relation containing the *after-images* of all rows updated or inserted by the statement.

`SELECT` does not modify any rows so you cannot create `SELECT` triggers. Rules and views may provide workable solutions to problems that seem to need `SELECT` triggers.

Refer to Chapter 37 for more information about triggers.

## Parameters

*name*

The name to give the new trigger. This must be distinct from the name of any other trigger for the same table. The name cannot be schema-qualified — the trigger inherits the schema of its table. For a constraint trigger, this is also the name to use when modifying the trigger's behavior using `SET CONSTRAINTS`.

`BEFORE`

`AFTER`

`INSTEAD OF`

Determines whether the function is called before, after, or instead of the event. A constraint trigger can only be specified as `AFTER`.



*event*

One of INSERT, UPDATE, DELETE, or TRUNCATE; this specifies the event that will fire the trigger. Multiple events can be specified using OR, except when transition relations are requested.

For UPDATE events, it is possible to specify a list of columns using this syntax:

```
UPDATE OF column_name1 [ , column_name2 ... ]
```

The trigger will only fire if at least one of the listed columns is mentioned as a target of the UPDATE command or if one of the listed columns is a generated column that depends on a column that is the target of the UPDATE.

INSTEAD OF UPDATE events do not allow a list of columns. A column list cannot be specified when requesting transition relations, either.

*table\_name*

The name (optionally schema-qualified) of the table, view, or foreign table the trigger is for.

*referenced\_table\_name*

The (possibly schema-qualified) name of another table referenced by the constraint. This option is used for foreign-key constraints and is not recommended for general use. This can only be specified for constraint triggers.

```
DEFERRABLE  
NOT DEFERRABLE  
INITIALLY IMMEDIATE  
INITIALLY DEFERRED
```

The default timing of the trigger. See the CREATE TABLE documentation for details of these constraint options. This can only be specified for constraint triggers.

## REFERENCING

This keyword immediately precedes the declaration of one or two relation names that provide access to the transition relations of the triggering statement.

```
OLD TABLE  
NEW TABLE
```

This clause indicates whether the following relation name is for the before-image transition relation or the after-image transition relation.

*transition\_relation\_name*

The (unqualified) name to be used within the trigger for this transition relation.

```
FOR EACH ROW  
FOR EACH STATEMENT
```

This specifies whether the trigger function should be fired once for every row affected by the trigger event, or just once per SQL statement. If neither is specified, FOR EACH STATEMENT is the default. Constraint triggers can only be specified FOR EACH ROW.

*condition*

A Boolean expression that determines whether the trigger function will actually be executed. If WHEN is specified, the function will only be called if the *condition* returns true. In FOR

EACH ROW triggers, the WHEN condition can refer to columns of the old and/or new row values by writing `OLD.column_name` or `NEW.column_name` respectively. Of course, INSERT triggers cannot refer to OLD and DELETE triggers cannot refer to NEW.

INSTEAD OF triggers do not support WHEN conditions.

Currently, WHEN expressions cannot contain subqueries.

Note that for constraint triggers, evaluation of the WHEN condition is not deferred, but occurs immediately after the row update operation is performed. If the condition does not evaluate to true then the trigger is not queued for deferred execution.

#### *function\_name*

A user-supplied function that is declared as taking no arguments and returning type `trigger`, which is executed when the trigger fires.

In the syntax of CREATE TRIGGER, the keywords FUNCTION and PROCEDURE are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword PROCEDURE here is historical and deprecated.

#### *arguments*

An optional comma-separated list of arguments to be provided to the function when the trigger is executed. The arguments are literal string constants. Simple names and numeric constants can be written here, too, but they will all be converted to strings. Please check the description of the implementation language of the trigger function to find out how these arguments can be accessed within the function; it might be different from normal function arguments.

## Notes

To create a trigger on a table, the user must have the TRIGGER privilege on the table. The user must also have EXECUTE privilege on the trigger function.

Use DROP TRIGGER to remove a trigger.

A column-specific trigger (one defined using the UPDATE OF `column_name` syntax) will fire when any of its columns are listed as targets in the UPDATE command's SET list. It is possible for a column's value to change even when the trigger is not fired, because changes made to the row's contents by BEFORE UPDATE triggers are not considered. Conversely, a command such as UPDATE ... SET `x = x` ... will fire a trigger on column `x`, even though the column's value did not change.

There are a few built-in trigger functions that can be used to solve common problems without having to write your own trigger code; see Section 9.28.

In a BEFORE trigger, the WHEN condition is evaluated just before the function is or would be executed, so using WHEN is not materially different from testing the same condition at the beginning of the trigger function. Note in particular that the NEW row seen by the condition is the current value, as possibly modified by earlier triggers. Also, a BEFORE trigger's WHEN condition is not allowed to examine the system columns of the NEW row (such as `ctid`), because those won't have been set yet.

In an AFTER trigger, the WHEN condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an AFTER trigger's WHEN condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows.

In some cases it is possible for a single SQL command to fire more than one kind of trigger. For instance an INSERT with an ON CONFLICT DO UPDATE clause may cause both insert and update operations, so it will fire both kinds of triggers as needed. The transition relations supplied to triggers

are specific to their event type; thus an `INSERT` trigger will see only the inserted rows, while an `UPDATE` trigger will see only the updated rows.

Row updates or deletions caused by foreign-key enforcement actions, such as `ON UPDATE CASCADE` or `ON DELETE SET NULL`, are treated as part of the `SQL` command that caused them (note that such actions are never deferred). Relevant triggers on the affected table will be fired, so that this provides another way in which a `SQL` command might fire triggers not directly matching its type. In simple cases, triggers that request transition relations will see all changes caused in their table by a single original `SQL` command as a single transition relation. However, there are cases in which the presence of an `AFTER ROW` trigger that requests transition relations will cause the foreign-key enforcement actions triggered by a single `SQL` command to be split into multiple steps, each with its own transition relation(s). In such cases, any statement-level triggers that are present will be fired once per creation of a transition relation set, ensuring that the triggers see each affected row in a transition relation once and only once.

Statement-level triggers on a view are fired only if the action on the view is handled by a row-level `INSTEAD OF` trigger. If the action is handled by an `INSTEAD` rule, then whatever statements are emitted by the rule are executed in place of the original statement naming the view, so that the triggers that will be fired are those on tables named in the replacement statements. Similarly, if the view is automatically updatable, then the action is handled by automatically rewriting the statement into an action on the view's base table, so that the base table's statement-level triggers are the ones that are fired.

Creating a row-level trigger on a partitioned table will cause identical triggers to be created in all its existing partitions; and any partitions created or attached later will contain an identical trigger, too. If the partition is detached from its parent, the trigger is removed. Triggers on partitioned tables may not be `INSTEAD OF`.

Modifying a partitioned table or a table with inheritance children fires statement-level triggers attached to the explicitly named table, but not statement-level triggers for its partitions or child tables. In contrast, row-level triggers are fired on the rows in affected partitions or child tables, even if they are not explicitly named in the query. If a statement-level trigger has been defined with transition relations named by a `REFERENCING` clause, then before and after images of rows are visible from all affected partitions or child tables. In the case of inheritance children, the row images include only columns that are present in the table that the trigger is attached to. Currently, row-level triggers with transition relations cannot be defined on partitions or inheritance child tables.

## Examples

Execute the function `check_account_update` whenever a row of the table `accounts` is about to be updated:

```
CREATE TRIGGER check_update
  BEFORE UPDATE ON accounts
  FOR EACH ROW
  EXECUTE FUNCTION check_account_update();
```

The same, but only execute the function if column `balance` is specified as a target in the `UPDATE` command:

```
CREATE TRIGGER check_update
  BEFORE UPDATE OF balance ON accounts
  FOR EACH ROW
  EXECUTE FUNCTION check_account_update();
```

This form only executes the function if column `balance` has in fact changed value:

```
CREATE TRIGGER check_update
  BEFORE UPDATE ON accounts
  FOR EACH ROW
  WHEN (OLD.balance IS DISTINCT FROM NEW.balance)
  EXECUTE FUNCTION check_account_update();
```

Call a function to log updates of `accounts`, but only if something changed:

```
CREATE TRIGGER log_update
  AFTER UPDATE ON accounts
  FOR EACH ROW
  WHEN (OLD.* IS DISTINCT FROM NEW.*)
  EXECUTE FUNCTION log_account_update();
```

Execute the function `view_insert_row` for each row to insert rows into the tables underlying a view:

```
CREATE TRIGGER view_insert
  INSTEAD OF INSERT ON my_view
  FOR EACH ROW
  EXECUTE FUNCTION view_insert_row();
```

Execute the function `check_transfer_balances_to_zero` for each statement to confirm that the transfer rows offset to a net of zero:

```
CREATE TRIGGER transfer_insert
  AFTER INSERT ON transfer
  REFERENCING NEW TABLE AS inserted
  FOR EACH STATEMENT
  EXECUTE FUNCTION check_transfer_balances_to_zero();
```

Execute the function `check_matching_pairs` for each row to confirm that changes are made to matching pairs at the same time (by the same statement):

```
CREATE TRIGGER paired_items_update
  AFTER UPDATE ON paired_items
  REFERENCING NEW TABLE AS newtab OLD TABLE AS oldtab
  FOR EACH ROW
  EXECUTE FUNCTION check_matching_pairs();
```

Section 37.4 contains a complete example of a trigger function written in C.

## Compatibility

The `CREATE TRIGGER` statement in LightDB implements a subset of the SQL standard. The following functionalities are currently missing:

- While transition table names for `AFTER` triggers are specified using the `REFERENCING` clause in the standard way, the row variables used in `FOR EACH ROW` triggers may not be specified in a `REFERENCING` clause. They are available in a manner that is dependent on the language in which the trigger function is written, but is fixed for any one language. Some languages effectively behave as though there is a `REFERENCING` clause containing `OLD ROW AS OLD NEW ROW AS NEW`.
- The standard allows transition tables to be used with column-specific `UPDATE` triggers, but then the set of rows that should be visible in the transition tables depends on the trigger's column list. This is not currently implemented by LightDB.

- LightDB only allows the execution of a user-defined function for the triggered action. The standard allows the execution of a number of other SQL commands, such as `CREATE TABLE`, as the triggered action. This limitation is not hard to work around by creating a user-defined function that executes the desired commands.

SQL specifies that multiple triggers should be fired in time-of-creation order. LightDB uses name order, which was judged to be more convenient.

SQL specifies that `BEFORE DELETE` triggers on cascaded deletes fire *after* the cascaded `DELETE` completes. The LightDB behavior is for `BEFORE DELETE` to always fire before the delete action, even a cascading one. This is considered more consistent. There is also nonstandard behavior if `BEFORE` triggers modify rows or prevent updates during an update that is caused by a referential action. This can lead to constraint violations or stored data that does not honor the referential constraint.

The ability to specify multiple actions for a single trigger using `OR` is a LightDB extension of the SQL standard.

The ability to fire triggers for `TRUNCATE` is a LightDB extension of the SQL standard, as is the ability to define statement-level triggers on views.

`CREATE CONSTRAINT TRIGGER` is a LightDB extension of the SQL standard.

## See Also

`ALTER TRIGGER`, `DROP TRIGGER`, `CREATE FUNCTION`, `SET CONSTRAINTS`

---

# CREATE TYPE

CREATE TYPE — define a new data type

## Synopsis

```
CREATE TYPE name AS  
  ( [ attribute_name data_type [ COLLATE collation ] [, ... ] ] )
```

```
CREATE TYPE name AS ENUM  
  ( [ 'label' [, ... ] ] )
```

```
CREATE TYPE name AS RANGE (  
  SUBTYPE = subtype  
  [ , SUBTYPE_OPCLASS = subtype_operator_class ]  
  [ , COLLATION = collation ]  
  [ , CANONICAL = canonical_function ]  
  [ , SUBTYPE_DIFF = subtype_diff_function ]  
)
```

```
CREATE TYPE name (  
  INPUT = input_function,  
  OUTPUT = output_function  
  [ , RECEIVE = receive_function ]  
  [ , SEND = send_function ]  
  [ , TYPMOD_IN = type_modifier_input_function ]  
  [ , TYPMOD_OUT = type_modifier_output_function ]  
  [ , ANALYZE = analyze_function ]  
  [ , INTERNALLENGTH = { internallength | VARIABLE } ]  
  [ , PASSEDBYVALUE ]  
  [ , ALIGNMENT = alignment ]  
  [ , STORAGE = storage ]  
  [ , LIKE = like_type ]  
  [ , CATEGORY = category ]  
  [ , PREFERRED = preferred ]  
  [ , DEFAULT = default ]  
  [ , ELEMENT = element ]  
  [ , DELIMITER = delimiter ]  
  [ , COLLATABLE = collatable ]  
)
```

```
CREATE TYPE name
```

```
CREATE [ OR REPLACE ] TYPE name AS TABLE OF data_type
```

```
CREATE [ OR REPLACE ] TYPE name as_is OBJECT  
  ( [ object_type_element_list ] )
```

where *as\_is* is:

```
AS | IS
```

and *object\_type\_element\_list* is:

```
TableFuncElementList [ object_type_func_list ]
```

```

and TableFuncElementList is:

attribute_name data_type [ COLLATE collation ] [, ... ]

and object_type_func_list is:

{ type_function_spec | type_procedure_spec } [, ... ]

and type_function_spec is:

MEMBER FUNCTION func_name ( [ [ argmode ] [ argname ] argtype
[ { DEFAULT | = } default_expr ] [, ...] ] ) RETURN rettype

and type_procedure_spec is:

MEMBER FUNCTION func_name ( [ [ argmode ] [ argname ] argtype
[ { DEFAULT | = } default_expr ] [, ...] ] )

CREATE [ OR REPLACE ] TYPE
BODY name as_is subprog_decl_in_type_list END

where subprog_decl_in_type_list is:
{ func_decl_in_type | proc_decl_in_type } [ ... ]

and func_decl_in_type is:
MEMBER FUNCTION func_name ( [ [ argmode ] [ argname
] argtype [ { DEFAULT | = } default_expr ] [, ...] ] )
RETURN rettype as_is pl_block ;

and proc_decl_in_type is:
MEMBER PROCEDURE func_name ( [ [ argmode ] [ argname ] argtype
[ { DEFAULT | = } default_expr ] [, ...] ] ) as_is pl_block ;

and as_is is:
AS | IS

and pl_block is:
[ DECLARE decl_stmts ] BEGIN statement [ , ... ] END

```

## Description

CREATE TYPE registers a new data type for use in the current database. The user who defines a type becomes its owner.

If a schema name is given then the type is created in the specified schema. Otherwise it is created in the current schema. The type name must be distinct from the name of any existing type or domain in the same schema. (Because tables have associated data types, the type name must also be distinct from the name of any existing table in the same schema.)

There are five forms of CREATE TYPE, as shown in the syntax synopsis above. They respectively create a *composite type*, an *enum type*, a *range type*, a *base type*, or a *shell type*. The first four of these are discussed in turn below. A shell type is simply a placeholder for a type to be defined later; it is created by issuing CREATE TYPE with no parameters except for the type name. Shell types are needed as forward references when creating range types and base types, as discussed in those sections.

## Composite Types

The first form of `CREATE TYPE` creates a composite type. The composite type is specified by a list of attribute names and data types. An attribute's collation can be specified too, if its data type is collatable. A composite type is essentially the same as the row type of a table, but using `CREATE TYPE` avoids the need to create an actual table when all that is wanted is to define a type. A stand-alone composite type is useful, for example, as the argument or return type of a function.

To be able to create a composite type, you must have `USAGE` privilege on all attribute types.

## Enumerated Types

The second form of `CREATE TYPE` creates an enumerated (enum) type, as described in Section 8.7. Enum types take a list of quoted labels, each of which must be less than `NAMEDATALEN` bytes long (64 bytes in a standard LightDB build). (It is possible to create an enumerated type with zero labels, but such a type cannot be used to hold values before at least one label is added using `ALTER TYPE`.)

## Range Types

The third form of `CREATE TYPE` creates a new range type, as described in Section 8.17.

The range type's *subtype* can be any type with an associated b-tree operator class (to determine the ordering of values for the range type). Normally the subtype's default b-tree operator class is used to determine ordering; to use a non-default operator class, specify its name with *subtype\_opclass*. If the subtype is collatable, and you want to use a non-default collation in the range's ordering, specify the desired collation with the *collation* option.

The optional *canonical* function must take one argument of the range type being defined, and return a value of the same type. This is used to convert range values to a canonical form, when applicable. See Section 8.17.8 for more information. Creating a *canonical* function is a bit tricky, since it must be defined before the range type can be declared. To do this, you must first create a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the function can be declared using the shell type as argument and result, and finally the range type can be declared using the same name. This automatically replaces the shell type entry with a valid range type.

The optional *subtype\_diff* function must take two values of the *subtype* type as argument, and return a `double precision` value representing the difference between the two given values. While this is optional, providing it allows much greater efficiency of GiST indexes on columns of the range type. See Section 8.17.8 for more information.

## Base Types

The fourth form of `CREATE TYPE` creates a new base type (scalar type). To create a new base type, you must be a superuser. (This restriction is made because an erroneous type definition could confuse or even crash the server.)

The parameters can appear in any order, not only that illustrated above, and most are optional. You must register two or more functions (using `CREATE FUNCTION`) before defining the type. The support functions *input\_function* and *output\_function* are required, while the functions *receive\_function*, *send\_function*, *type\_modifier\_input\_function*, *type\_modifier\_output\_function* and *analyze\_function* are optional. Generally these functions have to be coded in C or another low-level language.

The *input\_function* converts the type's external textual representation to the internal representation used by the operators and functions defined for the type. *output\_function* performs the reverse transformation. The input function can be declared as taking one argument of type `cstring`, or as taking three arguments of types `cstring`, `oid`, `integer`. The first argument



is the input text as a C string, the second argument is the type's own OID (except for array types, which instead receive their element type's OID), and the third is the `typmod` of the destination column, if known (-1 will be passed if not). The input function must return a value of the data type itself. Usually, an input function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain input functions, which might need to reject `NULL` inputs.) The output function must be declared as taking one argument of the new data type. The output function must return type `cstring`. Output functions are not invoked for `NULL` values.

The optional `receive_function` converts the type's external binary representation to the internal representation. If this function is not supplied, the type cannot participate in binary input. The binary representation should be chosen to be cheap to convert to internal form, while being reasonably portable. (For example, the standard integer data types use network byte order as the external binary representation, while the internal representation is in the machine's native byte order.) The receive function should perform adequate checking to ensure that the value is valid. The receive function can be declared as taking one argument of type `internal`, or as taking three arguments of types `internal`, `oid`, `integer`. The first argument is a pointer to a `StringInfo` buffer holding the received byte string; the optional arguments are the same as for the text input function. The receive function must return a value of the data type itself. Usually, a receive function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain receive functions, which might need to reject `NULL` inputs.) Similarly, the optional `send_function` converts from the internal representation to the external binary representation. If this function is not supplied, the type cannot participate in binary output. The send function must be declared as taking one argument of the new data type. The send function must return type `bytea`. Send functions are not invoked for `NULL` values.

You should at this point be wondering how the input and output functions can be declared to have results or arguments of the new type, when they have to be created before the new type can be created. The answer is that the type should first be defined as a *shell type*, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the C I/O functions can be defined referencing the shell type. Finally, `CREATE TYPE` with a full definition replaces the shell entry with a complete, valid type definition, after which the new type can be used normally.

The optional `type_modifier_input_function` and `type_modifier_output_function` are needed if the type supports modifiers, that is optional constraints attached to a type declaration, such as `char(5)` or `numeric(30,2)`. LightDB allows user-defined types to take one or more simple constants or identifiers as modifiers. However, this information must be capable of being packed into a single non-negative integer value for storage in the system catalogs. The `type_modifier_input_function` is passed the declared modifier(s) in the form of a `cstring` array. It must check the values for validity (throwing an error if they are wrong), and if they are correct, return a single non-negative integer value that will be stored as the column "typmod". Type modifiers will be rejected if the type does not have a `type_modifier_input_function`. The `type_modifier_output_function` converts the internal integer `typmod` value back to the correct form for user display. It must return a `cstring` value that is the exact string to append to the type name; for example `numeric`'s function might return `(30,2)`. It is allowed to omit the `type_modifier_output_function`, in which case the default display format is just the stored `typmod` integer value enclosed in parentheses.

The optional `analyze_function` performs type-specific statistics collection for columns of the data type. By default, `ANALYZE` will attempt to gather statistics using the type's "equals" and "less-than" operators, if there is a default b-tree operator class for the type. For non-scalar types this behavior is likely to be unsuitable, so it can be overridden by specifying a custom analysis function. The analysis function must be declared to take a single argument of type `internal`, and return a `boolean` result. The detailed API for analysis functions appears in `src/include/commands/vacuum.h`.

While the details of the new type's internal representation are only known to the I/O functions and other functions you create to work with the type, there are several properties of the internal representation

that must be declared to LightDB. Foremost of these is *internallength*. Base data types can be fixed-length, in which case *internallength* is a positive integer, or variable-length, indicated by setting *internallength* to `VARIABLE`. (Internally, this is represented by setting `typplen` to -1.) The internal representation of all variable-length types must start with a 4-byte integer giving the total length of this value of the type. (Note that the length field is often encoded, as described in Section 64.2; it's unwise to access it directly.)

The optional flag `PASSEDBYVALUE` indicates that values of this data type are passed by value, rather than by reference. Types passed by value must be fixed-length, and their internal representation cannot be larger than the size of the `Datum` type (4 bytes on some machines, 8 bytes on others).

The *alignment* parameter specifies the storage alignment required for the data type. The allowed values equate to alignment on 1, 2, 4, or 8 byte boundaries. Note that variable-length types must have an alignment of at least 4, since they necessarily contain an `int4` as their first component.

The *storage* parameter allows selection of storage strategies for variable-length data types. (Only `plain` is allowed for fixed-length types.) `plain` specifies that data of the type will always be stored in-line and not compressed. `extended` specifies that the system will first try to compress a long data value, and will move the value out of the main table row if it's still too long. `external` allows the value to be moved out of the main table, but the system will not try to compress it. `main` allows compression, but discourages moving the value out of the main table. (Data items with this storage strategy might still be moved out of the main table if there is no other way to make a row fit, but they will be kept in the main table preferentially over `extended` and `external` items.)

All *storage* values other than `plain` imply that the functions of the data type can handle values that have been *toasted*, as described in Section 64.2 and Section 36.13.1. The specific other value given merely determines the default TOAST storage strategy for columns of a toastable data type; users can pick other strategies for individual columns using `ALTER TABLE SET STORAGE`.

The *like\_type* parameter provides an alternative method for specifying the basic representation properties of a data type: copy them from some existing type. The values of *internallength*, *passedbyvalue*, *alignment*, and *storage* are copied from the named type. (It is possible, though usually undesirable, to override some of these values by specifying them along with the `LIKE` clause.) Specifying representation this way is especially useful when the low-level implementation of the new type “piggybacks” on an existing type in some fashion.

The *category* and *preferred* parameters can be used to help control which implicit cast will be applied in ambiguous situations. Each data type belongs to a category named by a single ASCII character, and each type is either “preferred” or not within its category. The parser will prefer casting to preferred types (but only from other types within the same category) when this rule is helpful in resolving overloaded functions or operators. For more details see Chapter 10. For types that have no implicit casts to or from any other types, it is sufficient to leave these settings at the defaults. However, for a group of related types that have implicit casts, it is often helpful to mark them all as belonging to a category and select one or two of the “most general” types as being preferred within the category. The *category* parameter is especially useful when adding a user-defined type to an existing built-in category, such as the numeric or string types. However, it is also possible to create new entirely-user-defined type categories. Select any ASCII character other than an upper-case letter to name such a category.

A default value can be specified, in case a user wants columns of the data type to default to something other than the null value. Specify the default with the `DEFAULT` key word. (Such a default can be overridden by an explicit `DEFAULT` clause attached to a particular column.)

To indicate that a type is an array, specify the type of the array elements using the `ELEMENT` key word. For example, to define an array of 4-byte integers (`int4`), specify `ELEMENT = int4`. More details about array types appear below.

To indicate the delimiter to be used between values in the external representation of arrays of this type, *delimiter* can be set to a specific character. The default delimiter is the comma (`,`). Note that the delimiter is associated with the array element type, not the array type itself.

If the optional Boolean parameter *collatable* is true, column definitions and expressions of the type may carry collation information through use of the `COLLATE` clause. It is up to the implementations of the functions operating on the type to actually make use of the collation information; this does not happen automatically merely by marking the type collatable.

## Array Types

Whenever a user-defined type is created, LightDB automatically creates an associated array type, whose name consists of the element type's name prepended with an underscore, and truncated if necessary to keep it less than `NAMEDATALEN` bytes long. (If the name so generated collides with an existing type name, the process is repeated until a non-colliding name is found.) This implicitly-created array type is variable length and uses the built-in input and output functions `array_in` and `array_out`. The array type tracks any changes in its element type's owner or schema, and is dropped if the element type is.

You might reasonably ask why there is an `ELEMENT` option, if the system makes the correct array type automatically. The only case where it's useful to use `ELEMENT` is when you are making a fixed-length type that happens to be internally an array of a number of identical things, and you want to allow these things to be accessed directly by subscripting, in addition to whatever operations you plan to provide for the type as a whole. For example, type `point` is represented as just two floating-point numbers, which can be accessed using `point[0]` and `point[1]`. Note that this facility only works for fixed-length types whose internal form is exactly a sequence of identical fixed-length fields. A subscriptable variable-length type must have the generalized internal representation used by `array_in` and `array_out`. For historical reasons (i.e., this is clearly wrong but it's far too late to change it), subscripting of fixed-length array types starts from zero, rather than from one as for variable-length arrays.

## Nested Table Types

Similar to arrays, but with no length limit, it is mainly used in stored procedures.

## Object Types

Similar to composition types, but can carry functions.

## Parameters

*name*

The name (optionally schema-qualified) of a type to be created.

*attribute\_name*

The name of an attribute (column) for the composite type.

*data\_type*

The name of an existing data type to become a column of the composite type.

*collation*

The name of an existing collation to be associated with a column of a composite type, or with a range type.

*label*

A string literal representing the textual label associated with one value of an enum type.

*subtype*

The name of the element type that the range type will represent ranges of.

*subtype\_operator\_class*

The name of a b-tree operator class for the subtype.

*canonical\_function*

The name of the canonicalization function for the range type.

*subtype\_diff\_function*

The name of a difference function for the subtype.

*input\_function*

The name of a function that converts data from the type's external textual form to its internal form.

*output\_function*

The name of a function that converts data from the type's internal form to its external textual form.

*receive\_function*

The name of a function that converts data from the type's external binary form to its internal form.

*send\_function*

The name of a function that converts data from the type's internal form to its external binary form.

*type\_modifier\_input\_function*

The name of a function that converts an array of modifier(s) for the type into internal form.

*type\_modifier\_output\_function*

The name of a function that converts the internal form of the type's modifier(s) to external textual form.

*analyze\_function*

The name of a function that performs statistical analysis for the data type.

*internallength*

A numeric constant that specifies the length in bytes of the new type's internal representation. The default assumption is that it is variable-length.

*alignment*

The storage alignment requirement of the data type. If specified, it must be `char`, `int2`, `int4`, or `double`; the default is `int4`.

*storage*

The storage strategy for the data type. If specified, must be `plain`, `external`, `extended`, or `main`; the default is `plain`.

*like\_type*

The name of an existing data type that the new type will have the same representation as. The values of *internallength*, *passedbyvalue*, *alignment*, and *storage* are copied from that type, unless overridden by explicit specification elsewhere in this `CREATE TYPE` command.

*category*

The category code (a single ASCII character) for this type. The default is 'U' for “user-defined type”. Other standard category codes can be found in Table 48.71. You may also choose other ASCII characters in order to create custom categories.

*preferred*

True if this type is a preferred type within its type category, else false. The default is false. Be very careful about creating a new preferred type within an existing type category, as this could cause surprising changes in behavior.

*default*

The default value for the data type. If this is omitted, the default is null.

*element*

The type being created is an array; this specifies the type of the array elements.

*delimiter*

The delimiter character to be used between values in arrays made of this type.

*collatable*

True if this type's operations can use collation information. The default is false.

*func\_name*

The name of the function to create.

*argmode*

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Only OUT arguments can follow a VARIADIC one. Also, OUT and INOUT arguments cannot be used together with the RETURNS TABLE notation.

*argname*

The name of an argument. Some languages (including SQL and PL/oraSQL) let you use the name in the function body. For other languages the name of an input argument is just extra documentation, so far as the function itself is concerned; but you can use input argument names when calling a function to improve readability (see Section 4.3). In any case, the name of an output argument is significant, because it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

*argtype*

The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. Pseudo-types indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a function independent of changes to the definition of a table.

*default\_expr*

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. Only input (including INOUT) parameters

can have a default value. All input parameters following a parameter with a default value must have default values as well.

#### *rettype*

The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or can reference the type of a table column. Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. If the function is not supposed to return a value, specify `void` as the return type.

When there are `OUT` or `INOUT` parameters, the `RETURNS` clause can be omitted. If present, it must agree with the result type implied by the output parameters: `RECORD` if there are multiple output parameters, or the same type as the single output parameter.

The `SETOF` modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing `table_name.column_name%TYPE`.

#### *decl\_stmts*

PL/oraSQL declares statement blocks.

#### *statement*

PL/oraSQL execution block.

## Notes

Because there are no restrictions on use of a data type once it's been created, creating a base type or range type is tantamount to granting public execute permission on the functions mentioned in the type definition. This is usually not an issue for the sorts of functions that are useful in a type definition. But you might want to think twice before designing a type in a way that would require “secret” information to be used while converting it to or from external form.

Before LightDB version 8.3, the name of a generated array type was always exactly the element type's name with one underscore character (`_`) prepended. (Type names were therefore restricted in length to one fewer character than other names.) While this is still usually the case, the array type name may vary from this in case of maximum-length names or collisions with user type names that begin with underscore. Writing code that depends on this convention is therefore deprecated. Instead, use `pg_type.typarray` to locate the array type associated with a given type.

It may be advisable to avoid using type and table names that begin with underscore. While the server will change generated array type names to avoid collisions with user-given names, there is still risk of confusion, particularly with old client software that may assume that type names beginning with underscores always represent arrays.

Before LightDB version 8.2, the shell-type creation syntax `CREATE TYPE name` did not exist. The way to create a new base type was to create its input function first. In this approach, LightDB will first see the name of the new data type as the return type of the input function. The shell type is implicitly created in this situation, and then it can be referenced in the definitions of the remaining I/O functions. This approach still works, but is deprecated and might be disallowed in some future release. Also, to avoid accidentally cluttering the catalogs with shell types as a result of simple typos in function definitions, a shell type will only be made this way when the input function is written in C.

## Examples

This example creates a composite type and uses it in a function definition:

```
CREATE TYPE compfoo AS (f1 int, f2 text);
```

```
CREATE FUNCTION getfoo() RETURNS SETOF compfoo AS $$
    SELECT fooid, fooname FROM foo
$$ LANGUAGE SQL;
```

This example creates an enumerated type and uses it in a table definition:

```
CREATE TYPE bug_status AS ENUM ('new', 'open', 'closed');

CREATE TABLE bug (
    id serial,
    description text,
    status bug_status
);
```

This example creates a range type:

```
CREATE TYPE float8_range AS RANGE (subtype = float8, subtype_diff =
    float8mi);
```

This example creates the base data type box and then uses the type in a table definition:

```
CREATE TYPE box;

CREATE FUNCTION my_box_in_function(cstring) RETURNS box AS ... ;
CREATE FUNCTION my_box_out_function(box) RETURNS cstring AS ... ;

CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function
);

CREATE TABLE myboxes (
    id integer,
    description box
);
```

If the internal structure of box were an array of four float4 elements, we might instead use:

```
CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function,
    ELEMENT = float4
);
```

which would allow a box value's component numbers to be accessed by subscripting. Otherwise the type behaves the same as before.

This example creates a large object type and uses it in a table definition:

```
CREATE TYPE bigobj (
    INPUT = lo_filein, OUTPUT = lo_fileout,
    INTERNALLENGTH = VARIABLE
);
```

```
CREATE TABLE big_objs (
    id integer,
    obj bigobj
);
```

This example creates a Nested Table type and uses it in a anonymous block:

```
CREATE TYPE names2 IS TABLE OF VARCHAR(15);

DECLARE
    nt names2 ;
BEGIN
    nt(1) = 'D Caruso';
    nt(2) = 'J Hamil';
    nt(3) = 'R Singh';
    DBMS_OUTPUT.PUT_LINE(nt(2));
END;
/
```

This example creates an object type:

```
CREATE TYPE tp AS OBJECT (
    x INT,
    y INT,
    MEMBER FUNCTION d(prompt VARCHAR) RETURN VARCHAR,
    MEMBER PROCEDURE p(prompt VARCHAR)
);
```

This example creates an object type body:

```
CREATE TYPE BODY tp AS
    MEMBER FUNCTION d(prompt VARCHAR) RETURN VARCHAR IS
    DECLARE
        v VARCHAR;
    BEGIN
        v := '(' || self.x || ',' || self.y || ')';
        raise notice '%', v;
        return v;
    END;

    MEMBER PROCEDURE p(prompt VARCHAR) IS
    BEGIN
        raise notice '%', '(' || self.x || ',' || self.y || ')';
    END;
END;
/
```

More examples, including suitable input and output functions, are in Section 36.13.

## Compatibility

The first form of the `CREATE TYPE` command, which creates a composite type, conforms to the SQL standard. The other forms are LightDB extensions. The `CREATE TYPE` statement in the SQL standard also defines other forms that are not implemented in LightDB.



The ability to create a composite type with zero attributes is a LightDB-specific deviation from the standard (analogous to the same case in `CREATE TABLE`).

`CREATE OR REPLACE TYPE name AS TABLE OF data_type`, You can either create a new Nested Table or replace an old Nested Table.

`CREATE OR REPLACE TYPE name AS OBJECT`, You can either create a new OBJECT or replace an old OBJECT.

`CREATE OR REPLACE TYPE BODY name AS subprog_decl_in_type_list END`, You can either create a new BODY or replace an old BODY.

## See Also

`ALTER TYPE`, `CREATE DOMAIN`, `CREATE FUNCTION`, `DROP TYPE`

---

# CREATE USER

CREATE USER — define a new database role

## Synopsis

```
CREATE USER name [ [ WITH ] option [ ... ] ] IDENTIFIED  
BY password option_for_oracle ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER  
    | CREATEDB | NOCREATEDB  
    | CREATEROLE | NOCREATEROLE  
    | INHERIT | NOINHERIT  
    | LOGIN | NOLOGIN  
    | REPLICATION | NOREPLICATION  
    | BYPASSRLS | NOBYPASSRLS  
    | CONNECTION LIMIT connlimit  
    | [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
    | VALID UNTIL 'timestamp'  
    | IN ROLE role_name [ , ... ]  
    | IN GROUP role_name [ , ... ]  
    | ROLE role_name [ , ... ]  
    | ADMIN role_name [ , ... ]  
    | USER role_name [ , ... ]  
    | SYSID uid
```

where *option\_for\_oracle* can be:

```
    DEFAULT TABLESPACE tablespace  
    | TEMPORARY TABLESPACE tablespace
```

## Parameters

IDENTIFIED BY

Used to CREATE USER statement compatible with Oracle. *option\_for\_oracle* that only syntax support is provided, not function support. In order to be compatible with the Oracle grant function, it is not allowed to CREATE USER with the names of 'connect' and 'resource' in Oracle mode. It must be used in Oracle database.

## Description

CREATE USER is now an alias for CREATE ROLE. The only difference is that when the command is spelled CREATE USER, LOGIN is assumed by default, whereas NOLOGIN is assumed when the command is spelled CREATE ROLE.

## Compatibility

The CREATE USER statement is a LightDB extension. The SQL standard leaves the definition of users to the implementation.

## See Also

CREATE ROLE

---

# CREATE USER MAPPING

CREATE USER MAPPING — define a new mapping of a user to a foreign server

## Synopsis

```
CREATE USER MAPPING [ IF NOT EXISTS ] FOR { user_name | USER |  
CURRENT_USER | PUBLIC }  
    SERVER server_name  
    [ OPTIONS ( option 'value' [ , ... ] ) ]
```

## Description

CREATE USER MAPPING defines a mapping of a user to a foreign server. A user mapping typically encapsulates connection information that a foreign-data wrapper uses together with the information encapsulated by a foreign server to access an external data resource.

The owner of a foreign server can create user mappings for that server for any user. Also, a user can create a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

## Parameters

IF NOT EXISTS

Do not throw an error if a mapping of the given user to the given foreign server already exists. A notice is issued in this case. Note that there is no guarantee that the existing user mapping is anything like the one that would have been created.

*user\_name*

The name of an existing user that is mapped to foreign server. CURRENT\_USER and USER match the name of the current user. When PUBLIC is specified, a so-called public mapping is created that is used when no user-specific mapping is applicable.

*server\_name*

The name of an existing server for which the user mapping is to be created.

OPTIONS ( *option* '*value*' [ , ... ] )

This clause specifies the options of the user mapping. The options typically define the actual user name and password of the mapping. Option names must be unique. The allowed option names and values are specific to the server's foreign-data wrapper.

## Examples

Create a user mapping for user bob, server foo:

```
CREATE USER MAPPING FOR bob SERVER foo OPTIONS (user 'bob',  
password 'secret');
```

## Compatibility

CREATE USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED).

## See Also

ALTER USER MAPPING, DROP USER MAPPING, CREATE FOREIGN DATA WRAPPER,  
CREATE SERVER

---

# CREATE VIEW

CREATE VIEW — define a new view

## Synopsis

```
CREATE [ OR REPLACE ] [ TEMP | TEMPORARY ] [ FORCE ] [ RECURSIVE ]  
[ EDITIONABLE ] VIEW name [ ( column_name [, ...] ) ]  
  [ WITH ( view_option_name [= view_option_value] [, ...] ) ]  
  AS query  
  [ WITH [ CASCADED | LOCAL ] CHECK OPTION ]
```

## Description

CREATE VIEW defines a view of a query. The view is not physically materialized. Instead, the query is run every time the view is referenced in a query.

CREATE OR REPLACE VIEW is similar, but if a view of the same name already exists, it is replaced. The new query must generate the same columns that were generated by the existing view query (that is, the same column names in the same order and with the same data types), but it may add additional columns to the end of the list. The calculations giving rise to the output columns may be completely different.

If a schema name is given (for example, CREATE VIEW myschema.myview ...) then the view is created in the specified schema. Otherwise it is created in the current schema. Temporary views exist in a special schema, so a schema name cannot be given when creating a temporary view. The name of the view must be distinct from the name of any other view, table, sequence, index or foreign table in the same schema.

## Parameters

TEMPORARY or TEMP

If specified, the view is created as a temporary view. Temporary views are automatically dropped at the end of the current session. Existing permanent relations with the same name are not visible to the current session while the temporary view exists, unless they are referenced with schema-qualified names.

If any of the tables referenced by the view are temporary, the view is created as a temporary view (whether TEMPORARY is specified or not).

FORCE

This keyword is only for syntax support and has no actual functionality. It is used to be compatible with the use of FORCE in CREATE VIEW in Oracle.

In Oracle, specify FORCE if you want to create the view regardless of whether the base tables of the view or the referenced object types exist or the owner of the schema containing the view has privileges on them.

This syntax is only supported in Oracle compatibility mode.

EDITIONABLE

This keyword is only for syntax support and has no actual functionality. It is used to be compatible with the use of EDITIONABLE in CREATE VIEW in Oracle.

In Oracle, specify `EDITIONABLE` if you want to create the view regardless of whether the base tables of the view or the referenced object types exist or the owner of the schema containing the view has privileges on them.

This syntax is only supported in Oracle compatibility mode.

#### RECURSIVE

Creates a recursive view. The syntax

```
CREATE RECURSIVE VIEW [ schema . ] view_name (column_names) AS
SELECT ...;
```

is equivalent to

```
CREATE VIEW [ schema . ] view_name AS WITH RECURSIVE view_name
(column_names) AS (SELECT ...) SELECT column_names
FROM view_name;
```

A view column name list must be specified for a recursive view.

#### *name*

The name (optionally schema-qualified) of a view to be created.

#### *column\_name*

An optional list of names to be used for columns of the view. If not given, the column names are deduced from the query.

```
WITH ( view_option_name [= view_option_value] [, ... ] )
```

This clause specifies optional parameters for a view; the following parameters are supported:

`check_option` (enum)

This parameter may be either `local` or `cascaded`, and is equivalent to specifying `WITH [ CASCADED | LOCAL ] CHECK OPTION` (see below). This option can be changed on existing views using `ALTER VIEW`.

`security_barrier` (boolean)

This should be used if the view is intended to provide row-level security. See Section 39.5 for full details.

#### *query*

A `SELECT` or `VALUES` command which will provide the columns and rows of the view.

```
WITH [ CASCADED | LOCAL ] CHECK OPTION
```

This option controls the behavior of automatically updatable views. When this option is specified, `INSERT` and `UPDATE` commands on the view will be checked to ensure that new rows satisfy the view-defining condition (that is, the new rows are checked to ensure that they are visible through the view). If they are not, the update will be rejected. If the `CHECK OPTION` is not specified, `INSERT` and `UPDATE` commands on the view are allowed to create rows that are not visible through the view. The following check options are supported:

**LOCAL**

New rows are only checked against the conditions defined directly in the view itself. Any conditions defined on underlying base views are not checked (unless they also specify the `CHECK OPTION`).

**CASCADED**

New rows are checked against the conditions of the view and all underlying base views. If the `CHECK OPTION` is specified, and neither `LOCAL` nor `CASCADED` is specified, then `CASCADED` is assumed.

The `CHECK OPTION` may not be used with `RECURSIVE` views.

Note that the `CHECK OPTION` is only supported on views that are automatically updatable, and do not have `INSTEAD OF` triggers or `INSTEAD` rules. If an automatically updatable view is defined on top of a base view that has `INSTEAD OF` triggers, then the `LOCAL CHECK OPTION` may be used to check the conditions on the automatically updatable view, but the conditions on the base view with `INSTEAD OF` triggers will not be checked (a cascaded check option will not cascade down to a trigger-updatable view, and any check options defined directly on a trigger-updatable view will be ignored). If the view or any of its base relations has an `INSTEAD` rule that causes the `INSERT` or `UPDATE` command to be rewritten, then all check options will be ignored in the rewritten query, including any checks from automatically updatable views defined on top of the relation with the `INSTEAD` rule.

## Notes

Use the `DROP VIEW` statement to drop views.

Be careful that the names and types of the view's columns will be assigned the way you want. For example:

```
CREATE VIEW vista AS SELECT 'Hello World';
```

is bad form because the column name defaults to `?column?`; also, the column data type defaults to `text`, which might not be what you wanted. Better style for a string literal in a view's result is something like:

```
CREATE VIEW vista AS SELECT text 'Hello World' AS hello;
```

Access to tables referenced in the view is determined by permissions of the view owner. In some cases, this can be used to provide secure but restricted access to the underlying tables. However, not all views are secure against tampering; see Section 39.5 for details. Functions called in the view are treated the same as if they had been called directly from the query using the view. Therefore the user of a view must have permissions to call all functions used by the view.

When `CREATE OR REPLACE VIEW` is used on an existing view, only the view's defining `SELECT` rule is changed. Other view properties, including ownership, permissions, and non-`SELECT` rules, remain unchanged. You must own the view to replace it (this includes being a member of the owning role).

## Updatable Views

Simple views are automatically updatable: the system will allow `INSERT`, `UPDATE` and `DELETE` statements to be used on the view in the same way as on a regular table. A view is automatically updatable if it satisfies all of the following conditions:

- The view must have exactly one entry in its `FROM` list, which must be a table or another updatable view.
- The view definition must not contain `WITH`, `DISTINCT`, `GROUP BY`, `HAVING`, `LIMIT`, or `OFFSET` clauses at the top level.
- The view definition must not contain set operations (`UNION`, `INTERSECT` or `EXCEPT`) at the top level.
- The view's select list must not contain any aggregates, window functions or set-returning functions.

An automatically updatable view may contain a mix of updatable and non-updatable columns. A column is updatable if it is a simple reference to an updatable column of the underlying base relation; otherwise the column is read-only, and an error will be raised if an `INSERT` or `UPDATE` statement attempts to assign a value to it.

If the view is automatically updatable the system will convert any `INSERT`, `UPDATE` or `DELETE` statement on the view into the corresponding statement on the underlying base relation. `INSERT` statements that have an `ON CONFLICT UPDATE` clause are fully supported.

If an automatically updatable view contains a `WHERE` condition, the condition restricts which rows of the base relation are available to be modified by `UPDATE` and `DELETE` statements on the view. However, an `UPDATE` is allowed to change a row so that it no longer satisfies the `WHERE` condition, and thus is no longer visible through the view. Similarly, an `INSERT` command can potentially insert base-relation rows that do not satisfy the `WHERE` condition and thus are not visible through the view (`ON CONFLICT UPDATE` may similarly affect an existing row not visible through the view). The `CHECK OPTION` may be used to prevent `INSERT` and `UPDATE` commands from creating such rows that are not visible through the view.

If an automatically updatable view is marked with the `security_barrier` property then all the view's `WHERE` conditions (and any conditions using operators which are marked as `LEAKPROOF`) will always be evaluated before any conditions that a user of the view has added. See Section 39.5 for full details. Note that, due to this, rows which are not ultimately returned (because they do not pass the user's `WHERE` conditions) may still end up being locked. `EXPLAIN` can be used to see which conditions are applied at the relation level (and therefore do not lock rows) and which are not.

A more complex view that does not satisfy all these conditions is read-only by default: the system will not allow an insert, update, or delete on the view. You can get the effect of an updatable view by creating `INSTEAD OF` triggers on the view, which must convert attempted inserts, etc. on the view into appropriate actions on other tables. For more information see `CREATE TRIGGER`. Another possibility is to create rules (see `CREATE RULE`), but in practice triggers are easier to understand and use correctly.

Note that the user performing the insert, update or delete on the view must have the corresponding insert, update or delete privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the update does not need any permissions on the underlying base relations (see Section 39.5).

## Examples

Create a view consisting of all comedy films:

```
CREATE VIEW comedies AS
  SELECT *
  FROM films
  WHERE kind = 'Comedy';
```

This will create a view containing the columns that are in the `film` table at the time of view creation. Though `*` was used to create the view, columns added later to the table will not be part of the view.



Create a view with LOCAL CHECK OPTION:

```
CREATE VIEW universal_comedies AS
  SELECT *
  FROM comedies
  WHERE classification = 'U'
  WITH LOCAL CHECK OPTION;
```

This will create a view based on the comedies view, showing only films with kind = 'Comedy' and classification = 'U'. Any attempt to INSERT or UPDATE a row in the view will be rejected if the new row doesn't have classification = 'U', but the film kind will not be checked.

Create a view with CASCADED CHECK OPTION:

```
CREATE VIEW pg_comedies AS
  SELECT *
  FROM comedies
  WHERE classification = 'PG'
  WITH CASCADED CHECK OPTION;
```

This will create a view that checks both the kind and classification of new rows.

Create a view with a mix of updatable and non-updatable columns:

```
CREATE VIEW comedies AS
  SELECT f.*,
         country_code_to_name(f.country_code) AS country,
         (SELECT avg(r.rating)
          FROM user_ratings r
          WHERE r.film_id = f.id) AS avg_rating
  FROM films f
  WHERE f.kind = 'Comedy';
```

This view will support INSERT, UPDATE and DELETE. All the columns from the films table will be updatable, whereas the computed columns country and avg\_rating will be read-only.

Create a recursive view consisting of the numbers from 1 to 100:

```
CREATE RECURSIVE VIEW public.nums_1_100 (n) AS
  VALUES (1)
  UNION ALL
  SELECT n+1 FROM nums_1_100 WHERE n < 100;
```

Notice that although the recursive view's name is schema-qualified in this CREATE, its internal self-reference is not schema-qualified. This is because the implicitly-created CTE's name cannot be schema-qualified.

Create a force view:

```
CREATE FORCE VIEW comedies AS
  SELECT *
  FROM films
  WHERE kind = 'Comedy';
```

Notice that the FORCE VIEW is only for syntax support and has no actual functionality.

## Compatibility

`CREATE OR REPLACE VIEW` is a LightDB language extension. So is the concept of a temporary view. The `WITH ( ... )` clause is an extension as well.

## See Also

`ALTER VIEW`, `DROP VIEW`, `CREATE MATERIALIZED VIEW`

---

# DEALLOCATE

DEALLOCATE — deallocate a prepared statement

## Synopsis

```
DEALLOCATE [ PREPARE ] { name | ALL }
```

## Description

DEALLOCATE is used to deallocate a previously prepared SQL statement. If you do not explicitly deallocate a prepared statement, it is deallocated when the session ends.

For more information on prepared statements, see PREPARE.

## Parameters

PREPARE

This key word is ignored.

*name*

The name of the prepared statement to deallocate.

ALL

Deallocate all prepared statements.

## Compatibility

The SQL standard includes a DEALLOCATE statement, but it is only for use in embedded SQL.

## See Also

EXECUTE, PREPARE

---

# DECLARE

DECLARE — define a cursor

## Synopsis

```
DECLARE name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
        CURSOR [ { WITH | WITHOUT } HOLD ] FOR query
```

## Description

DECLARE allows a user to create cursors, which can be used to retrieve a small number of rows at a time out of a larger query. After the cursor is created, rows are fetched from it using FETCH.

### Note

This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 41.7.

## Parameters

*name*

The name of the cursor to be created.

BINARY

Causes the cursor to return data in binary rather than in text format.

INSENSITIVE

Indicates that data retrieved from the cursor should be unaffected by updates to the table(s) underlying the cursor that occur after the cursor is created. In LightDB, this is the default behavior; so this key word has no effect and is only accepted for compatibility with the SQL standard.

SCROLL

NO SCROLL

SCROLL specifies that the cursor can be used to retrieve rows in a nonsequential fashion (e.g., backward). Depending upon the complexity of the query's execution plan, specifying SCROLL might impose a performance penalty on the query's execution time. NO SCROLL specifies that the cursor cannot be used to retrieve rows in a nonsequential fashion. The default is to allow scrolling in some cases; this is not the same as specifying SCROLL. See Notes below for details.

WITH HOLD

WITHOUT HOLD

WITH HOLD specifies that the cursor can continue to be used after the transaction that created it successfully commits. WITHOUT HOLD specifies that the cursor cannot be used outside of the transaction that created it. If neither WITHOUT HOLD nor WITH HOLD is specified, WITHOUT HOLD is the default.

*query*

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

The key words `BINARY`, `INSENSITIVE`, and `SCROLL` can appear in any order.

## Notes

Normal cursors return data in text format, the same as a `SELECT` would produce. The `BINARY` option specifies that the cursor should return data in binary format. This reduces conversion effort for both the server and client, at the cost of more programmer effort to deal with platform-dependent binary data formats. As an example, if a query returns a value of one from an integer column, you would get a string of 1 with a default cursor, whereas with a binary cursor you would get a 4-byte field containing the internal representation of the value (in big-endian byte order).

Binary cursors should be used carefully. Many applications, including `ltsql`, are not prepared to handle binary cursors and expect data to come back in the text format.

### Note

When the client application uses the “extended query” protocol to issue a `FETCH` command, the `Bind` protocol message specifies whether data is to be retrieved in text or binary format. This choice overrides the way that the cursor is defined. The concept of a binary cursor as such is thus obsolete when using extended query protocol — any cursor can be treated as either text or binary.

Unless `WITH HOLD` is specified, the cursor created by this command can only be used within the current transaction. Thus, `DECLARE` without `WITH HOLD` is useless outside a transaction block: the cursor would survive only to the completion of the statement. Therefore `LightDB` reports an error if such a command is used outside a transaction block. Use `BEGIN` and `COMMIT` (or `ROLLBACK`) to define a transaction block.

If `WITH HOLD` is specified and the transaction that created the cursor successfully commits, the cursor can continue to be accessed by subsequent transactions in the same session. (But if the creating transaction is aborted, the cursor is removed.) A cursor created with `WITH HOLD` is closed when an explicit `CLOSE` command is issued on it, or the session ends. In the current implementation, the rows represented by a held cursor are copied into a temporary file or memory area so that they remain available for subsequent transactions.

`WITH HOLD` may not be specified when the query includes `FOR UPDATE` or `FOR SHARE`.

The `SCROLL` option should be specified when defining a cursor that will be used to fetch backwards. This is required by the SQL standard. However, for compatibility with earlier versions, `LightDB` will allow backward fetches without `SCROLL`, if the cursor's query plan is simple enough that no extra overhead is needed to support it. However, application developers are advised not to rely on using backward fetches from a cursor that has not been created with `SCROLL`. If `NO SCROLL` is specified, then backward fetches are disallowed in any case.

Backward fetches are also disallowed when the query includes `FOR UPDATE` or `FOR SHARE`; therefore `SCROLL` may not be specified in this case.

### Caution

Scrollable cursors may give unexpected results if they invoke any volatile functions (see Section 36.7). When a previously fetched row is re-fetched, the functions might be re-executed, perhaps leading to results different from the first time. It's best to specify `NO SCROLL` for a query involving volatile functions. If that is not practical, one workaround is to declare the cursor `SCROLL WITH HOLD` and commit the transaction before reading any rows from it. This will force the entire output of the cursor to be

materialized in temporary storage, so that volatile functions are executed exactly once for each row.

If the cursor's query includes `FOR UPDATE` or `FOR SHARE`, then returned rows are locked at the time they are first fetched, in the same way as for a regular `SELECT` command with these options. In addition, the returned rows will be the most up-to-date versions; therefore these options provide the equivalent of what the SQL standard calls a “sensitive cursor”. (Specifying `INSENSITIVE` together with `FOR UPDATE` or `FOR SHARE` is an error.)

### Caution

It is generally recommended to use `FOR UPDATE` if the cursor is intended to be used with `UPDATE . . . WHERE CURRENT OF` or `DELETE . . . WHERE CURRENT OF`. Using `FOR UPDATE` prevents other sessions from changing the rows between the time they are fetched and the time they are updated. Without `FOR UPDATE`, a subsequent `WHERE CURRENT OF` command will have no effect if the row was changed since the cursor was created.

Another reason to use `FOR UPDATE` is that without it, a subsequent `WHERE CURRENT OF` might fail if the cursor query does not meet the SQL standard's rules for being “simply updatable” (in particular, the cursor must reference just one table and not use grouping or `ORDER BY`). Cursors that are not simply updatable might work, or might not, depending on plan choice details; so in the worst case, an application might work in testing and then fail in production. If `FOR UPDATE` is specified, the cursor is guaranteed to be updatable.

The main reason not to use `FOR UPDATE` with `WHERE CURRENT OF` is if you need the cursor to be scrollable, or to be insensitive to the subsequent updates (that is, continue to show the old data). If this is a requirement, pay close heed to the caveats shown above.

The SQL standard only makes provisions for cursors in embedded SQL. The LightDB server does not implement an `OPEN` statement for cursors; a cursor is considered to be open when it is declared. However, ECPG, the embedded SQL preprocessor for LightDB, supports the standard SQL cursor conventions, including those involving `DECLARE` and `OPEN` statements.

You can see all available cursors by querying the `pg_cursors` system view.

## Examples

To declare a cursor:

```
DECLARE liahona CURSOR FOR SELECT * FROM films;
```

See `FETCH` for more examples of cursor usage.

## Compatibility

The SQL standard says that it is implementation-dependent whether cursors are sensitive to concurrent updates of the underlying data by default. In LightDB, cursors are insensitive by default, and can be made sensitive by specifying `FOR UPDATE`. Other products may work differently.

The SQL standard allows cursors only in embedded SQL and in modules. LightDB permits cursors to be used interactively.

Binary cursors are a LightDB extension.

## **See Also**

CLOSE, FETCH, MOVE

---

# DELETE

DELETE — delete rows of a table

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
DELETE FROM [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    [ USING from_item [, ...] ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
    { FIRST | LAST } ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ {RETURNING|RETURN} * | output_expression [ [ AS ] output_name
    ] [, ...] ]
```

## Description

DELETE deletes rows that satisfy the WHERE clause from the specified table. If the WHERE clause is absent, the effect is to delete all rows in the table. The result is a valid, but empty table.

### Tip

TRUNCATE provides a faster mechanism to remove all rows from a table.

There are two ways to delete rows in a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the USING clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes DELETE to compute and return value(s) based on each row actually deleted. Any expression using the table's columns, and/or columns of other tables mentioned in USING, can be computed. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the DELETE privilege on the table to delete from it, as well as the SELECT privilege for any table in the USING clause or whose values are read in the *condition*.

If the ORDER BY clause is specified, you can delete rows in the specified order. It's semantic like SELECT ORDER BY clause. Notice, do not support delete inherit table with ORDER BY clause, not support canopy also.

If the LIMIT or OFFSET clause is specified, you can delete a subset of rows. It's semantic like SELECT LIMIT clause. Notice, do not support update inherit table with LIMIT or OFFSET clause, not support canopy also.

## Parameters

*with\_query*

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the DELETE query. See Section 7.8 and SELECT for details.



*table\_name*

The name (optionally schema-qualified) of the table to delete rows from. If `ONLY` is specified before the table name, matching rows are deleted from the named table only. If `ONLY` is not specified, matching rows are also deleted from any tables inheriting from the named table. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

*alias*

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `DELETE FROM foo AS f`, the remainder of the `DELETE` statement must refer to this table as `f` not `foo`.

*from\_item*

A table expression allowing columns from other tables to appear in the `WHERE` condition. This uses the same syntax as the `FROM` clause of a `SELECT` statement; for example, an alias for the table name can be specified. Do not repeat the target table as a *from\_item* unless you wish to set up a self-join (in which case it must appear with an alias in the *from\_item*).

*condition*

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be deleted.

*cursor\_name*

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be deleted is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `DELETE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See `DECLARE` for more information about using cursors with `WHERE CURRENT OF`.

*output\_expression*

An expression to be computed and returned by the `DELETE` command after each row is deleted. The expression can use any column names of the table named by *table\_name* or table(s) listed in `USING`. Write `*` to return all columns.

*output\_name*

A name to use for a returned column.

## Outputs

On successful completion, a `DELETE` command returns a command tag of the form

`DELETE count`

The *count* is the number of rows deleted. Note that the number may be less than the number of rows that matched the *condition* when deletes were suppressed by a `BEFORE DELETE` trigger. If *count* is 0, no rows were deleted by the query (this is not considered an error).

If the `DELETE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) deleted by the command.

## Notes

LightDB lets you reference columns of other tables in the `WHERE` condition by specifying the other tables in the `USING` clause. For example, to delete all films produced by a given producer, one can do:

```
DELETE FROM films USING producers
  WHERE producer_id = producers.id AND producers.name = 'foo';
```

What is essentially happening here is a join between `films` and `producers`, with all successfully joined `films` rows being marked for deletion. This syntax is not standard. A more standard way to do it is:

```
DELETE FROM films
  WHERE producer_id IN (SELECT id FROM producers WHERE name =
    'foo');
```

In some cases the join style is easier to write or faster to execute than the sub-select style.

## Examples

Delete all films but musicals:

```
DELETE FROM films WHERE kind <> 'Musical';
```

Clear the table `films`:

```
DELETE FROM films;
```

Delete completed tasks, returning full details of the deleted rows:

```
DELETE FROM tasks WHERE status = 'DONE' RETURNING *;
DELETE FROM tasks WHERE status = 'DONE' RETURN *;
```

Delete the row of `tasks` on which the cursor `c_tasks` is currently positioned:

```
DELETE FROM tasks WHERE CURRENT OF c_tasks;
```

Delete the rows of `citys` on which order by `id` limit 5.

```
DELETE FROM citys order by id LIMIT 5;
```

## Compatibility

This command conforms to the SQL standard, except that the `USING` and `RETURNING` clauses are LightDB extensions, as is the ability to use `WITH` with `DELETE`.

`FROM` is optional since LightDB 23.2, please refer to the examples as below:

Clear the table `films`:

```
DELETE films;
```

Delete all films but musicals:

```
DELETE films WHERE kind <> 'Musical';
```

## See Also

TRUNCATE

---

# DISCARD

DISCARD — discard session state

## Synopsis

```
DISCARD { ALL | PLANS | SEQUENCES | TEMPORARY | TEMP }
```

## Description

DISCARD releases internal resources associated with a database session. This command is useful for partially or fully resetting the session's state. There are several subcommands to release different types of resources; the DISCARD ALL variant subsumes all the others, and also resets additional state.

## Parameters

PLANS

Releases all cached query plans, forcing re-planning to occur the next time the associated prepared statement is used.

SEQUENCES

Discards all cached sequence-related state, including `currval()`/`lastval()` information and any preallocated sequence values that have not yet been returned by `nextval()`. (See CREATE SEQUENCE for a description of preallocated sequence values.)

TEMPORARY or TEMP

Drops all temporary tables created in the current session.

ALL

Releases all temporary resources associated with the current session and resets the session to its initial state. Currently, this has the same effect as executing the following sequence of statements:

```
CLOSE ALL;  
SET SESSION AUTHORIZATION DEFAULT;  
RESET ALL;  
DEALLOCATE ALL;  
UNLISTEN *;  
SELECT pg_advisory_unlock_all();  
DISCARD PLANS;  
DISCARD TEMP;  
DISCARD SEQUENCES;
```

## Notes

DISCARD ALL cannot be executed inside a transaction block.

## Compatibility

DISCARD is a LightDB extension.

---

# DO

DO — execute an anonymous code block

## Synopsis

```
DO [ (type [, ...]) USING (argument [, ...]) ] [ LANGUAGE lang_name ] code
```

## Description

DO executes an anonymous code block, or in other words a transient anonymous function in a procedural language.

The code block is treated as though it were the body of a function with no parameters, returning `void`. It is parsed and executed a single time.

With the `USING` clause, the code block is treated as though it were the body of a function with parameters, returning `record`. With `prepareStatement`, it can be parsed once and executed multiple times, but it is cheap to parse it. Normally it used in `ecpg`.

The optional `USING` clause can be written either before or after the code block, but it can only be used for `plorasql` now.

The optional `LANGUAGE` clause can be written either before or after the code block.

## Parameters

*code*

The procedural language code to be executed. This must be specified as a string literal, just as in `CREATE FUNCTION`. Use of a dollar-quoted literal is recommended.

*lang\_name*

The name of the procedural language the code is written in. If omitted, the default is `plpgsql`.

*type*

The type of the argument. the argument's mode is always `inout`.

*argument*

The argument used for executing an anonymous code block like `CALL`.

## Notes

The procedural language to be used must already have been installed into the current database by means of `CREATE EXTENSION`. `plpgsql` is installed by default, but other languages are not.

The user must have `USAGE` privilege for the procedural language, or must be a superuser if the language is untrusted. This is the same privilege requirement as for creating a function in the language.

If `DO` is executed in a transaction block, then the procedure code cannot execute transaction control statements. Transaction control statements are only allowed if `DO` is executed in its own transaction.

## Examples

Grant all privileges on all views in schema `public` to role `webuser`:

```
DO $$DECLARE r record;
BEGIN
    FOR r IN SELECT table_schema, table_name FROM
        information_schema.tables
            WHERE table_type = 'VIEW' AND table_schema = 'public'
    LOOP
        EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) ||
            '.' || quote_ident(r.table_name) || ' TO webuser';
    END LOOP;
END$$;
```

Grant all privileges on all views in schema `public` to role `webuser` by arguments in `LANGUAGE plorasql`:

```
DO $$DECLARE r record;
BEGIN
    FOR r IN SELECT table_schema, table_name FROM
        information_schema.tables
            WHERE table_type = $1 AND table_schema = $2
    LOOP
        EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) ||
            '.' || quote_ident(r.table_name) || ' TO webuser';
    END LOOP;
END$$ (text, text) USING ('VIEW', 'public') LANGUAGE plorasql;
```

See Section 34.5.4 for the usage in `ecpg`.

## Compatibility

There is no `DO` statement in the SQL standard.

## See Also

`CREATE LANGUAGE`

---

# DROP ACCESS METHOD

DROP ACCESS METHOD — remove an access method

## Synopsis

```
DROP ACCESS METHOD [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP ACCESS METHOD removes an existing access method. Only superusers can drop access methods.

## Parameters

IF EXISTS

Do not throw an error if the access method does not exist. A notice is issued in this case.

*name*

The name of an existing access method.

CASCADE

Automatically drop objects that depend on the access method (such as operator classes, operator families, and indexes), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the access method if any objects depend on it. This is the default.

## Examples

Drop the access method heptree:

```
DROP ACCESS METHOD heptree;
```

## Compatibility

DROP ACCESS METHOD is a LightDB extension.

## See Also

CREATE ACCESS METHOD

---

# DROP AGGREGATE

DROP AGGREGATE — remove an aggregate function

## Synopsis

```
DROP AGGREGATE [ IF EXISTS ] name ( aggregate_signature ) [ , ... ]  
[ CASCADE | RESTRICT ]
```

where *aggregate\_signature* is:

```
* |  
[ argmode ] [ argname ] argtype [ , ... ] |  
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]  
[ argname ] argtype [ , ... ]
```

## Description

DROP AGGREGATE removes an existing aggregate function. To execute this command the current user must be the owner of the aggregate function.

## Parameters

IF EXISTS

Do not throw an error if the aggregate does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing aggregate function.

*argmode*

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

*argname*

The name of an argument. Note that DROP AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

*argtype*

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write \* in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

CASCADE

Automatically drop objects that depend on the aggregate function (such as views using it), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the aggregate function if any objects depend on it. This is the default.



## Notes

Alternative syntaxes for referencing ordered-set aggregates are described under ALTER AGGREGATE.

## Examples

To remove the aggregate function `myavg` for type `integer`:

```
DROP AGGREGATE myavg(integer);
```

To remove the hypothetical-set aggregate function `myrank`, which takes an arbitrary list of ordering columns and a matching list of direct arguments:

```
DROP AGGREGATE myrank(VARIADIC "any" ORDER BY VARIADIC "any");
```

To remove multiple aggregate functions in one command:

```
DROP AGGREGATE myavg(integer), myavg(bigint);
```

## Compatibility

There is no `DROP AGGREGATE` statement in the SQL standard.

## See Also

ALTER AGGREGATE, CREATE AGGREGATE

---

# DROP CAST

DROP CAST — remove a cast

## Synopsis

```
DROP CAST [ IF EXISTS ] (source_type AS target_type) [ CASCADE |  
RESTRICT ]
```

## Description

DROP CAST removes a previously defined cast.

To be able to drop a cast, you must own the source or the target data type. These are the same privileges that are required to create a cast.

## Parameters

IF EXISTS

Do not throw an error if the cast does not exist. A notice is issued in this case.

*source\_type*

The name of the source data type of the cast.

*target\_type*

The name of the target data type of the cast.

CASCADE  
RESTRICT

These key words do not have any effect, since there are no dependencies on casts.

## Examples

To drop the cast from type text to type int:

```
DROP CAST (text AS int);
```

## Compatibility

The DROP CAST command conforms to the SQL standard.

## See Also

CREATE CAST

---

# DROP COLLATION

DROP COLLATION — remove a collation

## Synopsis

```
DROP COLLATION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP COLLATION removes a previously defined collation. To be able to drop a collation, you must own the collation.

## Parameters

IF EXISTS

Do not throw an error if the collation does not exist. A notice is issued in this case.

*name*

The name of the collation. The collation name can be schema-qualified.

CASCADE

Automatically drop objects that depend on the collation, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the collation if any objects depend on it. This is the default.

## Examples

To drop the collation named `german`:

```
DROP COLLATION german;
```

## Compatibility

The DROP COLLATION command conforms to the SQL standard, apart from the IF EXISTS option, which is a LightDB extension.

## See Also

ALTER COLLATION, CREATE COLLATION

---

# DROP CONVERSION

DROP CONVERSION — remove a conversion

## Synopsis

```
DROP CONVERSION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP CONVERSION removes a previously defined conversion. To be able to drop a conversion, you must own the conversion.

## Parameters

IF EXISTS

Do not throw an error if the conversion does not exist. A notice is issued in this case.

*name*

The name of the conversion. The conversion name can be schema-qualified.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on conversions.

## Examples

To drop the conversion named myname:

```
DROP CONVERSION myname ;
```

## Compatibility

There is no DROP CONVERSION statement in the SQL standard, but a DROP TRANSLATION statement that goes along with the CREATE TRANSLATION statement that is similar to the CREATE CONVERSION statement in LightDB.

## See Also

ALTER CONVERSION, CREATE CONVERSION

---

# DROP DATABASE

DROP DATABASE — remove a database

## Synopsis

```
DROP DATABASE [ IF EXISTS ] name [ [ WITH ] ( option [, ...] ) ]
```

where *option* can be:

FORCE

## Description

DROP DATABASE drops a database. It removes the catalog entries for the database and deletes the directory containing the data. It can only be executed by the database owner. It cannot be executed while you are connected to the target database. (Connect to `postgres` or any other database to issue this command.) Also, if anyone else is connected to the target database, this command will fail unless you use the `FORCE` option described below.

DROP DATABASE cannot be undone. Use it with care!

## Parameters

IF EXISTS

Do not throw an error if the database does not exist. A notice is issued in this case.

*name*

The name of the database to remove.

FORCE

Attempt to terminate all existing connections to the target database. It doesn't terminate if prepared transactions, active logical replication slots or subscriptions are present in the target database.

This will fail if the current user has no permissions to terminate other connections. Required permissions are the same as with `pg_terminate_backend`, described in Section 9.27.2. This will also fail if we are not able to terminate connections.

## Notes

DROP DATABASE cannot be executed inside a transaction block.

This command cannot be executed while connected to the target database. Thus, it might be more convenient to use the program `dropdb` instead, which is a wrapper around this command.

## Compatibility

There is no DROP DATABASE statement in the SQL standard.

## See Also

CREATE DATABASE

---

# DROP DOMAIN

DROP DOMAIN — remove a domain

## Synopsis

```
DROP DOMAIN [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP DOMAIN removes a domain. Only the owner of a domain can remove it.

## Parameters

IF EXISTS

Do not throw an error if the domain does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing domain.

CASCADE

Automatically drop objects that depend on the domain (such as table columns), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the domain if any objects depend on it. This is the default.

## Examples

To remove the domain `box`:

```
DROP DOMAIN box;
```

## Compatibility

This command conforms to the SQL standard, except for the IF EXISTS option, which is a LightDB extension.

## See Also

CREATE DOMAIN, ALTER DOMAIN

---

# DROP EVENT TRIGGER

DROP EVENT TRIGGER — remove an event trigger

## Synopsis

```
DROP EVENT TRIGGER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP EVENT TRIGGER removes an existing event trigger. To execute this command, the current user must be the owner of the event trigger.

## Parameters

IF EXISTS

Do not throw an error if the event trigger does not exist. A notice is issued in this case.

*name*

The name of the event trigger to remove.

CASCADE

Automatically drop objects that depend on the trigger, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the trigger if any objects depend on it. This is the default.

## Examples

Destroy the trigger `snitch`:

```
DROP EVENT TRIGGER snitch;
```

## Compatibility

There is no DROP EVENT TRIGGER statement in the SQL standard.

## See Also

CREATE EVENT TRIGGER, ALTER EVENT TRIGGER

---

# DROP EXTENSION

DROP EXTENSION — remove an extension

## Synopsis

```
DROP EXTENSION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP EXTENSION removes extensions from the database. Dropping an extension causes its component objects, and other explicitly dependent routines (see ALTER ROUTINE, the depends on extension action), to be dropped as well.

You must own the extension to use DROP EXTENSION.

## Parameters

IF EXISTS

Do not throw an error if the extension does not exist. A notice is issued in this case.

*name*

The name of an installed extension.

CASCADE

Automatically drop objects that depend on the extension, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

This option prevents the specified extensions from being dropped if there exists non-extension-member objects that depends on any the extensions. This is the default.

## Examples

To remove the extension `hstore` from the current database:

```
DROP EXTENSION hstore;
```

This command will fail if any of `hstore`'s objects are in use in the database, for example if any tables have columns of the `hstore` type. Add the `CASCADE` option to forcibly remove those dependent objects as well.

## Compatibility

DROP EXTENSION is a LightDB extension.

## See Also

CREATE EXTENSION, ALTER EXTENSION



---

# DROP FOREIGN DATA WRAPPER

DROP FOREIGN DATA WRAPPER — remove a foreign-data wrapper

## Synopsis

```
DROP FOREIGN DATA WRAPPER [ IF EXISTS ] name [ , ... ] [ CASCADE |  
RESTRICT ]
```

## Description

DROP FOREIGN DATA WRAPPER removes an existing foreign-data wrapper. To execute this command, the current user must be the owner of the foreign-data wrapper.

## Parameters

IF EXISTS

Do not throw an error if the foreign-data wrapper does not exist. A notice is issued in this case.

*name*

The name of an existing foreign-data wrapper.

CASCADE

Automatically drop objects that depend on the foreign-data wrapper (such as foreign tables and servers), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the foreign-data wrapper if any objects depend on it. This is the default.

## Examples

Drop the foreign-data wrapper `dbi`:

```
DROP FOREIGN DATA WRAPPER dbi;
```

## Compatibility

DROP FOREIGN DATA WRAPPER conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a LightDB extension.

## See Also

CREATE FOREIGN DATA WRAPPER, ALTER FOREIGN DATA WRAPPER

---

# DROP FOREIGN TABLE

DROP FOREIGN TABLE — remove a foreign table

## Synopsis

```
DROP FOREIGN TABLE [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

## Description

DROP FOREIGN TABLE removes a foreign table. Only the owner of a foreign table can remove it.

## Parameters

IF EXISTS

Do not throw an error if the foreign table does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the foreign table to drop.

CASCADE

Automatically drop objects that depend on the foreign table (such as views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the foreign table if any objects depend on it. This is the default.

## Examples

To destroy two foreign tables, `films` and `distributors`:

```
DROP FOREIGN TABLE films, distributors;
```

## Compatibility

This command conforms to ISO/IEC 9075-9 (SQL/MED), except that the standard only allows one foreign table to be dropped per command, and apart from the `IF EXISTS` option, which is a LightDB extension.

## See Also

ALTER FOREIGN TABLE, CREATE FOREIGN TABLE

---

# DROP FUNCTION

DROP FUNCTION — remove a function

## Synopsis

```
DROP FUNCTION [ IF EXISTS ] name [ ( [ [ argmode ] [ argname ] ] argtype [ , ... ] ) ] [ , ... ]  
[ CASCADE | RESTRICT ]
```

## Description

DROP FUNCTION removes the definition of an existing function. To execute this command the user must be the owner of the function. The argument types to the function must be specified, since several different functions can exist with the same name and different argument lists.

## Parameters

IF EXISTS

Do not throw an error if the function does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing function. If no argument list is specified, the name must be unique in its schema.

*argmode*

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that DROP FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

*argname*

The name of an argument. Note that DROP FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

*argtype*

The data type(s) of the function's arguments (optionally schema-qualified), if any.

CASCADE

Automatically drop objects that depend on the function (such as operators or triggers), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the function if any objects depend on it. This is the default.

## Examples

This command removes the square root function:

```
DROP FUNCTION sqrt(integer);
```

Drop multiple functions in one command:

```
DROP FUNCTION sqrt(integer), sqrt(bigint);
```

If the function name is unique in its schema, it can be referred to without an argument list:

```
DROP FUNCTION update_employee_salaries;
```

Note that this is different from

```
DROP FUNCTION update_employee_salaries();
```

which refers to a function with zero arguments, whereas the first variant can refer to a function with any number of arguments, including zero, as long as the name is unique.

## Compatibility

This command conforms to the SQL standard, with these LightDB extensions:

- The standard only allows one function to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names

## See Also

CREATE FUNCTION, ALTER FUNCTION, DROP PROCEDURE, DROP ROUTINE

---

# DROP GROUP

DROP GROUP — remove a database role

## Synopsis

```
DROP GROUP [ IF EXISTS ] name [, ...]
```

## Description

DROP GROUP is now an alias for DROP ROLE.

## Compatibility

There is no DROP GROUP statement in the SQL standard.

## See Also

DROP ROLE

---

# DROP INDEX

DROP INDEX — remove an index

## Synopsis

```
DROP INDEX [ CONCURRENTLY ] [ IF EXISTS ] name [ , ... ] [ ON tname ] [ CASCADE | RESTRICT ]
```

## Description

DROP INDEX drops an existing index from the database system. To execute this command you must be the owner of the index.

## Parameters

### CONCURRENTLY

Drop the index without locking out concurrent selects, inserts, updates, and deletes on the index's table. A normal DROP INDEX acquires an ACCESS EXCLUSIVE lock on the table, blocking other accesses until the index drop can be completed. With this option, the command instead waits until conflicting transactions have completed.

There are several caveats to be aware of when using this option. Only one index name can be specified, and the CASCADE option is not supported. (Thus, an index that supports a UNIQUE or PRIMARY KEY constraint cannot be dropped this way.) Also, regular DROP INDEX commands can be performed within a transaction block, but DROP INDEX CONCURRENTLY cannot. Lastly, indexes on partitioned tables cannot be dropped using this option.

For temporary tables, DROP INDEX is always non-concurrent, as no other session can access them, and non-concurrent index drop is cheaper.

### IF EXISTS

Do not throw an error if the index does not exist. A notice is issued in this case.

### *name*

The name (optionally schema-qualified) of an index to remove.

### *tname*

The tname (optionally tablename) of an index to remove. but this is a syntactic sugar that is equivalent to not using 'ON tname'

### CASCADE

Automatically drop objects that depend on the index, and in turn all objects that depend on those objects (see Section 5.14).

### RESTRICT

Refuse to drop the index if any objects depend on it. This is the default.

## Examples

This command will remove the index `title_idx`:

```
DROP INDEX title_idx;
```

## Compatibility

`DROP INDEX` is a LightDB language extension. There are no provisions for indexes in the SQL standard.

## See Also

[CREATE INDEX](#)

---

# DROP LANGUAGE

DROP LANGUAGE — remove a procedural language

## Synopsis

```
DROP [ PROCEDURAL ] LANGUAGE [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

## Description

DROP LANGUAGE removes the definition of a previously registered procedural language. You must be a superuser or the owner of the language to use DROP LANGUAGE.

### Note

As of LightDB 9.1, most procedural languages have been made into “extensions”, and should therefore be removed with DROP EXTENSION not DROP LANGUAGE.

## Parameters

IF EXISTS

Do not throw an error if the language does not exist. A notice is issued in this case.

*name*

The name of an existing procedural language. For backward compatibility, the name can be enclosed by single quotes.

CASCADE

Automatically drop objects that depend on the language (such as functions in the language), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the language if any objects depend on it. This is the default.

## Examples

This command removes the procedural language `plsample`:

```
DROP LANGUAGE plsample;
```

## Compatibility

There is no DROP LANGUAGE statement in the SQL standard.

## See Also

ALTER LANGUAGE, CREATE LANGUAGE



---

# DROP MATERIALIZED VIEW

DROP MATERIALIZED VIEW — remove a materialized view

## Synopsis

```
DROP MATERIALIZED VIEW [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

## Description

DROP MATERIALIZED VIEW drops an existing materialized view. To execute this command you must be the owner of the materialized view.

## Parameters

IF EXISTS

Do not throw an error if the materialized view does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the materialized view to remove.

CASCADE

Automatically drop objects that depend on the materialized view (such as other materialized views, or regular views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the materialized view if any objects depend on it. This is the default.

## Examples

This command will remove the materialized view called `order_summary`:

```
DROP MATERIALIZED VIEW order_summary;
```

## Compatibility

DROP MATERIALIZED VIEW is a LightDB extension.

## See Also

CREATE MATERIALIZED VIEW, ALTER MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

---

# DROP OPERATOR

DROP OPERATOR — remove an operator

## Synopsis

```
DROP OPERATOR [ IF EXISTS ] name ( { left_type | NONE } ,  
  { right_type | NONE } ) [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP OPERATOR drops an existing operator from the database system. To execute this command you must be the owner of the operator.

## Parameters

IF EXISTS

Do not throw an error if the operator does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing operator.

*left\_type*

The data type of the operator's left operand; write NONE if the operator has no left operand.

*right\_type*

The data type of the operator's right operand; write NONE if the operator has no right operand.

CASCADE

Automatically drop objects that depend on the operator (such as views using it), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator if any objects depend on it. This is the default.

## Examples

Remove the power operator  $a^b$  for type integer:

```
DROP OPERATOR ^ (integer, integer);
```

Remove the left unary bitwise complement operator  $\sim b$  for type bit:

```
DROP OPERATOR ~ (none, bit);
```

Remove the right unary factorial operator  $x!$  for type bigint:

```
DROP OPERATOR ! (bigint, none);
```

Remove multiple operators in one command:

```
DROP OPERATOR ~ (none, bit), ! (bigint, none);
```

## Compatibility

There is no `DROP OPERATOR` statement in the SQL standard.

## See Also

`CREATE OPERATOR`, `ALTER OPERATOR`

---

# DROP OPERATOR CLASS

DROP OPERATOR CLASS — remove an operator class

## Synopsis

```
DROP OPERATOR CLASS [ IF EXISTS ] name USING index_method [ CASCADE  
| RESTRICT ]
```

## Description

DROP OPERATOR CLASS drops an existing operator class. To execute this command you must be the owner of the operator class.

DROP OPERATOR CLASS does not drop any of the operators or functions referenced by the class. If there are any indexes depending on the operator class, you will need to specify CASCADE for the drop to complete.

## Parameters

IF EXISTS

Do not throw an error if the operator class does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing operator class.

*index\_method*

The name of the index access method the operator class is for.

CASCADE

Automatically drop objects that depend on the operator class (such as indexes), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator class if any objects depend on it. This is the default.

## Notes

DROP OPERATOR CLASS will not drop the operator family containing the class, even if there is nothing else left in the family (in particular, in the case where the family was implicitly created by CREATE OPERATOR CLASS). An empty operator family is harmless, but for the sake of tidiness you might wish to remove the family with DROP OPERATOR FAMILY; or perhaps better, use DROP OPERATOR FAMILY in the first place.

## Examples

Remove the B-tree operator class `widget_ops`:

```
DROP OPERATOR CLASS widget_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator class. Add `CASCADE` to drop such indexes along with the operator class.

## Compatibility

There is no `DROP OPERATOR CLASS` statement in the SQL standard.

## See Also

`ALTER OPERATOR CLASS`, `CREATE OPERATOR CLASS`, `DROP OPERATOR FAMILY`

---

# DROP OPERATOR FAMILY

DROP OPERATOR FAMILY — remove an operator family

## Synopsis

```
DROP OPERATOR FAMILY [ IF EXISTS ] name USING index_method
[ CASCADE | RESTRICT ]
```

## Description

DROP OPERATOR FAMILY drops an existing operator family. To execute this command you must be the owner of the operator family.

DROP OPERATOR FAMILY includes dropping any operator classes contained in the family, but it does not drop any of the operators or functions referenced by the family. If there are any indexes depending on operator classes within the family, you will need to specify CASCADE for the drop to complete.

## Parameters

IF EXISTS

Do not throw an error if the operator family does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing operator family.

*index\_method*

The name of the index access method the operator family is for.

CASCADE

Automatically drop objects that depend on the operator family, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator family if any objects depend on it. This is the default.

## Examples

Remove the B-tree operator family `float_ops`:

```
DROP OPERATOR FAMILY float_ops USING btree;
```

This command will not succeed if there are any existing indexes that use operator classes within the family. Add CASCADE to drop such indexes along with the operator family.

## Compatibility

There is no DROP OPERATOR FAMILY statement in the SQL standard.

## **See Also**

ALTER OPERATOR FAMILY, CREATE OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

---

# DROP OWNED

DROP OWNED — remove database objects owned by a database role

## Synopsis

```
DROP OWNED BY { name | CURRENT_USER | SESSION_USER } [, ...]  
[ CASCADE | RESTRICT ]
```

## Description

DROP OWNED drops all the objects within the current database that are owned by one of the specified roles. Any privileges granted to the given roles on objects in the current database or on shared objects (databases, tablespaces) will also be revoked.

## Parameters

*name*

The name of a role whose objects will be dropped, and whose privileges will be revoked.

CASCADE

Automatically drop objects that depend on the affected objects, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the objects owned by a role if any other database objects depend on one of the affected objects. This is the default.

## Notes

DROP OWNED is often used to prepare for the removal of one or more roles. Because DROP OWNED only affects the objects in the current database, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

Using the CASCADE option might make the command recurse to objects owned by other users.

The REASSIGN OWNED command is an alternative that reassigns the ownership of all the database objects owned by one or more roles. However, REASSIGN OWNED does not deal with privileges for other objects.

Databases and tablespaces owned by the role(s) will not be removed.

See Section 19.4 for more discussion.

## Compatibility

The DROP OWNED command is a LightDB extension.

## See Also

REASSIGN OWNED, DROP ROLE



---

# DROP POLICY

DROP POLICY — remove a row level security policy from a table

## Synopsis

```
DROP POLICY [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

## Description

DROP POLICY removes the specified policy from the table. Note that if the last policy is removed for a table and the table still has row level security enabled via ALTER TABLE, then the default-deny policy will be used. ALTER TABLE ... DISABLE ROW LEVEL SECURITY can be used to disable row level security for a table, whether policies for the table exist or not.

## Parameters

IF EXISTS

Do not throw an error if the policy does not exist. A notice is issued in this case.

*name*

The name of the policy to drop.

*table\_name*

The name (optionally schema-qualified) of the table that the policy is on.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on policies.

## Examples

To drop the policy called p1 on the table named my\_table:

```
DROP POLICY p1 ON my_table;
```

## Compatibility

DROP POLICY is a LightDB extension.

## See Also

CREATE POLICY, ALTER POLICY

---

# DROP PROCEDURE

DROP PROCEDURE — remove a procedure

## Synopsis

```
DROP PROCEDURE [ IF EXISTS ] name [ ( [ [ argmode ] [ argname ]
] argtype [ , ... ] ) ] [ , ... ]
[ CASCADE | RESTRICT ]
```

## Description

DROP PROCEDURE removes the definition of an existing procedure. To execute this command the user must be the owner of the procedure. The argument types to the procedure must be specified, since several different procedures can exist with the same name and different argument lists.

## Parameters

IF EXISTS

Do not throw an error if the procedure does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

*argmode*

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

*argname*

The name of an argument. Note that DROP PROCEDURE does not actually pay any attention to argument names, since only the argument data types are needed to determine the procedure's identity.

*argtype*

The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

CASCADE

Automatically drop objects that depend on the procedure, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the procedure if any objects depend on it. This is the default.

## Examples

```
DROP PROCEDURE do_db_maintenance();
```

## Compatibility

This command conforms to the SQL standard, with these LightDB extensions:

- The standard only allows one procedure to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names

## See Also

`CREATE PROCEDURE`, `ALTER PROCEDURE`, `DROP FUNCTION`, `DROP ROUTINE`

---

# DROP PUBLICATION

DROP PUBLICATION — remove a publication

## Synopsis

```
DROP PUBLICATION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP PUBLICATION removes an existing publication from the database.

A publication can only be dropped by its owner or a superuser.

## Parameters

IF EXISTS

Do not throw an error if the publication does not exist. A notice is issued in this case.

*name*

The name of an existing publication.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on publications.

## Examples

Drop a publication:

```
DROP PUBLICATION mypublication;
```

## Compatibility

DROP PUBLICATION is a LightDB extension.

## See Also

CREATE PUBLICATION, ALTER PUBLICATION

---

# DROP ROLE

DROP ROLE — remove a database role

## Synopsis

```
DROP ROLE [ IF EXISTS ] name [, ...]
```

## Description

DROP ROLE removes the specified role(s). To drop a superuser role, you must be a superuser yourself; to drop non-superuser roles, you must have CREATEROLE privilege.

A role cannot be removed if it is still referenced in any database of the cluster; an error will be raised if so. Before dropping the role, you must drop all the objects it owns (or reassign their ownership) and revoke any privileges the role has been granted on other objects. The REASSIGN OWNED and DROP OWNED commands can be useful for this purpose; see Section 19.4 for more discussion.

However, it is not necessary to remove role memberships involving the role; DROP ROLE automatically revokes any memberships of the target role in other roles, and of other roles in the target role. The other roles are not dropped nor otherwise affected.

## Parameters

IF EXISTS

Do not throw an error if the role does not exist. A notice is issued in this case.

*name*

The name of the role to remove.

## Notes

LightDB includes a program dropuser that has the same functionality as this command (in fact, it calls this command) but can be run from the command shell.

## Examples

To drop a role:

```
DROP ROLE jonathan;
```

## Compatibility

The SQL standard defines DROP ROLE, but it allows only one role to be dropped at a time, and it specifies different privilege requirements than LightDB uses.

## See Also

CREATE ROLE, ALTER ROLE, SET ROLE

---

# DROP ROUTINE

DROP ROUTINE — remove a routine

## Synopsis

```
DROP ROUTINE [ IF EXISTS ] name [ ( [ [ argmode ] [ argname ] ] argtype [ , ... ] ) ] [ , ... ]  
[ CASCADE | RESTRICT ]
```

## Description

DROP ROUTINE removes the definition of an existing routine, which can be an aggregate function, a normal function, or a procedure. See under DROP AGGREGATE, DROP FUNCTION, and DROP PROCEDURE for the description of the parameters, more examples, and further details.

## Examples

To drop the routine `foo` for type `integer`:

```
DROP ROUTINE foo(integer);
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

## Compatibility

This command conforms to the SQL standard, with these LightDB extensions:

- The standard only allows one routine to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names
- Aggregate functions are an extension.

## See Also

DROP AGGREGATE, DROP FUNCTION, DROP PROCEDURE, ALTER ROUTINE

Note that there is no `CREATE ROUTINE` command.

---

# DROP RULE

DROP RULE — remove a rewrite rule

## Synopsis

```
DROP RULE [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

## Description

DROP RULE drops a rewrite rule.

## Parameters

IF EXISTS

Do not throw an error if the rule does not exist. A notice is issued in this case.

*name*

The name of the rule to drop.

*table\_name*

The name (optionally schema-qualified) of the table or view that the rule applies to.

CASCADE

Automatically drop objects that depend on the rule, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the rule if any objects depend on it. This is the default.

## Examples

To drop the rewrite rule `newrule`:

```
DROP RULE newrule ON mytable;
```

## Compatibility

DROP RULE is a LightDB language extension, as is the entire query rewrite system.

## See Also

CREATE RULE, ALTER RULE

---

# DROP SCHEMA

DROP SCHEMA — remove a schema

## Synopsis

```
DROP SCHEMA [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP SCHEMA removes schemas from the database.

A schema can only be dropped by its owner or a superuser. Note that the owner can drop the schema (and thereby all contained objects) even if they do not own some of the objects within the schema.

## Parameters

IF EXISTS

Do not throw an error if the schema does not exist. A notice is issued in this case.

*name*

The name of a schema.

CASCADE

Automatically drop objects (tables, functions, etc.) that are contained in the schema, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the schema if it contains any objects. This is the default.

## Notes

Using the CASCADE option might make the command remove objects in other schemas besides the one(s) named.

## Examples

To remove schema `mystuff` from the database, along with everything it contains:

```
DROP SCHEMA mystuff CASCADE;
```

## Compatibility

DROP SCHEMA is fully conforming with the SQL standard, except that the standard only allows one schema to be dropped per command, and apart from the IF EXISTS option, which is a LightDB extension.

## See Also

ALTER SCHEMA, CREATE SCHEMA



---

# DROP SEQUENCE

DROP SEQUENCE — remove a sequence

## Synopsis

```
DROP SEQUENCE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP SEQUENCE removes sequence number generators. A sequence can only be dropped by its owner or a superuser.

## Parameters

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of a sequence.

CASCADE

Automatically drop objects that depend on the sequence, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the sequence if any objects depend on it. This is the default.

## Examples

To remove the sequence `serial`:

```
DROP SEQUENCE serial;
```

## Compatibility

DROP SEQUENCE conforms to the SQL standard, except that the standard only allows one sequence to be dropped per command, and apart from the IF EXISTS option, which is a LightDB extension.

## See Also

CREATE SEQUENCE, ALTER SEQUENCE

---

# DROP SERVER

DROP SERVER — remove a foreign server descriptor

## Synopsis

```
DROP SERVER [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP SERVER removes an existing foreign server descriptor. To execute this command, the current user must be the owner of the server.

## Parameters

IF EXISTS

Do not throw an error if the server does not exist. A notice is issued in this case.

*name*

The name of an existing server.

CASCADE

Automatically drop objects that depend on the server (such as user mappings), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the server if any objects depend on it. This is the default.

## Examples

Drop a server `foo` if it exists:

```
DROP SERVER IF EXISTS foo;
```

## Compatibility

DROP SERVER conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a LightDB extension.

## See Also

CREATE SERVER, ALTER SERVER

---

# DROP STATISTICS

DROP STATISTICS — remove extended statistics

## Synopsis

```
DROP STATISTICS [ IF EXISTS ] name [ , ... ] [ CASCADE | RESTRICT ]
```

## Description

DROP STATISTICS removes statistics object(s) from the database. Only the statistics object's owner, the schema owner, or a superuser can drop a statistics object.

## Parameters

IF EXISTS

Do not throw an error if the statistics object does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the statistics object to drop.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on statistics.

## Examples

To destroy two statistics objects in different schemas, without failing if they don't exist:

```
DROP STATISTICS IF EXISTS
  accounting.users_uid_creation,
  public.grants_user_role;
```

## Compatibility

There is no DROP STATISTICS command in the SQL standard.

## See Also

ALTER STATISTICS, CREATE STATISTICS

---

# DROP SUBSCRIPTION

DROP SUBSCRIPTION — remove a subscription

## Synopsis

```
DROP SUBSCRIPTION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP SUBSCRIPTION removes a subscription from the database cluster.

A subscription can only be dropped by a superuser.

DROP SUBSCRIPTION cannot be executed inside a transaction block if the subscription is associated with a replication slot. (You can use ALTER SUBSCRIPTION to unset the slot.)

## Parameters

*name*

The name of a subscription to be dropped.

CASCADE  
RESTRICT

These key words do not have any effect, since there are no dependencies on subscriptions.

## Notes

When dropping a subscription that is associated with a replication slot on the remote host (the normal state), DROP SUBSCRIPTION will connect to the remote host and try to drop the replication slot as part of its operation. This is necessary so that the resources allocated for the subscription on the remote host are released. If this fails, either because the remote host is not reachable or because the remote replication slot cannot be dropped or does not exist or never existed, the DROP SUBSCRIPTION command will fail. To proceed in this situation, disassociate the subscription from the replication slot by executing ALTER SUBSCRIPTION ... SET (slot\_name = NONE). After that, DROP SUBSCRIPTION will no longer attempt any actions on a remote host. Note that if the remote replication slot still exists, it should then be dropped manually; otherwise it will continue to reserve WAL and might eventually cause the disk to fill up. See also Section 28.2.1.

If a subscription is associated with a replication slot, then DROP SUBSCRIPTION cannot be executed inside a transaction block.

## Examples

Drop a subscription:

```
DROP SUBSCRIPTION mysub;
```

## Compatibility

DROP SUBSCRIPTION is a LightDB extension.

## **See Also**

CREATE SUBSCRIPTION, ALTER SUBSCRIPTION

---

# DROP TABLE

DROP TABLE — remove a table

## Synopsis

```
DROP TABLE [ IF EXISTS ] name [, ...] [ CASCADE [CONSTRAINTS] |  
RESTRICT ]
```

## Description

DROP TABLE removes tables from the database. Only the table owner, the schema owner, and superuser can drop a table. To empty a table of rows without destroying the table, use DELETE or TRUNCATE.

DROP TABLE always removes any indexes, rules, triggers, and constraints that exist for the target table. However, to drop a table that is referenced by a view or a foreign-key constraint of another table, CASCADE must be specified. (CASCADE will remove a dependent view entirely, but in the foreign-key case it will only remove the foreign-key constraint, not the other table entirely.)

## Parameters

IF EXISTS

Do not throw an error if the table does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the table to drop.

CASCADE

Automatically drop objects that depend on the table (such as views), and in turn all objects that depend on those objects (see Section 5.14).

CASCADE CONSTRAINTS

Automatically drop objects that depend on the table (such as views), and in turn all objects that depend on those objects. This is compatible with Oracle syntax and has the same actual functionality as CASCADE (see Section 5.14).

RESTRICT

Refuse to drop the table if any objects depend on it. This is the default.

## Examples

To destroy two tables, `films` and `distributors`:

```
DROP TABLE films, distributors;
```

To destroy table `films` and automatically drop objects that depend on the table:

```
DROP TABLE films CASCADE;
```

or

```
DROP TABLE films CASCADE CONSTRAINTS;
```

## Compatibility

This command conforms to the SQL standard, except that the standard only allows one table to be dropped per command, and apart from the `IF EXISTS` option, which is a LightDB extension.

## See Also

ALTER TABLE, CREATE TABLE

---

# DROP TABLESPACE

DROP TABLESPACE — remove a tablespace

## Synopsis

```
DROP TABLESPACE [ IF EXISTS ] name
```

## Description

DROP TABLESPACE removes a tablespace from the system.

A tablespace can only be dropped by its owner or a superuser. The tablespace must be empty of all database objects before it can be dropped. It is possible that objects in other databases might still reside in the tablespace even if no objects in the current database are using the tablespace. Also, if the tablespace is listed in the `temp_tablespaces` setting of any active session, the DROP might fail due to temporary files residing in the tablespace.

## Parameters

IF EXISTS

Do not throw an error if the tablespace does not exist. A notice is issued in this case.

*name*

The name of a tablespace.

## Notes

DROP TABLESPACE cannot be executed inside a transaction block.

## Examples

To remove tablespace `mystuff` from the system:

```
DROP TABLESPACE mystuff;
```

## Compatibility

DROP TABLESPACE is a LightDB extension.

## See Also

CREATE TABLESPACE, ALTER TABLESPACE



---

# DROP TEXT SEARCH CONFIGURATION

DROP TEXT SEARCH CONFIGURATION — remove a text search configuration

## Synopsis

```
DROP TEXT SEARCH CONFIGURATION [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

## Description

DROP TEXT SEARCH CONFIGURATION drops an existing text search configuration. To execute this command you must be the owner of the configuration.

## Parameters

IF EXISTS

Do not throw an error if the text search configuration does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing text search configuration.

CASCADE

Automatically drop objects that depend on the text search configuration, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search configuration if any objects depend on it. This is the default.

## Examples

Remove the text search configuration `my_english`:

```
DROP TEXT SEARCH CONFIGURATION my_english;
```

This command will not succeed if there are any existing indexes that reference the configuration in `to_tsvector` calls. Add `CASCADE` to drop such indexes along with the text search configuration.

## Compatibility

There is no `DROP TEXT SEARCH CONFIGURATION` statement in the SQL standard.

## See Also

ALTER TEXT SEARCH CONFIGURATION, CREATE TEXT SEARCH CONFIGURATION

---

# DROP TEXT SEARCH DICTIONARY

DROP TEXT SEARCH DICTIONARY — remove a text search dictionary

## Synopsis

```
DROP TEXT SEARCH DICTIONARY [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

## Description

DROP TEXT SEARCH DICTIONARY drops an existing text search dictionary. To execute this command you must be the owner of the dictionary.

## Parameters

IF EXISTS

Do not throw an error if the text search dictionary does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing text search dictionary.

CASCADE

Automatically drop objects that depend on the text search dictionary, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search dictionary if any objects depend on it. This is the default.

## Examples

Remove the text search dictionary `english`:

```
DROP TEXT SEARCH DICTIONARY english;
```

This command will not succeed if there are any existing text search configurations that use the dictionary. Add `CASCADE` to drop such configurations along with the dictionary.

## Compatibility

There is no DROP TEXT SEARCH DICTIONARY statement in the SQL standard.

## See Also

ALTER TEXT SEARCH DICTIONARY, CREATE TEXT SEARCH DICTIONARY

---

# DROP TEXT SEARCH PARSER

DROP TEXT SEARCH PARSER — remove a text search parser

## Synopsis

```
DROP TEXT SEARCH PARSER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP TEXT SEARCH PARSER drops an existing text search parser. You must be a superuser to use this command.

## Parameters

IF EXISTS

Do not throw an error if the text search parser does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing text search parser.

CASCADE

Automatically drop objects that depend on the text search parser, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search parser if any objects depend on it. This is the default.

## Examples

Remove the text search parser `my_parser`:

```
DROP TEXT SEARCH PARSER my_parser;
```

This command will not succeed if there are any existing text search configurations that use the parser. Add `CASCADE` to drop such configurations along with the parser.

## Compatibility

There is no `DROP TEXT SEARCH PARSER` statement in the SQL standard.

## See Also

ALTER TEXT SEARCH PARSER, CREATE TEXT SEARCH PARSER

---

# DROP TEXT SEARCH TEMPLATE

DROP TEXT SEARCH TEMPLATE — remove a text search template

## Synopsis

```
DROP TEXT SEARCH TEMPLATE [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

## Description

DROP TEXT SEARCH TEMPLATE drops an existing text search template. You must be a superuser to use this command.

## Parameters

IF EXISTS

Do not throw an error if the text search template does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of an existing text search template.

CASCADE

Automatically drop objects that depend on the text search template, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search template if any objects depend on it. This is the default.

## Examples

Remove the text search template thesaurus:

```
DROP TEXT SEARCH TEMPLATE thesaurus;
```

This command will not succeed if there are any existing text search dictionaries that use the template. Add CASCADE to drop such dictionaries along with the template.

## Compatibility

There is no DROP TEXT SEARCH TEMPLATE statement in the SQL standard.

## See Also

ALTER TEXT SEARCH TEMPLATE, CREATE TEXT SEARCH TEMPLATE

---

# DROP TRANSFORM

DROP TRANSFORM — remove a transform

## Synopsis

```
DROP TRANSFORM [ IF EXISTS ] FOR type_name LANGUAGE lang_name
[ CASCADE | RESTRICT ]
```

## Description

DROP TRANSFORM removes a previously defined transform.

To be able to drop a transform, you must own the type and the language. These are the same privileges that are required to create a transform.

## Parameters

IF EXISTS

Do not throw an error if the transform does not exist. A notice is issued in this case.

*type\_name*

The name of the data type of the transform.

*lang\_name*

The name of the language of the transform.

CASCADE

Automatically drop objects that depend on the transform, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the transform if any objects depend on it. This is the default.

## Examples

To drop the transform for type `hstore` and language `plpythonu`:

```
DROP TRANSFORM FOR hstore LANGUAGE plpythonu;
```

## Compatibility

This form of DROP TRANSFORM is a LightDB extension. See CREATE TRANSFORM for details.

## See Also

CREATE TRANSFORM

---

# DROP TRIGGER

DROP TRIGGER — remove a trigger

## Synopsis

```
DROP TRIGGER [ IF EXISTS ] name ON table_name [ CASCADE |  
RESTRICT ]
```

## Description

DROP TRIGGER removes an existing trigger definition. To execute this command, the current user must be the owner of the table for which the trigger is defined.

## Parameters

IF EXISTS

Do not throw an error if the trigger does not exist. A notice is issued in this case.

*name*

The name of the trigger to remove.

*table\_name*

The name (optionally schema-qualified) of the table for which the trigger is defined.

CASCADE

Automatically drop objects that depend on the trigger, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the trigger if any objects depend on it. This is the default.

## Examples

Destroy the trigger `if_dist_exists` on the table `films`:

```
DROP TRIGGER if_dist_exists ON films;
```

## Compatibility

The DROP TRIGGER statement in LightDB is incompatible with the SQL standard. In the SQL standard, trigger names are not local to tables, so the command is simply DROP TRIGGER *name*.

## See Also

CREATE TRIGGER

---

# DROP TYPE

DROP TYPE — remove a data type

## Synopsis

```
DROP TYPE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

```
DROP TYPE BODY name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP TYPE removes a user-defined data type. Only the owner of a type can remove it.

DROP TYPE BODY removes function definition for user-defined object type. Only the owner of a type can remove it.

## Parameters

IF EXISTS

Do not throw an error if the type does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the data type to remove.

CASCADE

Automatically drop objects that depend on the type (such as table columns, functions, and operators), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the type if any objects depend on it. This is the default.

## Examples

To remove the data type `box`:

```
DROP TYPE box;
```

To remove the object type body `tp`:

```
DROP TYPE BODY tp;
```

## Compatibility

This command is similar to the corresponding command in the SQL standard, apart from the IF EXISTS option, which is a LightDB extension. But note that much of the CREATE TYPE command and the data type extension mechanisms in LightDB differ from the SQL standard.

## See Also

ALTER TYPE, CREATE TYPE



---

# DROP USER

DROP USER — remove a database role

## Synopsis

```
DROP USER [ IF EXISTS ] name [ , ... ] [ CASCADE | RESTRICT ]
```

## Description

DROP USER is simply an alternate spelling of DROP ROLE.

## Parameters

CASCADE

Used to DROP USER statement compatible with Oracle. Automatically drop objects (tables, functions, etc.) that are contained in the user, and in turn all objects that depend on those objects (see Section 5.14). It must be used in Oracle database.

RESTRICT

Used to DROP USER statement compatible with Oracle. Refuse to drop the user if it contains any objects. This is the default. It must be used in Oracle database.

## Compatibility

The DROP USER statement is a LightDB extension. The SQL standard leaves the definition of users to the implementation.

## See Also

DROP ROLE

---

# DROP USER MAPPING

DROP USER MAPPING — remove a user mapping for a foreign server

## Synopsis

```
DROP USER MAPPING [ IF EXISTS ] FOR { user_name | USER |  
CURRENT_USER | PUBLIC } SERVER server_name
```

## Description

DROP USER MAPPING removes an existing user mapping from foreign server.

The owner of a foreign server can drop user mappings for that server for any user. Also, a user can drop a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

## Parameters

IF EXISTS

Do not throw an error if the user mapping does not exist. A notice is issued in this case.

*user\_name*

User name of the mapping. CURRENT\_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

*server\_name*

Server name of the user mapping.

## Examples

Drop a user mapping bob, server foo if it exists:

```
DROP USER MAPPING IF EXISTS FOR bob SERVER foo;
```

## Compatibility

DROP USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a LightDB extension.

## See Also

CREATE USER MAPPING, ALTER USER MAPPING

---

# DROP VIEW

DROP VIEW — remove a view

## Synopsis

```
DROP VIEW [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

## Description

DROP VIEW drops an existing view. To execute this command you must be the owner of the view.

## Parameters

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

*name*

The name (optionally schema-qualified) of the view to remove.

CASCADE

Automatically drop objects that depend on the view (such as other views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the view if any objects depend on it. This is the default.

## Examples

This command will remove the view called `kinds`:

```
DROP VIEW kinds;
```

## Compatibility

This command conforms to the SQL standard, except that the standard only allows one view to be dropped per command, and apart from the IF EXISTS option, which is a LightDB extension.

## See Also

ALTER VIEW, CREATE VIEW

---

# END

END — commit the current transaction

## Synopsis

```
END [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

## Description

END commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs. This command is a LightDB extension that is equivalent to COMMIT.

## Parameters

WORK  
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

## Notes

Use ROLLBACK to abort a transaction.

Issuing END when not inside a transaction does no harm, but it will provoke a warning message.

## Examples

To commit the current transaction and make all changes permanent:

```
END ;
```

## Compatibility

END is a LightDB extension that provides functionality equivalent to COMMIT, which is specified in the SQL standard.

## See Also

BEGIN, COMMIT, ROLLBACK

---

# EXECUTE

EXECUTE — execute a prepared statement

## Synopsis

```
EXECUTE name [ ( parameter [, ...] ) ]
```

## Description

EXECUTE is used to execute a previously prepared statement. Since prepared statements only exist for the duration of a session, the prepared statement must have been created by a PREPARE statement executed earlier in the current session.

If the PREPARE statement that created the statement specified some parameters, a compatible set of parameters must be passed to the EXECUTE statement, or else an error is raised. Note that (unlike functions) prepared statements are not overloaded based on the type or number of their parameters; the name of a prepared statement must be unique within a database session.

For more information on the creation and usage of prepared statements, see PREPARE.

## Parameters

*name*

The name of the prepared statement to execute.

*parameter*

The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

## Outputs

The command tag returned by EXECUTE is that of the prepared statement, and not EXECUTE.

## Examples

Examples are given in Examples in the PREPARE documentation.

## Compatibility

The SQL standard includes an EXECUTE statement, but it is only for use in embedded SQL. This version of the EXECUTE statement also uses a somewhat different syntax.

## See Also

DEALLOCATE, PREPARE

---

# EXPLAIN

EXPLAIN — show the execution plan of a statement

## Synopsis

```
EXPLAIN [ ( option [, ...] ) ] statement  
EXPLAIN [ ANALYZE ] [ VERBOSE ] statement
```

where *option* can be one of:

```
ANALYZE [ boolean ]  
VERBOSE [ boolean ]  
COSTS [ boolean ]  
SETTINGS [ boolean ]  
BUFFERS [ boolean ]  
WAL [ boolean ]  
TIMING [ boolean ]  
SUMMARY [ boolean ]  
FORMAT { TEXT | XML | JSON | YAML }
```

## Description

This command displays the execution plan that the LightDB planner generates for the supplied statement. The execution plan shows how the table(s) referenced by the statement will be scanned — by plain sequential scan, index scan, etc. — and if multiple tables are referenced, what join algorithms will be used to bring together the required rows from each input table.

The most critical part of the display is the estimated statement execution cost, which is the planner's guess at how long it will take to run the statement (measured in cost units that are arbitrary, but conventionally mean disk page fetches). Actually two numbers are shown: the start-up cost before the first row can be returned, and the total cost to return all the rows. For most queries the total cost is what matters, but in contexts such as a subquery in `EXISTS`, the planner will choose the smallest start-up cost instead of the smallest total cost (since the executor will stop after getting one row, anyway). Also, if you limit the number of rows to return with a `LIMIT` clause, the planner makes an appropriate interpolation between the endpoint costs to estimate which plan is really the cheapest.

The `ANALYZE` option causes the statement to be actually executed, not only planned. Then actual run time statistics are added to the display, including the total elapsed time expended within each plan node (in milliseconds) and the total number of rows it actually returned. This is useful for seeing whether the planner's estimates are close to reality.

### Important

Keep in mind that the statement is actually executed when the `ANALYZE` option is used. Although `EXPLAIN` will discard any output that a `SELECT` would return, other side effects of the statement will happen as usual. If you wish to use `EXPLAIN ANALYZE` on an `INSERT`, `UPDATE`, `DELETE`, `CREATE TABLE AS`, or `EXECUTE` statement without letting the command affect your data, use this approach:

```
BEGIN;  
EXPLAIN ANALYZE ...;
```

```
ROLLBACK ;
```

Only the `ANALYZE` and `VERBOSE` options can be specified, and only in that order, without surrounding the option list in parentheses. Prior to LightDB 9.0, the unparenthesized syntax was the only one supported. It is expected that all new options will be supported only in the parenthesized syntax.

## Parameters

### ANALYZE

Carry out the command and show actual run times and other statistics. This parameter defaults to `FALSE`.

### VERBOSE

Display additional information regarding the plan. Specifically, include the output column list for each node in the plan tree, schema-qualify table and function names, always label variables in expressions with their range table alias, and always print the name of each trigger for which statistics are displayed. This parameter defaults to `FALSE`.

### COSTS

Include information on the estimated startup and total cost of each plan node, as well as the estimated number of rows and the estimated width of each row. This parameter defaults to `TRUE`.

### SETTINGS

Include information on configuration parameters. Specifically, include options affecting query planning with value different from the built-in default value. This parameter defaults to `FALSE`.

### BUFFERS

Include information on buffer usage. Specifically, include the number of shared blocks hit, read, dirtied, and written, the number of local blocks hit, read, dirtied, and written, the number of temp blocks read and written, and the time spent reading and writing data file blocks (in milliseconds) if `track_io_timing` is enabled. A *hit* means that a read was avoided because the block was found already in cache when needed. Shared blocks contain data from regular tables and indexes; local blocks contain data from temporary tables and indexes; while temp blocks contain short-term working data used in sorts, hashes, Materialize plan nodes, and similar cases. The number of blocks *dirtied* indicates the number of previously unmodified blocks that were changed by this query; while the number of blocks *written* indicates the number of previously-dirtied blocks evicted from cache by this backend during query processing. The number of blocks shown for an upper-level node includes those used by all its child nodes. In text format, only non-zero values are printed. It defaults to `FALSE`.

### WAL

Include information on WAL record generation. Specifically, include the number of records, number of full page images (fpi) and the amount of WAL generated in bytes. In text format, only non-zero values are printed. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `FALSE`.

### TIMING

Include actual startup time and time spent in each node in the output. The overhead of repeatedly reading the system clock can slow down the query significantly on some systems, so it may be useful to set this parameter to `FALSE` when only actual row counts, and not exact times, are

needed. Run time of the entire statement is always measured, even when node-level timing is turned off with this option. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `TRUE`.

#### SUMMARY

Include summary information (e.g., totaled timing information) after the query plan. Summary information is included by default when `ANALYZE` is used but otherwise is not included by default, but can be enabled using this option. Planning time in `EXPLAIN EXECUTE` includes the time required to fetch the plan from the cache and the time required for re-planning, if necessary.

#### FORMAT

Specify the output format, which can be `TEXT`, `XML`, `JSON`, or `YAML`. Non-text output contains the same information as the text output format, but is easier for programs to parse. This parameter defaults to `TEXT`.

#### *boolean*

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

#### *statement*

Any `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `VALUES`, `EXECUTE`, `DECLARE`, `CREATE TABLE AS`, or `CREATE MATERIALIZED VIEW AS` statement, whose execution plan you wish to see.

## Outputs

The command's result is a textual description of the plan selected for the *statement*, optionally annotated with execution statistics. Section 14.1 describes the information provided.

## Notes

In order to allow the LightDB query planner to make reasonably informed decisions when optimizing queries, the `pg_statistic` data should be up-to-date for all tables used in the query. Normally the autovacuum daemon will take care of that automatically. But if a table has recently had substantial changes in its contents, you might need to do a manual `ANALYZE` rather than wait for autovacuum to catch up with the changes.

In order to measure the run-time cost of each node in the execution plan, the current implementation of `EXPLAIN ANALYZE` adds profiling overhead to query execution. As a result, running `EXPLAIN ANALYZE` on a query can sometimes take significantly longer than executing the query normally. The amount of overhead depends on the nature of the query, as well as the platform being used. The worst case occurs for plan nodes that in themselves require very little time per execution, and on machines that have relatively slow operating system calls for obtaining the time of day.

## Examples

To show the plan for a simple query on a table with a single integer column and 10000 rows:

```
EXPLAIN SELECT * FROM foo;
```

```
QUERY PLAN
```

```
-----  
Seq Scan on foo (cost=0.00..155.00 rows=10000 width=4)
```



---

## EXPLAIN

---

(1 row)

Here is the same query, with JSON output formatting:

```
EXPLAIN (FORMAT JSON) SELECT * FROM foo;
      QUERY PLAN
```

```
-----
[
  {
    "Plan": {
      "Node Type": "Seq Scan",
      "Relation Name": "foo",
      "Alias": "foo",
      "Startup Cost": 0.00,
      "Total Cost": 155.00,
      "Plan Rows": 10000,
      "Plan Width": 4
    }
  }
]
(1 row)
```

If there is an index and we use a query with an indexable WHERE condition, EXPLAIN might show a different plan:

```
EXPLAIN SELECT * FROM foo WHERE i = 4;
```

```
      QUERY PLAN
```

```
-----
Index Scan using fi on foo (cost=0.00..5.98 rows=1 width=4)
  Index Cond: (i = 4)
(2 rows)
```

Here is the same query, but in YAML format:

```
EXPLAIN (FORMAT YAML) SELECT * FROM foo WHERE i='4';
      QUERY PLAN
```

```
-----
- Plan:
  Node Type: "Index Scan"
  Scan Direction: "Forward"
  Index Name: "fi"
  Relation Name: "foo"
  Alias: "foo"
  Startup Cost: 0.00
  Total Cost: 5.98
  Plan Rows: 1
  Plan Width: 4
  Index Cond: "(i = 4)"
(1 row)
```

XML format is left as an exercise for the reader.

Here is the same plan with cost estimates suppressed:

```
EXPLAIN (COSTS FALSE) SELECT * FROM foo WHERE i = 4;
```

## QUERY PLAN

```
-----
Index Scan using fi on foo
  Index Cond: (i = 4)
(2 rows)
```

Here is an example of a query plan for a query using an aggregate function:

```
EXPLAIN SELECT sum(i) FROM foo WHERE i < 10;
```

## QUERY PLAN

```
-----
--
Aggregate  (cost=23.93..23.93 rows=1 width=4)
  -> Index Scan using fi on foo  (cost=0.00..23.92 rows=6
width=4)
      Index Cond: (i < 10)
(3 rows)
```

Here is an example of using `EXPLAIN EXECUTE` to display the execution plan for a prepared query:

```
PREPARE query(int, int) AS SELECT sum(bar) FROM test
  WHERE id > $1 AND id < $2
  GROUP BY foo;
```

```
EXPLAIN ANALYZE EXECUTE query(100, 200);
```

## QUERY PLAN

```
-----
HashAggregate  (cost=9.54..9.54 rows=1 width=8) (actual
time=0.156..0.161 rows=11 loops=1)
  Group Key: foo
  -> Index Scan using test_pkey on test  (cost=0.29..9.29 rows=50
width=8) (actual time=0.039..0.091 rows=99 loops=1)
      Index Cond: ((id > $1) AND (id < $2))
Planning time: 0.197 ms
Execution time: 0.225 ms
(6 rows)
```

Of course, the specific numbers shown here depend on the actual contents of the tables involved. Also note that the numbers, and even the selected query strategy, might vary between LightDB releases due to planner improvements. In addition, the `ANALYZE` command uses random sampling to estimate data statistics; therefore, it is possible for cost estimates to change after a fresh run of `ANALYZE`, even if the actual distribution of data in the table has not changed.

## Compatibility

There is no `EXPLAIN` statement defined in the SQL standard.

## See Also

`ANALYZE`

---

# FETCH

FETCH — retrieve rows from a query using a cursor

## Synopsis

```
FETCH [ direction [ FROM | IN ] ] cursor_name
```

where *direction* can be empty or one of:

```
NEXT  
PRIOR  
FIRST  
LAST  
ABSOLUTE count  
RELATIVE count  
count  
ALL  
FORWARD  
FORWARD count  
FORWARD ALL  
BACKWARD  
BACKWARD count  
BACKWARD ALL
```

## Description

FETCH retrieves rows using a previously-created cursor.

A cursor has an associated position, which is used by FETCH. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result. When created, a cursor is positioned before the first row. After fetching some rows, the cursor is positioned on the row most recently retrieved. If FETCH runs off the end of the available rows then the cursor is left positioned after the last row, or before the first row if fetching backward. FETCH ALL or FETCH BACKWARD ALL will always leave the cursor positioned after the last row or before the first row.

The forms NEXT, PRIOR, FIRST, LAST, ABSOLUTE, RELATIVE fetch a single row after moving the cursor appropriately. If there is no such row, an empty result is returned, and the cursor is left positioned before the first row or after the last row as appropriate.

The forms using FORWARD and BACKWARD retrieve the indicated number of rows moving in the forward or backward direction, leaving the cursor positioned on the last-returned row (or after/before all rows, if the *count* exceeds the number of rows available).

RELATIVE 0, FORWARD 0, and BACKWARD 0 all request fetching the current row without moving the cursor, that is, re-fetching the most recently fetched row. This will succeed unless the cursor is positioned before the first row or after the last row; in which case, no row is returned.

### Note

This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 41.7.3.

## Parameters

### *direction*

*direction* defines the fetch direction and number of rows to fetch. It can be one of the following:

#### NEXT

Fetch the next row. This is the default if *direction* is omitted.

#### PRIOR

Fetch the prior row.

#### FIRST

Fetch the first row of the query (same as ABSOLUTE 1).

#### LAST

Fetch the last row of the query (same as ABSOLUTE -1).

#### ABSOLUTE *count*

Fetch the *count*'th row of the query, or the  $\text{abs}(\textit{count})$ 'th row from the end if *count* is negative. Position before first row or after last row if *count* is out of range; in particular, ABSOLUTE 0 positions before the first row.

#### RELATIVE *count*

Fetch the *count*'th succeeding row, or the  $\text{abs}(\textit{count})$ 'th prior row if *count* is negative. RELATIVE 0 re-fetches the current row, if any.

### *count*

Fetch the next *count* rows (same as FORWARD *count*).

#### ALL

Fetch all remaining rows (same as FORWARD ALL).

#### FORWARD

Fetch the next row (same as NEXT).

#### FORWARD *count*

Fetch the next *count* rows. FORWARD 0 re-fetches the current row.

#### FORWARD ALL

Fetch all remaining rows.

#### BACKWARD

Fetch the prior row (same as PRIOR).

#### BACKWARD *count*

Fetch the prior *count* rows (scanning backwards). BACKWARD 0 re-fetches the current row.

BACKWARD ALL

Fetch all prior rows (scanning backwards).

*count*

*count* is a possibly-signed integer constant, determining the location or number of rows to fetch. For FORWARD and BACKWARD cases, specifying a negative *count* is equivalent to changing the sense of FORWARD and BACKWARD.

*cursor\_name*

An open cursor's name.

## Outputs

On successful completion, a FETCH command returns a command tag of the form

FETCH *count*

The *count* is the number of rows fetched (possibly zero). Note that in `ltsql`, the command tag will not actually be displayed, since `ltsql` displays the fetched rows instead.

## Notes

The cursor should be declared with the `SCROLL` option if one intends to use any variants of `FETCH` other than `FETCH NEXT` or `FETCH FORWARD` with a positive count. For simple queries `LightDB` will allow backwards fetch from cursors not declared with `SCROLL`, but this behavior is best not relied on. If the cursor is declared with `NO SCROLL`, no backward fetches are allowed.

`ABSOLUTE` fetches are not any faster than navigating to the desired row with a relative move: the underlying implementation must traverse all the intermediate rows anyway. Negative absolute fetches are even worse: the query must be read to the end to find the last row, and then traversed backward from there. However, rewinding to the start of the query (as with `FETCH ABSOLUTE 0`) is fast.

`DECLARE` is used to define a cursor. Use `MOVE` to change cursor position without retrieving data.

## Examples

The following example traverses a table using a cursor:

```
BEGIN WORK;

-- Set up a cursor:
DECLARE liahona SCROLL CURSOR FOR SELECT * FROM films;

-- Fetch the first 5 rows in the cursor liahona:
FETCH FORWARD 5 FROM liahona;
```

code len	title	did	date_prod	kind
BL101 01:44	The Third Man	101	1949-12-23	Drama
BL102 01:43	The African Queen	101	1951-08-11	Romantic

```

JL201 | Une Femme est une Femme | 102 | 1961-03-12 | Romantic |
01:25
P_301 | Vertigo | 103 | 1958-11-14 | Action |
02:08
P_302 | Becket | 103 | 1964-02-03 | Drama |
02:28

-- Fetch the previous row:
FETCH PRIOR FROM liahona;

code | title | did | date_prod | kind | len
-----+-----+-----+-----+-----+-----
P_301 | Vertigo | 103 | 1958-11-14 | Action | 02:08

-- Close the cursor and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

## Compatibility

The SQL standard defines `FETCH` for use in embedded SQL only. The variant of `FETCH` described here returns the data as if it were a `SELECT` result rather than placing it in host variables. Other than this point, `FETCH` is fully upward-compatible with the SQL standard.

The `FETCH` forms involving `FORWARD` and `BACKWARD`, as well as the forms `FETCH count` and `FETCH ALL`, in which `FORWARD` is implicit, are LightDB extensions.

The SQL standard allows only `FROM` preceding the cursor name; the option to use `IN`, or to leave them out altogether, is an extension.

Add GUC parameter `lightdb_cursor_after_commit`. When the parameter value is on, the cursor can continue after the transaction commits. When the parameter value is off, the cursor cannot proceed after the transaction is committed. The default value of this parameter is off.

## See Also

`CLOSE`, `DECLARE`, `MOVE`

---

# GRANT

GRANT — define access privileges

## Synopsis

```
GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES
| TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON { [ TABLE ] table_name [, ...]
      | ALL TABLES IN SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name
[, ...] )
  [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
  ON [ TABLE ] table_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON { SEQUENCE sequence_name [, ...]
      | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL
  [ PRIVILEGES ] }
  ON DATABASE database_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON DOMAIN domain_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON FOREIGN DATA WRAPPER fdw_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON FOREIGN SERVER server_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [ PRIVILEGES ] }
  ON { { FUNCTION | PROCEDURE | ROUTINE } routine_name
  [ ( [ [ argmode ] [ arg_name ] arg_type [, ...] ) ] [, ...]
      | ALL { FUNCTIONS | PROCEDURES | ROUTINES } IN
  SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON LANGUAGE lang_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
  ON LARGE OBJECT loid [, ...]
```

```

    TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
    ON SCHEMA schema_name [, ...]
    TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { CREATE | ALL [ PRIVILEGES ] }
    ON TABLESPACE tablespace_name [, ...]
    TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE type_name [, ...]
    TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT role_name [, ...] TO role_specification [, ...]
    [ WITH ADMIN OPTION ]
    [ GRANTED BY role_specification ]

GRANT option_for_oracle TO role_specification [, ...]
    [ WITH ADMIN OPTION ]

```

where *role\_specification* can be:

```

    [ GROUP ] role_name
    | PUBLIC
    | CURRENT_USER
    | SESSION_USER

```

where *option\_for\_oracle* can be:

```

    CONNECT
    | RESOURCE
    | UNLIMITED TABLESPACE

```

## Description

The GRANT command has two basic variants: one that grants privileges on a database object (table, column, view, foreign table, sequence, database, foreign-data wrapper, foreign server, function, procedure, procedural language, schema, or tablespace), and one that grants membership in a role. These variants are similar in many ways, but they are different enough to be described separately.

## GRANT on Database Objects

This variant of the GRANT command gives specific privileges on a database object to one or more roles. These privileges are added to those already granted, if any.

The key word PUBLIC indicates that the privileges are to be granted to all roles, including those that might be created later. PUBLIC can be thought of as an implicitly defined group that always includes all roles. Any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC.

If WITH GRANT OPTION is specified, the recipient of the privilege can in turn grant it to others. Without a grant option, the recipient cannot do that. Grant options cannot be granted to PUBLIC.

There is no need to grant privileges to the owner of an object (usually the user that created it), as the owner has all privileges by default. (The owner could, however, choose to revoke some of their own privileges for safety.)

The right to drop an object, or to alter its definition in any way, is not treated as a grantable privilege; it is inherent in the owner, and cannot be granted or revoked. (However, a similar effect can be obtained



by granting or revoking membership in the role that owns the object; see below.) The owner implicitly has all grant options for the object, too.

The possible privileges are:

SELECT  
INSERT  
UPDATE  
DELETE  
TRUNCATE  
REFERENCES  
TRIGGER  
CREATE  
CONNECT  
TEMPORARY  
EXECUTE  
USAGE

Specific types of privileges, as defined in Section 5.7.

TEMP

Alternative spelling for TEMPORARY.

ALL PRIVILEGES

Grant all of the privileges available for the object's type. The PRIVILEGES key word is optional in LightDB, though it is required by strict SQL.

The FUNCTION syntax works for plain functions, aggregate functions, and window functions, but not for procedures; use PROCEDURE for those. Alternatively, use ROUTINE to refer to a function, aggregate function, window function, or procedure regardless of its precise type.

There is also an option to grant privileges on all objects of the same type within one or more schemas. This functionality is currently supported only for tables, sequences, functions, and procedures. ALL TABLES also affects views and foreign tables, just like the specific-object GRANT command. ALL FUNCTIONS also affects aggregate and window functions, but not procedures, again just like the specific-object GRANT command. Use ALL ROUTINES to include procedures.

## GRANT on Roles

This variant of the GRANT command grants membership in a role to one or more other roles. Membership in a role is significant because it conveys the privileges granted to a role to each of its members.

If WITH ADMIN OPTION is specified, the member can in turn grant membership in the role to others, and revoke membership in the role as well. Without the admin option, ordinary users cannot do that. A role is not considered to hold WITH ADMIN OPTION on itself, but it may grant or revoke membership in itself from a database session where the session user matches the role. Database superusers can grant or revoke membership in any role to anyone. Roles having CREATEROLE privilege can grant or revoke membership in any role that is not a superuser.

If GRANTED BY is specified, the grant is recorded as having been done by the specified role. Only database superusers may use this option, except when it names the same role executing the command.

Unlike the case with privileges, membership in a role cannot be granted to PUBLIC. Note also that this form of the command does not allow the noise word GROUP in *role\_specification*.

## Notes

The REVOKE command is used to revoke access privileges.

Since LightDB 8.1, the concepts of users and groups have been unified into a single kind of entity called a role. It is therefore no longer necessary to use the keyword `GROUP` to identify whether a grantee is a user or a group. `GROUP` is still allowed in the command, but it is a noise word.

A user may perform `SELECT`, `INSERT`, etc. on a column if they hold that privilege for either the specific column or its whole table. Granting the privilege at the table level and then revoking it for one column will not do what one might wish: the table-level grant is unaffected by a column-level operation.

When a non-owner of an object attempts to `GRANT` privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will grant only those privileges for which the user has grant options. The `GRANT ALL PRIVILEGES` forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

It should be noted that database superusers can access all objects regardless of object privilege settings. This is comparable to the rights of `root` in a Unix system. As with `root`, it's unwise to operate as a superuser except when absolutely necessary.

If a superuser chooses to issue a `GRANT` or `REVOKE` command, the command is performed as though it were issued by the owner of the affected object. In particular, privileges granted via such a command will appear to have been granted by the object owner. (For role membership, the membership appears to have been granted by the containing role itself.)

`GRANT` and `REVOKE` can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case the privileges will be recorded as having been granted by the role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can grant privileges on `t1` to `u2`, but those privileges will appear to have been granted directly by `g1`. Any other member of role `g1` could revoke them later.

If the role executing `GRANT` holds the required privileges indirectly via more than one role membership path, it is unspecified which containing role will be recorded as having done the grant. In such cases it is best practice to use `SET ROLE` to become the specific role you want to do the `GRANT` as.

Granting permission on a table does not automatically extend permissions to any sequences used by the table, including sequences tied to `SERIAL` columns. Permissions on sequences must be set separately.

See Section 5.7 for more information about specific privilege types, as well as how to inspect objects' privileges.

About Compatible Oracle Grant Statement *option\_for\_oracle*. Currently, only syntax support is provided, not function support. It must be used in Oracle database.

## Examples

Grant insert privilege to all users on table `films`:

```
GRANT INSERT ON films TO PUBLIC;
```

Grant all available privileges to user `manuel` on view `kinds`:

```
GRANT ALL PRIVILEGES ON kinds TO manuel;
```

Note that while the above will indeed grant all privileges if executed by a superuser or the owner of kinds, when executed by someone else it will only grant those permissions for which the someone else has grant options.

Grant membership in role `admins` to user `joe`:

```
GRANT admins TO joe;
```

Oracle-compatible grant statement:

```
GRANT CONNECT TO HS_SES;  
GRANT RESOURCE TO HS_SES;  
GRANT UNLIMITED TABLESPACE TO HS_SES;
```

## Compatibility

According to the SQL standard, the `PRIVILEGES` key word in `ALL PRIVILEGES` is required. The SQL standard does not support setting the privileges on more than one object per command.

LightDB allows an object owner to revoke their own ordinary privileges: for example, a table owner can make the table read-only to themselves by revoking their own `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE` privileges. This is not possible according to the SQL standard. The reason is that LightDB treats the owner's privileges as having been granted by the owner to themselves; therefore they can revoke them too. In the SQL standard, the owner's privileges are granted by an assumed entity `“_SYSTEM”`. Not being `“_SYSTEM”`, the owner cannot revoke these rights.

According to the SQL standard, grant options can be granted to `PUBLIC`; LightDB only supports granting grant options to roles.

The SQL standard allows the `GRANTED BY` option to be used in all forms of `GRANT`. LightDB only supports it when granting role membership, and even then only superusers may use it in nontrivial ways.

The SQL standard provides for a `USAGE` privilege on other kinds of objects: character sets, collations, translations.

In the SQL standard, sequences only have a `USAGE` privilege, which controls the use of the `NEXT VALUE FOR` expression, which is equivalent to the function `nextval` in LightDB. The sequence privileges `SELECT` and `UPDATE` are LightDB extensions. The application of the sequence `USAGE` privilege to the `currval` function is also a LightDB extension (as is the function itself).

Privileges on databases, tablespaces, schemas, and languages are LightDB extensions.

## See Also

`REVOKE`, `ALTER DEFAULT PRIVILEGES`

---

# IMPORT FOREIGN SCHEMA

IMPORT FOREIGN SCHEMA — import table definitions from a foreign server

## Synopsis

```
IMPORT FOREIGN SCHEMA remote_schema
  [ { LIMIT TO | EXCEPT } ( table_name [, ...] ) ]
  FROM SERVER server_name
  INTO local_schema
  [ OPTIONS ( option 'value' [, ...] ) ]
```

## Description

IMPORT FOREIGN SCHEMA creates foreign tables that represent tables existing on a foreign server. The new foreign tables will be owned by the user issuing the command and are created with the correct column definitions and options to match the remote tables.

By default, all tables and views existing in a particular schema on the foreign server are imported. Optionally, the list of tables can be limited to a specified subset, or specific tables can be excluded. The new foreign tables are all created in the target schema, which must already exist.

To use IMPORT FOREIGN SCHEMA, the user must have USAGE privilege on the foreign server, as well as CREATE privilege on the target schema.

## Parameters

*remote\_schema*

The remote schema to import from. The specific meaning of a remote schema depends on the foreign data wrapper in use.

LIMIT TO ( *table\_name* [, ...] )

Import only foreign tables matching one of the given table names. Other tables existing in the foreign schema will be ignored.

EXCEPT ( *table\_name* [, ...] )

Exclude specified foreign tables from the import. All tables existing in the foreign schema will be imported except the ones listed here.

*server\_name*

The foreign server to import from.

*local\_schema*

The schema in which the imported foreign tables will be created.

OPTIONS ( *option* '*value*' [, ...] )

Options to be used during the import. The allowed option names and values are specific to each foreign data wrapper.

## Examples

Import table definitions from a remote schema `foreign_films` on server `film_server`, creating the foreign tables in local schema `films`:

```
IMPORT FOREIGN SCHEMA foreign_films
  FROM SERVER film_server INTO films;
```

As above, but import only the two tables `actors` and `directors` (if they exist):

```
IMPORT FOREIGN SCHEMA foreign_films LIMIT TO (actors, directors)
  FROM SERVER film_server INTO films;
```

## Compatibility

The `IMPORT FOREIGN SCHEMA` command conforms to the SQL standard, except that the `OPTIONS` clause is a LightDB extension.

## See Also

`CREATE FOREIGN TABLE`, `CREATE SERVER`

---

# INSERT

INSERT — create new rows in a table

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
INSERT [IGNORE] INTO table_name [ [ AS ] alias ] [ ( column_name
[, ...] ) ]
    [ OVERRIDING { SYSTEM | USER } VALUE ]
    { DEFAULT VALUES | VALUES ( { expression | DEFAULT } [, ...] )
[, ...] | query }
    [ ON CONFLICT [ conflict_target ] conflict_action | ON
DUPLICATE KEY UPDATE { column_name = { expression | DEFAULT } }
[, ...] ]
    [ {RETURNING|RETURN} * | output_expression [ [ AS ] output_name
] [, ...] ]
```

where *conflict\_target* can be one of:

```
( { index_column_name | ( index_expression
) } [ COLLATE collation ] [ opclass ] [, ...] )
[ WHERE index_predicate ]
ON CONSTRAINT constraint_name
```

and *conflict\_action* is one of:

```
DO NOTHING
DO UPDATE SET { column_name = { expression | DEFAULT } |
( column_name [, ...] ) = [ ROW ]
( { expression | DEFAULT } [, ...] ) |
( column_name [, ...] ) = ( sub-SELECT )
} [, ...]
[ WHERE condition ]
```

```
INSERT ALL insert_into_clause [values_clause] query
| INSERT ALL conditional_insert_clause query
```

where *insert\_into\_clause* can be list of:

```
INTO table_name [ ( column_name [, ...] ) ]
```

and *values\_clause* is:

```
VALUES(, ...)
```

and *conditional\_insert\_clause* is one of:

```
WHEN condition THEN insert_into_clause [values_clause]
ELSE insert_into_clause [values_clause]
```

## Description

INSERT inserts new rows into a table. One can insert one or more rows specified by value expressions, or zero or more rows resulting from a query.

The target column names can be listed in any order. If no list of column names is given at all, the default is all the columns of the table in their declared order; or the first *N* column names, if there are only *N* columns supplied by the `VALUES` clause or *query*. The values supplied by the `VALUES` clause or *query* are associated with the explicit or implicit column list left-to-right.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is none.

If the expression for any column is not of the correct data type, automatic type conversion will be attempted.

`INSERT` into tables that lack unique indexes will not be blocked by concurrent activity. Tables with unique indexes might block if concurrent sessions perform actions that lock or modify rows matching the unique index values being inserted; the details are covered in Section 58.5. `ON CONFLICT` can be used to specify an alternative action to raising a unique constraint or exclusion constraint violation error. (See `ON CONFLICT` Clause below.)

The optional `RETURNING` clause causes `INSERT` to compute and return value(s) based on each row actually inserted (or updated, if an `ON CONFLICT DO UPDATE` clause was used). This is primarily useful for obtaining values that were supplied by defaults, such as a serial sequence number. However, any expression using the table's columns is allowed. The syntax of the `RETURNING` list is identical to that of the output list of `SELECT`. Only rows that were successfully inserted or updated will be returned. For example, if a row was locked but not updated because an `ON CONFLICT DO UPDATE . . . WHERE` clause *condition* was not satisfied, the row will not be returned.

You must have `INSERT` privilege on a table in order to insert into it. If `ON CONFLICT DO UPDATE` is present, `UPDATE` privilege on the table is also required.

If a column list is specified, you only need `INSERT` privilege on the listed columns. Similarly, when `ON CONFLICT DO UPDATE` is specified, you only need `UPDATE` privilege on the column(s) that are listed to be updated. However, `ON CONFLICT DO UPDATE` also requires `SELECT` privilege on any column whose values are read in the `ON CONFLICT DO UPDATE` expressions or *condition*.

Use of the `RETURNING` clause requires `SELECT` privilege on all columns mentioned in `RETURNING`. If you use the *query* clause to insert rows from a query, you of course need to have `SELECT` privilege on any table or column used in the query.

You can also use `INSERT ALL` statement to add rows to multiple table. In a multitable insert, you insert computed rows derived from the rows returned from the evaluation of a subquery into one or more tables.

## Parameters

### Inserting

This section covers parameters that may be used when only inserting new rows. Parameters *exclusively* used with the `ON CONFLICT` clause are described separately.

#### *with\_query*

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the `INSERT` query. See Section 7.8 and `SELECT` for details.

It is possible for the *query* (`SELECT` statement) to also contain a `WITH` clause. In such a case both sets of *with\_query* can be referenced within the *query*, but the second one takes precedence since it is more closely nested.

#### *ignore*

The `ignore` keyword was added to be compatible with MySQL syntax. With `ignore`, for the current implementation, the insertion of a row violates unique constraint lead to warnings instead of errors. MySQL compatible mode should be set to use `ignore`.

*table\_name*

The name (optionally schema-qualified) of an existing table.

*alias*

A substitute name for *table\_name*. When an alias is provided, it completely hides the actual name of the table. This is particularly useful when `ON CONFLICT DO UPDATE` targets a table named `excluded`, since that will otherwise be taken as the name of the special table representing the row proposed for insertion.

Only when the syntax compatible type of the database is oracle can the optional `AS` before alias be omitted.

*column\_name*

The name of a column in the table named by *table\_name*. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.) When referencing a column with `ON CONFLICT DO UPDATE`, do not include the table's name in the specification of a target column. For example, `INSERT INTO table_name ... ON CONFLICT DO UPDATE SET table_name.col = 1` is invalid (this follows the general behavior for `UPDATE`).

## OVERRIDING SYSTEM VALUE

If this clause is specified, then any values supplied for identity columns will override the default sequence-generated values.

For an identity column defined as `GENERATED ALWAYS`, it is an error to insert an explicit value (other than `DEFAULT`) without specifying either `OVERRIDING SYSTEM VALUE` or `OVERRIDING USER VALUE`. (For an identity column defined as `GENERATED BY DEFAULT`, `OVERRIDING SYSTEM VALUE` is the normal behavior and specifying it does nothing, but LightDB allows it as an extension.)

## OVERRIDING USER VALUE

If this clause is specified, then any values supplied for identity columns are ignored and the default sequence-generated values are applied.

This clause is useful for example when copying values between tables. Writing `INSERT INTO tbl2 OVERRIDING USER VALUE SELECT * FROM tbl1` will copy from `tbl1` all columns that are not identity columns in `tbl2` while values for the identity columns in `tbl2` will be generated by the sequences associated with `tbl2`.

## DEFAULT VALUES

All columns will be filled with their default values, as if `DEFAULT` were explicitly specified for each column. (An `OVERRIDING` clause is not permitted in this form.)

*expression*

An expression or value to assign to the corresponding column.

## DEFAULT

The corresponding column will be filled with its default value. An identity column will be filled with a new value generated by the associated sequence. For a generated column, specifying this is permitted but merely specifies the normal behavior of computing the column from its generation expression.

*query*

A query (`SELECT` statement) that supplies the rows to be inserted. Refer to the `SELECT` statement for a description of the syntax.



*output\_expression*

An expression to be computed and returned by the `INSERT` command after each row is inserted or updated. The expression can use any column names of the table named by *table\_name*. Write `*` to return all columns of the inserted or updated row(s).

*output\_name*

A name to use for a returned column.

*conditional\_insert\_clause*

Specify the *conditional\_insert\_clause* to perform a conditional multitable insert. LightDB filters each *insert\_into\_clause* through the corresponding `WHEN` condition, which determines whether that *insert\_into\_clause* is executed.

## ON CONFLICT Clause

The optional `ON CONFLICT` clause specifies an alternative action to raising a unique violation or exclusion constraint violation error. For each individual row proposed for insertion, either the insertion proceeds, or, if an *arbiter* constraint or index specified by *conflict\_target* is violated, the alternative *conflict\_action* is taken. `ON CONFLICT DO NOTHING` simply avoids inserting a row as its alternative action. `ON CONFLICT DO UPDATE` updates the existing row that conflicts with the row proposed for insertion as its alternative action.

*conflict\_target* can perform *unique index inference*. When performing inference, it consists of one or more *index\_column\_name* columns and/or *index\_expression* expressions, and an optional *index\_predicate*. All *table\_name* unique indexes that, without regard to order, contain exactly the *conflict\_target*-specified columns/expressions are inferred (chosen) as arbiter indexes. If an *index\_predicate* is specified, it must, as a further requirement for inference, satisfy arbiter indexes. Note that this means a non-partial unique index (a unique index without a predicate) will be inferred (and thus used by `ON CONFLICT`) if such an index satisfying every other criteria is available. If an attempt at inference is unsuccessful, an error is raised.

`ON CONFLICT DO UPDATE` guarantees an atomic `INSERT` or `UPDATE` outcome; provided there is no independent error, one of those two outcomes is guaranteed, even under high concurrency. This is also known as *UPSERT* — “UPDATE or INSERT”.

*conflict\_target*

Specifies which conflicts `ON CONFLICT` takes the alternative action on by choosing *arbiter indexes*. Either performs *unique index inference*, or names a constraint explicitly. For `ON CONFLICT DO NOTHING`, it is optional to specify a *conflict\_target*; when omitted, conflicts with all usable constraints (and unique indexes) are handled. For `ON CONFLICT DO UPDATE`, a *conflict\_target* *must* be provided.

*conflict\_action*

*conflict\_action* specifies an alternative `ON CONFLICT` action. It can be either `DO NOTHING`, or a `DO UPDATE` clause specifying the exact details of the `UPDATE` action to be performed in case of a conflict. The `SET` and `WHERE` clauses in `ON CONFLICT DO UPDATE` have access to the existing row using the table's name (or an alias), and to the row proposed for insertion using the special `excluded` table. `SELECT` privilege is required on any column in the target table where corresponding `excluded` columns are read.

Note that the effects of all per-row `BEFORE INSERT` triggers are reflected in `excluded` values, since those effects may have contributed to the row being excluded from insertion.

*index\_column\_name*

The name of a *table\_name* column. Used to infer arbiter indexes. Follows `CREATE INDEX` format. `SELECT` privilege on *index\_column\_name* is required.

*index\_expression*

Similar to *index\_column\_name*, but used to infer expressions on *table\_name* columns appearing within index definitions (not simple columns). Follows CREATE INDEX format. SELECT privilege on any column appearing within *index\_expression* is required.

*collation*

When specified, mandates that corresponding *index\_column\_name* or *index\_expression* use a particular collation in order to be matched during inference. Typically this is omitted, as collations usually do not affect whether or not a constraint violation occurs. Follows CREATE INDEX format.

*opclass*

When specified, mandates that corresponding *index\_column\_name* or *index\_expression* use particular operator class in order to be matched during inference. Typically this is omitted, as the *equality* semantics are often equivalent across a type's operator classes anyway, or because it's sufficient to trust that the defined unique indexes have the pertinent definition of equality. Follows CREATE INDEX format.

*index\_predicate*

Used to allow inference of partial unique indexes. Any indexes that satisfy the predicate (which need not actually be partial indexes) can be inferred. Follows CREATE INDEX format. SELECT privilege on any column appearing within *index\_predicate* is required.

*constraint\_name*

Explicitly specifies an arbiter *constraint* by name, rather than inferring a constraint or index.

*condition*

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated, although all rows will be locked when the ON CONFLICT DO UPDATE action is taken. Note that *condition* is evaluated last, after a conflict has been identified as a candidate to update.

Note that exclusion constraints are not supported as arbiters with ON CONFLICT DO UPDATE. In all cases, only NOT DEFERRABLE constraints and unique indexes are supported as arbiters.

INSERT with an ON CONFLICT DO UPDATE clause is a “deterministic” statement. This means that the command will not be allowed to affect any single existing row more than once; a cardinality violation error will be raised when this situation arises. Rows proposed for insertion should not duplicate each other in terms of attributes constrained by an arbiter index or constraint.

Note that it is currently not supported for the ON CONFLICT DO UPDATE clause of an INSERT applied to a partitioned table to update the partition key of a conflicting row such that it requires the row be moved to a new partition.

**Tip**

It is often preferable to use unique index inference rather than naming a constraint directly using ON CONFLICT ON CONSTRAINT *constraint\_name*. Inference will continue to work correctly when the underlying index is replaced by another more or less equivalent index in an overlapping way, for example when using CREATE UNIQUE INDEX ... CONCURRENTLY before dropping the index being replaced.

## ON DUPLICATE KEY UPDATE Clause

If you specify an `ON DUPLICATE KEY UPDATE` clause and a row to be inserted would cause a duplicate value in a `PRIMARY KEY`, an `UPDATE` of the old row occurs. For example, if column `a` is declared as `PRIMARY KEY` and contains the value 1, the following two statements have similar effect:

```
INSERT INTO t1 (a,b,c) VALUES (1,2,3) ON DUPLICATE KEY UPDATE
  c=t1.c+1;
```

```
UPDATE t1 SET c=c+1 WHERE a=1;
```

In assignment value expressions in the `ON DUPLICATE KEY UPDATE` clause, you can use the `VALUES(col_name)` function to refer to column values from the `INSERT` portion of the `INSERT ... ON DUPLICATE KEY UPDATE` statement instead of `excluded table`. In other words, `VALUES(col_name)` in the `ON DUPLICATE KEY UPDATE` clause refers to the value of `col_name` that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is supported only in the `ON DUPLICATE KEY UPDATE` clause or `INSERT` statements.

## Outputs

On successful completion, an `INSERT` command returns a command tag of the form

```
INSERT oid count
```

The *count* is the number of rows inserted or updated. *oid* is always 0 (it used to be the OID assigned to the inserted row if *count* was exactly one and the target table was declared `WITH OIDS` and 0 otherwise, but creating a table `WITH OIDS` is not supported anymore).

If the `INSERT` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) inserted or updated by the command.

## Notes

If the specified table is a partitioned table, each row is routed to the appropriate partition and inserted into it. If the specified table is a partition, an error will occur if one of the input rows violates the partition constraint.

## Examples

Insert a single row into table `films`:

```
INSERT INTO films VALUES
  ('UA502', 'Bananas', 105, '1971-07-13', 'Comedy', '82
  minutes');
```

In this example, the `len` column is omitted and therefore it will have the default value:

```
INSERT INTO films (code, title, did, date_prod, kind)
  VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

This example uses the `DEFAULT` clause for the date columns rather than specifying a value:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes');
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama');
```

To insert a row consisting entirely of default values:

```
INSERT INTO films DEFAULT VALUES;
```

To insert multiple rows using the multirow VALUES syntax:

```
INSERT INTO films (code, title, did, date_prod, kind) VALUES
    ('B6717', 'Tampopo', 110, '1985-02-10', 'Comedy'),
    ('HG120', 'The Dinner Game', 140, DEFAULT, 'Comedy');
```

This example inserts some rows into table `films` from a table `tmp_films` with the same column layout as `films`:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod <
    '2004-05-07';
```

This example inserts into array columns:

```
-- Create an empty 3x3 gameboard for noughts-and-crosses
INSERT INTO tictactoe (game, board[1:3][1:3])
    VALUES (1, '{{" "," "," "},{ " "," "," "},{ " "," "," "}}');
-- The subscripts in the above example aren't really needed
INSERT INTO tictactoe (game, board)
    VALUES (2, '{{X," "," "},{ " ",O," "},{ " ",X," "}}');
```

Insert a single row into table `distributors`, returning the sequence number generated by the `DEFAULT` clause:

```
INSERT INTO distributors (did, dname) VALUES (DEFAULT, 'XYZ
Widgets')
    RETURNING did;
INSERT INTO distributors (did, dname) VALUES (DEFAULT, 'XYZ
Widgets')
    RETURN did;
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, and record the whole updated row along with current time in a log table:

```
WITH upd AS (
    UPDATE employees SET sales_count = sales_count + 1 WHERE id =
        (SELECT sales_person FROM accounts WHERE name = 'Acme
Corporation')
    RETURNING *
)
INSERT INTO employees_log SELECT *, current_timestamp FROM upd;
```

Insert or update new distributors as appropriate. Assumes a unique index has been defined that constrains values appearing in the `did` column. Note that the special excluded table is used to reference values originally proposed for insertion:

```

INSERT INTO distributors (did, dname)
  VALUES (5, 'Gizmo Transglobal'), (6, 'Associated Computing,
  Inc')
  ON CONFLICT (did) DO UPDATE SET dname = EXCLUDED.dname;

```

Insert a distributor, or do nothing for rows proposed for insertion when an existing, excluded row (a row with a matching constrained column or columns after before row insert triggers fire) exists. Example assumes a unique index has been defined that constrains values appearing in the did column:

```

INSERT INTO distributors (did, dname) VALUES (7, 'Redline GmbH')
  ON CONFLICT (did) DO NOTHING;

```

Insert or update new distributors as appropriate. Example assumes a unique index has been defined that constrains values appearing in the did column. WHERE clause is used to limit the rows actually updated (any existing row not updated will still be locked, though):

```

-- Don't update existing distributors based in a certain ZIP code
INSERT INTO distributors AS d (did, dname) VALUES (8, 'Anvil
  Distribution')
  ON CONFLICT (did) DO UPDATE
  SET dname = EXCLUDED.dname || ' (formerly ' || d.dname || ')'
  WHERE d.zipcode <> '21201';

```

```

-- Name a constraint directly in the statement (uses associated
-- index to arbitrate taking the DO NOTHING action)
INSERT INTO distributors (did, dname) VALUES (9, 'Antwerp Design')
  ON CONFLICT ON CONSTRAINT distributors_pkey DO NOTHING;

```

Insert new distributor if possible; otherwise DO NOTHING. Example assumes a unique index has been defined that constrains values appearing in the did column on a subset of rows where the is\_active Boolean column evaluates to true:

```

-- This statement could infer a partial unique index on "did"
-- with a predicate of "WHERE is_active", but it could also
-- just use a regular unique constraint on "did"
INSERT INTO distributors (did, dname) VALUES (10, 'Conrad
  International')
  ON CONFLICT (did) WHERE is_active DO NOTHING;

```

Consider the table created by the following CREATE TABLE statement, then we run the statements shown in the ltsql client, the result is as follows:

```

CREATE TABLE test (
  id INT NOT NULL,
  name CHAR(16),
  age INT DEFAULT 0,
  PRIMARY KEY(id)
);

lightdb@testdb=# INSERT INTO test VALUES (1, 'Old name', '18');
INSERT 0 1

lightdb@testdb=# INSERT INTO test VALUES (2, 'Old name', '19') ON
  DUPLICATE KEY UPDATE name = 'New name';

```

## INSERT

---

```
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
```

id	name	age
1	Old name	18
2	Old name	19

(2 rows)

```
lightdb@testdb=# INSERT INTO test VALUES (2, 'Old name', '20') ON
DUPLICATE KEY UPDATE name = 'New name', age = test.age + 5;
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
```

id	name	age
1	Old name	18
2	New name	24

(2 rows)

```
lightdb@testdb=# INSERT INTO test VALUES (2, 'Old name', '20') ON
DUPLICATE KEY UPDATE name = 'New name', age = excluded.age;
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
```

id	name	age
1	Old name	18
2	New name	20

(2 rows)

```
lightdb@testdb=# INSERT INTO test VALUES (2, 'Old name', '20') ON
DUPLICATE KEY UPDATE name = VALUES(name), age = VALUES(age);
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
```

id	name	age
1	Old name	18
2	Old name	20

(2 rows)

```
lightdb@testdb=# INSERT INTO test VALUES (2, 'New name', '29') ON
DUPLICATE KEY UPDATE name = name, age = VALUES(age);
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
```

id	name	age
1	Old name	18
2	Old name	29

(2 rows)

Multitable insert, can use insert all statement to insert multiple table. Also perform a conditional multitable insert.

```
CREATE TABLE T1(a int , b text);
```

```
CREATE TABLE T1_1(a int , b text);
CREATE TABLE T1_2(a int , b text);

-- multi table insert
INSERT ALL INTO T1_1 VALUES(1,1) INTO T1_2 VALUES(2,2) SELECT *
FROM DUAL;
INSERT ALL INTO T1_1 VALUES(a,b) INTO T1_2 VALUES(a%100, b)
SELECT * FROM T1;
-- conditional multitable insert
INSERT ALL WHEN a > 2 THEN INTO T1_1 ELSE INTO T1_2 SELECT * FROM
T1;
```

Insert ignore in mysql compatible mode:

```
create database mydb with lightdb_syntax_compatible_type 'mysql';
\c mydb;
create table t( a int primary key, b int);
INSERT IGNORE INTO t(a,b) values(1,1),(2,2),(1,1);
```

## Compatibility

INSERT conforms to the SQL standard, except that the RETURNING clause is a LightDB extension, as is the ability to use WITH with INSERT, and the ability to specify an alternative action with ON CONFLICT. Also, the case in which a column name list is omitted, but not all the columns are filled from the VALUES clause or *query*, is disallowed by the standard.

Only when the syntax compatible type of the database is oracle can the optional AS before alias be omitted.

The SQL standard specifies that OVERRIDING SYSTEM VALUE can only be specified if an identity column that is generated always exists. LightDB allows the clause in any case and ignores it if it is not applicable.

ON DUPLICATE KEY UPDATE clause is a LightDB extension to the SQL standard. It is only supported while the syntax compatible type of the database is mysql. See lightdb\_syntax\_compatible\_type for details.

INSERT ALL statement is a LightDB extension to the SQL standard. It is only supported while the syntax compatible type of the database is oracle. See lightdb\_syntax\_compatible\_type for details.

Possible limitations of the *query* clause are documented under SELECT.

---

# LISTEN

LISTEN — listen for a notification

## Synopsis

```
LISTEN channel
```

## Description

LISTEN registers the current session as a listener on the notification channel named *channel*. If the current session is already registered as a listener for this notification channel, nothing is done.

Whenever the command NOTIFY *channel* is invoked, either by this session or another one connected to the same database, all the sessions currently listening on that notification channel are notified, and each will in turn notify its connected client application.

A session can be unregistered for a given notification channel with the UNLISTEN command. A session's listen registrations are automatically cleared when the session ends.

The method a client application must use to detect notification events depends on which LightDB application programming interface it uses. With the libpq library, the application issues LISTEN as an ordinary SQL command, and then must periodically call the function PQnotifies to find out whether any notification events have been received. Other interfaces such as libpqtc1 provide higher-level methods for handling notify events; indeed, with libpqtc1 the application programmer should not even issue LISTEN or UNLISTEN directly. See the documentation for the interface you are using for more details.

## Parameters

*channel*

Name of a notification channel (any identifier).

## Notes

LISTEN takes effect at transaction commit. If LISTEN or UNLISTEN is executed within a transaction that later rolls back, the set of notification channels being listened to is unchanged.

A transaction that has executed LISTEN cannot be prepared for two-phase commit.

There is a race condition when first setting up a listening session: if concurrently-committing transactions are sending notify events, exactly which of those will the newly listening session receive? The answer is that the session will receive all events committed after an instant during the transaction's commit step. But that is slightly later than any database state that the transaction could have observed in queries. This leads to the following rule for using LISTEN: first execute (and commit!) that command, then in a new transaction inspect the database state as needed by the application logic, then rely on notifications to find out about subsequent changes to the database state. The first few received notifications might refer to updates already observed in the initial database inspection, but this is usually harmless.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

## Examples

Configure and execute a listen/notify sequence from ltsql:



```
LISTEN virtual;  
NOTIFY virtual;  
Asynchronous notification "virtual" received from server process  
with PID 8448.
```

## Compatibility

There is no `LISTEN` statement in the SQL standard.

## See Also

NOTIFY, UNLISTEN

---

# LOAD

LOAD — load a shared library file

## Synopsis

```
LOAD 'filename'
```

## Description

This command loads a shared library file into the LightDB server's address space. If the file has been loaded already, the command does nothing. Shared library files that contain C functions are automatically loaded whenever one of their functions is called. Therefore, an explicit LOAD is usually only needed to load a library that modifies the server's behavior through “hooks” rather than providing a set of functions.

The library file name is typically given as just a bare file name, which is sought in the server's library search path (set by `dynamic_library_path`). Alternatively it can be given as a full path name. In either case the platform's standard shared library file name extension may be omitted. See Section 36.10.1 for more information on this topic.

Non-superusers can only apply LOAD to library files located in `$libdir/plugins/` — the specified *filename* must begin with exactly that string. (It is the database administrator's responsibility to ensure that only “safe” libraries are installed there.)

## Compatibility

LOAD is a LightDB extension.

## See Also

CREATE FUNCTION

---

# LOCK

LOCK — lock a table

## Synopsis

```
LOCK [ TABLE ] [ ONLY ] name [ * ] [, ...] [ IN lockmode MODE ]
[ NOWAIT ]
```

where *lockmode* is one of:

```
ACCESS SHARE | ROW SHARE | ROW EXCLUSIVE | SHARE UPDATE
EXCLUSIVE
| SHARE | SHARE ROW EXCLUSIVE | EXCLUSIVE | ACCESS EXCLUSIVE
```

## Description

LOCK TABLE obtains a table-level lock, waiting if necessary for any conflicting locks to be released. If NOWAIT is specified, LOCK TABLE does not wait to acquire the desired lock: if it cannot be acquired immediately, the command is aborted and an error is emitted. Once obtained, the lock is held for the remainder of the current transaction. (There is no UNLOCK TABLE command; locks are always released at transaction end.)

When a view is locked, all relations appearing in the view definition query are also locked recursively with the same lock mode.

When acquiring locks automatically for commands that reference tables, LightDB always uses the least restrictive lock mode possible. LOCK TABLE provides for cases when you might need more restrictive locking. For example, suppose an application runs a transaction at the READ COMMITTED isolation level and needs to ensure that data in a table remains stable for the duration of the transaction. To achieve this you could obtain SHARE lock mode over the table before querying. This will prevent concurrent data changes and ensure subsequent reads of the table see a stable view of committed data, because SHARE lock mode conflicts with the ROW EXCLUSIVE lock acquired by writers, and your LOCK TABLE *name* IN SHARE MODE statement will wait until any concurrent holders of ROW EXCLUSIVE mode locks commit or roll back. Thus, once you obtain the lock, there are no uncommitted writes outstanding; furthermore none can begin until you release the lock.

To achieve a similar effect when running a transaction at the REPEATABLE READ or SERIALIZABLE isolation level, you have to execute the LOCK TABLE statement before executing any SELECT or data modification statement. A REPEATABLE READ or SERIALIZABLE transaction's view of data will be frozen when its first SELECT or data modification statement begins. A LOCK TABLE later in the transaction will still prevent concurrent writes — but it won't ensure that what the transaction reads corresponds to the latest committed values.

If a transaction of this sort is going to change the data in the table, then it should use SHARE ROW EXCLUSIVE lock mode instead of SHARE mode. This ensures that only one transaction of this type runs at a time. Without this, a deadlock is possible: two transactions might both acquire SHARE mode, and then be unable to also acquire ROW EXCLUSIVE mode to actually perform their updates. (Note that a transaction's own locks never conflict, so a transaction can acquire ROW EXCLUSIVE mode when it holds SHARE mode — but not if anyone else holds SHARE mode.) To avoid deadlocks, make sure all transactions acquire locks on the same objects in the same order, and if multiple lock modes are involved for a single object, then transactions should always acquire the most restrictive mode first.

More information about the lock modes and locking strategies can be found in Section 13.3.

## Parameters

### *name*

The name (optionally schema-qualified) of an existing table to lock. If `ONLY` is specified before the table name, only that table is locked. If `ONLY` is not specified, the table and all its descendant tables (if any) are locked. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

The command `LOCK TABLE a, b;` is equivalent to `LOCK TABLE a; LOCK TABLE b;`. The tables are locked one-by-one in the order specified in the `LOCK TABLE` command.

### *lockmode*

The lock mode specifies which locks this lock conflicts with. Lock modes are described in Section 13.3.

If no lock mode is specified, then `ACCESS EXCLUSIVE`, the most restrictive mode, is used.

### `NOWAIT`

Specifies that `LOCK TABLE` should not wait for any conflicting locks to be released: if the specified lock(s) cannot be acquired immediately without waiting, the transaction is aborted.

## Notes

`LOCK TABLE ... IN ACCESS SHARE MODE` requires `SELECT` privileges on the target table. `LOCK TABLE ... IN ROW EXCLUSIVE MODE` requires `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` privileges on the target table. All other forms of `LOCK` require table-level `UPDATE`, `DELETE`, or `TRUNCATE` privileges.

The user performing the lock on the view must have the corresponding privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the lock does not need any permissions on the underlying base relations.

`LOCK TABLE` is useless outside a transaction block: the lock would remain held only to the completion of the statement. Therefore LightDB reports an error if `LOCK` is used outside a transaction block. Use `BEGIN` and `COMMIT` (or `ROLLBACK`) to define a transaction block.

`LOCK TABLE` only deals with table-level locks, and so the mode names involving `ROW` are all misnomers. These mode names should generally be read as indicating the intention of the user to acquire row-level locks within the locked table. Also, `ROW EXCLUSIVE` mode is a shareable table lock. Keep in mind that all the lock modes have identical semantics so far as `LOCK TABLE` is concerned, differing only in the rules about which modes conflict with which. For information on how to acquire an actual row-level lock, see Section 13.3.2 and The Locking Clause in the `SELECT` documentation.

## Examples

Obtain a `SHARE` lock on a primary key table when going to perform inserts into a foreign key table:

```
BEGIN WORK;
LOCK TABLE films IN SHARE MODE;
SELECT id FROM films
  WHERE name = 'Star Wars: Episode I - The Phantom Menace';
-- Do ROLLBACK if record was not returned
INSERT INTO films_user_comments VALUES
  (_id_, 'GREAT! I was waiting for it for so long!');
```

```
COMMIT WORK;
```

Take a `SHARE ROW EXCLUSIVE` lock on a primary key table when going to perform a delete operation:

```
BEGIN WORK;
LOCK TABLE films IN SHARE ROW EXCLUSIVE MODE;
DELETE FROM films_user_comments WHERE id IN
    (SELECT id FROM films WHERE rating < 5);
DELETE FROM films WHERE rating < 5;
COMMIT WORK;
```

## Compatibility

There is no `LOCK TABLE` in the SQL standard, which instead uses `SET TRANSACTION` to specify concurrency levels on transactions. LightDB supports that too; see `SET TRANSACTION` for details.

Except for `ACCESS SHARE`, `ACCESS EXCLUSIVE`, and `SHARE UPDATE EXCLUSIVE` lock modes, the LightDB lock modes and the `LOCK TABLE` syntax are compatible with those present in Oracle.

---

# MOVE

MOVE — position a cursor

## Synopsis

```
MOVE [ direction [ FROM | IN ] ] cursor_name
```

where *direction* can be empty or one of:

```
NEXT  
PRIOR  
FIRST  
LAST  
ABSOLUTE count  
RELATIVE count  
count  
ALL  
FORWARD  
FORWARD count  
FORWARD ALL  
BACKWARD  
BACKWARD count  
BACKWARD ALL
```

## Description

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only positions the cursor and does not return rows.

The parameters for the MOVE command are identical to those of the FETCH command; refer to FETCH for details on syntax and usage.

## Outputs

On successful completion, a MOVE command returns a command tag of the form

```
MOVE count
```

The *count* is the number of rows that a FETCH command with the same parameters would have returned (possibly zero).

## Examples

```
BEGIN WORK;  
DECLARE liahona CURSOR FOR SELECT * FROM films;  
  
-- Skip the first 5 rows:  
MOVE FORWARD 5 IN liahona;  
MOVE 5  
  
-- Fetch the 6th row from the cursor liahona:
```

```
FETCH 1 FROM liahona;
code | title | did | date_prod | kind | len
-----+-----+-----+-----+-----+-----
P_303 | 48 Hrs | 103 | 1982-10-22 | Action | 01:37
(1 row)

-- Close the cursor liahona and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

## Compatibility

There is no MOVE statement in the SQL standard.

## See Also

CLOSE, DECLARE, FETCH

---

# MERGE

MERGE — insert, update rows of a table based upon source data

## Synopsis

```
MERGE INTO target_table_name [ [ AS ] target_alias ]
USING data_source
ON join_condition
when_clause [...]

where data_source is

{ source_table_name |
  ( source_query )
}
[ [ AS ] source_alias ]

and when_clause is

{ WHEN MATCHED THEN { merge_update } |
  WHEN NOT MATCHED THEN { merge_insert }
}

and merge_insert is

INSERT [( column_name [, ...] )]
VALUES ( { expression | DEFAULT } [, ...] ) | DEFAULT
VALUES
}
[ WHERE condition ]

and merge_update is

UPDATE SET { column_name = {
  expression | DEFAULT } |
  ( column_name [, ...] ) = ( {
  expression | DEFAULT } [, ...] )
} [, ...]
[ WHERE condition ]
```

## Description

MERGE performs actions that modify rows in the *target\_table\_name*, using the *data\_source*. MERGE provides a single SQL statement that can conditionally INSERT or UPDATE rows, a task that would otherwise require multiple procedural language statements.

First, the MERGE command performs a join from *data\_source* to *target\_table\_name* producing zero or more candidate change rows. For each candidate change row the status of MATCHED or NOT MATCHED is set just once, after which WHEN clauses are evaluated in the order specified. If one of them is activated, the specified action occurs. No more than one WHEN clause can be activated for any candidate change row.



MERGE actions have the same effect as regular UPDATE, INSERT commands of the same names. The syntax of those commands is different, notably that there is no tablename is specified. All actions refer to the *target\_table\_name*.

There is no MERGE privilege. You must have the UPDATE privilege on the column(s) of the *target\_table\_name* referred to in the SET clause if you specify an update action, the INSERT privilege on the *target\_table\_name* if you specify an insert action. Privileges are tested once at statement start and are checked whether or not particular WHEN clauses are activated during the subsequent execution. You will require the SELECT privilege on the *data\_source* and any column(s) of the *target\_table\_name* referred to in a condition.

MERGE is not supported if the *target\_table\_name* has RULES defined on it.

### Caution

It is necessary to ensure that a record in the target table does not match multiple times with a record in the source table, as this may result in updated records in the target table not having a certain value.

## Parameters

*target\_table\_name*

The name (optionally schema-qualified) of the target table to merge into.

*target\_alias*

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given MERGE foo AS f, the remainder of the MERGE statement must refer to this table as f not foo.

*source\_table\_name*

The name (optionally schema-qualified) of the source table, view or transition table.

*source\_query*

A query (SELECT statement or VALUES statement) that supplies the rows to be merged into the *target\_table\_name*. Refer to the SELECT statement or VALUES statement for a description of the syntax.

*source\_alias*

A substitute name for the data source. When an alias is provided, it completely hides whether table or query was specified.

*join\_condition*

*join\_condition* is an expression resulting in a value of type boolean (similar to a WHERE clause) that specifies which rows in the *data\_source* match rows in the *target\_table\_name*.

### Warning

Only columns from *target\_table\_name* that attempt to match *data\_source* rows should appear in *join\_condition*. *join\_condition* subexpressions that only reference

*target\_table\_name* columns can only affect which action is taken, often in surprising ways.

#### *when\_clause*

At least one WHEN clause is required.

If the WHEN clause specifies WHEN MATCHED and the candidate change row matches a row in the *target\_table\_name* the WHEN clause is activated if the *condition* is absent or is present and evaluates to `true`. If the WHEN clause specifies WHEN NOT MATCHED and the candidate change row does not match a row in the *target\_table\_name* the WHEN clause is activated if the *condition* is absent or is present and evaluates to `true`.

#### *merge\_insert*

The specification of an INSERT action that inserts one row into the target table. The target column names can be listed in any order. If no list of column names is given at all, the default is all the columns of the table in their declared order.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is none.

If the expression for any column is not of the correct data type, automatic type conversion will be attempted.

If *target\_table\_name* is a partitioned table, each row is routed to the appropriate partition and inserted into it. If *target\_table\_name* is a partition, an error will occur if one of the input rows violates the partition constraint.

Column names may not be specified more than once. INSERT actions cannot contain sub-selects.

Only one VALUES clause can be specified. The VALUES clause can only refer to columns from the source relation, since by definition there is no matching target row.

#### *merge\_update*

The specification of an UPDATE action that updates the current row of the *target\_table\_name*. Column names may not be specified more than once.

Do not include the table name, as you would normally do with an UPDATE command. For example, UPDATE tab SET col = 1 is invalid.

#### *column\_name*

The name of a column in the *target\_table\_name*. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.) When referencing a column, do not include the table's name in the specification of a target column.

#### *expression*

An expression to assign to the column. The expression can use the old values of this and other columns in the table.

#### *condition*

An expression that returns a value of type `boolean`. If this expression returns `true` then the WHEN clause will be activated and the corresponding action will occur for that row. The expression may not contain functions that possibly performs writes to the database.

A condition on a `WHEN MATCHED` clause can refer to columns in both the source and the target relation. A condition on a `WHEN NOT MATCHED` clause can only refer to columns from the source relation, since by definition there is no matching target row.

## Outputs

On successful completion, a `MERGE` command returns a command tag of the form

```
MERGE total-count
```

The *total-count* is the total number of rows changed (whether inserted, updated, or deleted). If *total-count* is 0, no rows were changed in any way.

## Examples

Perform maintenance on `CustomerAccounts` based upon new `Transactions`.

```
MERGE INTO CustomerAccount CA
USING RecentTransactions T
ON T.CustomerId = CA.CustomerId
WHEN MATCHED THEN
UPDATE SET Balance = Balance + TransactionValue
WHEN NOT MATCHED THEN
INSERT (CustomerId, Balance)
VALUES (T.CustomerId, T.TransactionValue);
```

notice that this would be exactly equivalent to the following statement because the `MATCHED` result does not change during execution

```
MERGE INTO CustomerAccount CA
USING (Select CustomerId, TransactionValue From
RecentTransactions) AS T
ON CA.CustomerId = T.CustomerId
WHEN NOT MATCHED THEN
INSERT (CustomerId, Balance)
VALUES (T.CustomerId, T.TransactionValue)
WHEN MATCHED THEN
UPDATE SET Balance = Balance + TransactionValue;
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. Don't allow entries that have zero stock.

```
MERGE INTO wines w
USING wine_stock_changes s
ON s.winename = w.winename
WHEN NOT MATCHED THEN
INSERT VALUES(s.winename, s.stock_delta) WHERE
s.stock_delta > 0
WHEN MATCHED THEN
UPDATE SET stock = w.stock + s.stock_delta WHERE
w.stock + s.stock_delta > 0;
```

The wine\_stock\_changes table might be, for example, a temporary table recently loaded into the database.

---

# NOTIFY

NOTIFY — generate a notification

## Synopsis

```
NOTIFY channel [ , payload ]
```

## Description

The NOTIFY command sends a notification event together with an optional “payload” string to each client application that has previously executed LISTEN *channel* for the specified channel name in the current database. Notifications are visible to all users.

NOTIFY provides a simple interprocess communication mechanism for a collection of processes accessing the same LightDB database. A payload string can be sent along with the notification, and higher-level mechanisms for passing structured data can be built by using tables in the database to pass additional data from notifier to listener(s).

The information passed to the client for a notification event includes the notification channel name, the notifying session's server process PID, and the payload string, which is an empty string if it has not been specified.

It is up to the database designer to define the channel names that will be used in a given database and what each one means. Commonly, the channel name is the same as the name of some table in the database, and the notify event essentially means, “I changed this table, take a look at it to see what's new”. But no such association is enforced by the NOTIFY and LISTEN commands. For example, a database designer could use several different channel names to signal different sorts of changes to a single table. Alternatively, the payload string could be used to differentiate various cases.

When NOTIFY is used to signal the occurrence of changes to a particular table, a useful programming technique is to put the NOTIFY in a statement trigger that is triggered by table updates. In this way, notification happens automatically when the table is changed, and the application programmer cannot accidentally forget to do it.

NOTIFY interacts with SQL transactions in some important ways. Firstly, if a NOTIFY is executed inside a transaction, the notify events are not delivered until and unless the transaction is committed. This is appropriate, since if the transaction is aborted, all the commands within it have had no effect, including NOTIFY. But it can be disconcerting if one is expecting the notification events to be delivered immediately. Secondly, if a listening session receives a notification signal while it is within a transaction, the notification event will not be delivered to its connected client until just after the transaction is completed (either committed or aborted). Again, the reasoning is that if a notification were delivered within a transaction that was later aborted, one would want the notification to be undone somehow — but the server cannot “take back” a notification once it has sent it to the client. So notification events are only delivered between transactions. The upshot of this is that applications using NOTIFY for real-time signaling should try to keep their transactions short.

If the same channel name is signaled multiple times with identical payload strings within the same transaction, only one instance of the notification event is delivered to listeners. On the other hand, notifications with distinct payload strings will always be delivered as distinct notifications. Similarly, notifications from different transactions will never get folded into one notification. Except for dropping later instances of duplicate notifications, NOTIFY guarantees that notifications from the same transaction get delivered in the order they were sent. It is also guaranteed that messages from different transactions are delivered in the order in which the transactions committed.

It is common for a client that executes NOTIFY to be listening on the same notification channel itself. In that case it will get back a notification event, just like all the other listening sessions. Depending on the application logic, this could result in useless work, for example, reading a database table to find the same updates that that session just wrote out. It is possible to avoid such extra work by noticing whether the notifying session's server process PID (supplied in the notification event message) is the same as one's own session's PID (available from libpq). When they are the same, the notification event is one's own work bouncing back, and can be ignored.

## Parameters

*channel*

Name of the notification channel to be signaled (any identifier).

*payload*

The “payload” string to be communicated along with the notification. This must be specified as a simple string literal. In the default configuration it must be shorter than 8000 bytes. (If binary data or large amounts of information need to be communicated, it's best to put it in a database table and send the key of the record.)

## Notes

There is a queue that holds notifications that have been sent but not yet processed by all listening sessions. If this queue becomes full, transactions calling NOTIFY will fail at commit. The queue is quite large (8GB in a standard installation) and should be sufficiently sized for almost every use case. However, no cleanup can take place if a session executes LISTEN and then enters a transaction for a very long time. Once the queue is half full you will see warnings in the log file pointing you to the session that is preventing cleanup. In this case you should make sure that this session ends its current transaction so that cleanup can proceed.

The function `pg_notification_queue_usage` returns the fraction of the queue that is currently occupied by pending notifications. See Section 9.26 for more information.

A transaction that has executed NOTIFY cannot be prepared for two-phase commit.

## pg\_notify

To send a notification you can also use the function `pg_notify(text, text)`. The function takes the channel name as the first argument and the payload as the second. The function is much easier to use than the NOTIFY command if you need to work with non-constant channel names and payloads.

## Examples

Configure and execute a listen/notify sequence from ltsql:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process
with PID 8448.
NOTIFY virtual, 'This is the payload';
Asynchronous notification "virtual" with payload "This is the
payload" received from server process with PID 8448.

LISTEN foo;
SELECT pg_notify('fo' || 'o', 'pay' || 'load');
```

Asynchronous notification "foo" with payload "payload" received  
from server process with PID 14728.

## Compatibility

There is no NOTIFY statement in the SQL standard.

## See Also

LISTEN, UNLISTEN

---

# PREPARE

PREPARE — prepare a statement for execution

## Synopsis

```
PREPARE name [ ( data_type [, ...] ) ] AS statement  
PREPARE name FROM variable
```

## Description

PREPARE creates a prepared statement. A prepared statement is a server-side object that can be used to optimize performance. When the PREPARE statement is executed, the specified statement is parsed, analyzed, and rewritten. When an EXECUTE command is subsequently issued, the prepared statement is planned and executed. This division of labor avoids repetitive parse analysis work, while allowing the execution plan to depend on the specific parameter values supplied.

Prepared statements can take parameters: values that are substituted into the statement when it is executed. When creating the prepared statement, refer to parameters by position, using \$1, \$2, etc. A corresponding list of parameter data types can optionally be specified. When a parameter's data type is not specified or is declared as unknown, the type is inferred from the context in which the parameter is first referenced (if possible). When executing the statement, specify the actual values for these parameters in the EXECUTE statement. Refer to EXECUTE for more information about that.

Prepared statements only last for the duration of the current database session. When the session ends, the prepared statement is forgotten, so it must be recreated before being used again. This also means that a single prepared statement cannot be used by multiple simultaneous database clients; however, each client can create their own prepared statement to use. Prepared statements can be manually cleaned up using the DEALLOCATE command.

Prepared statements potentially have the largest performance advantage when a single session is being used to execute a large number of similar statements. The performance difference will be particularly significant if the statements are complex to plan or rewrite, e.g., if the query involves a join of many tables or requires the application of several rules. If the statement is relatively simple to plan and rewrite but relatively expensive to execute, the performance advantage of prepared statements will be less noticeable.

## Parameters

*name*

An arbitrary name given to this particular prepared statement. It must be unique within a single session and is subsequently used to execute or deallocate a previously prepared statement.

*data\_type*

The data type of a parameter to the prepared statement. If the data type of a particular parameter is unspecified or is specified as unknown, it will be inferred from the context in which the parameter is first referenced. To refer to the parameters in the prepared statement itself, use \$1, \$2, etc.

*statement*

Any SELECT, INSERT, UPDATE, DELETE, or VALUES statement.



*variable*

On `mysql mode#Seelightdb_dblevel_syntax_compatible_type#`, *variable* is a user variable containing the text of the SQL statement. Any `ALTER [ TABLE | INDEX | SEQUENCE | VIEW | MATERIALIZED VIEW ]`, `SELECT`, `INSERT`, `UPDATE`, `DELETE` or `VALUES` statement. The text must represent a single statement, not multiple statements.

## Notes

A prepared statement can be executed with either a *generic plan* or a *custom plan*. A generic plan is the same across all executions, while a custom plan is generated for a specific execution using the parameter values given in that call. Use of a generic plan avoids planning overhead, but in some situations a custom plan will be much more efficient to execute because the planner can make use of knowledge of the parameter values. (Of course, if the prepared statement has no parameters, then this is moot and a generic plan is always used.)

By default (that is, when `plan_cache_mode` is set to `auto`), the server will automatically choose whether to use a generic or custom plan for a prepared statement that has parameters. The current rule for this is that the first five executions are done with custom plans and the average estimated cost of those plans is calculated. Then a generic plan is created and its estimated cost is compared to the average custom-plan cost. Subsequent executions use the generic plan if its cost is not so much higher than the average custom-plan cost as to make repeated replanning seem preferable.

This heuristic can be overridden, forcing the server to use either generic or custom plans, by setting `plan_cache_mode` to `force_generic_plan` or `force_custom_plan` respectively. This setting is primarily useful if the generic plan's cost estimate is badly off for some reason, allowing it to be chosen even though its actual cost is much more than that of a custom plan.

To examine the query plan LightDB is using for a prepared statement, use `EXPLAIN`, for example

```
EXPLAIN EXECUTE name(parameter_values);
```

If a generic plan is in use, it will contain parameter symbols `$n`, while a custom plan will have the supplied parameter values substituted into it.

For more information on query planning and the statistics collected by LightDB for that purpose, see the `ANALYZE` documentation.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, LightDB will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of `search_path` changes from one use to the next, the statement will be re-parsed using the new `search_path`. (This latter behavior is new as of LightDB 9.3.) These rules make use of a prepared statement semantically almost equivalent to re-submitting the same query text over and over, but with a performance benefit if no object definitions are changed, especially if the best plan remains the same across uses. An example of a case where the semantic equivalence is not perfect is that if the statement refers to a table by an unqualified name, and then a new table of the same name is created in a schema appearing earlier in the `search_path`, no automatic re-parse will occur since no object used in the statement changed. However, if some other change forces a re-parse, the new table will be referenced in subsequent uses.

You can see all prepared statements available in the session by querying the `pg_prepared_statements` system view.

## Examples

Create a prepared statement for an `INSERT` statement, and then execute it:

```
PREPARE fooplan (int, text, bool, numeric) AS
  INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Create a prepared statement for a SELECT statement, and then execute it:

```
PREPARE usrrptplan (int) AS
  SELECT * FROM users u, logs l WHERE u.usrid=$1 AND
  u.usrid=l.usrid
  AND l.date = $2;
EXECUTE usrrptplan(1, current_date);
```

In this example, the data type of the second parameter is not specified, so it is inferred from the context in which \$2 is used.

On mysql mode#Seelightdb\_dblevel\_syntax\_compatible\_type#, Create a prepared statement for a INSERTstatement, and then execute it:

```
SET @sql = 'INSERT INTO my_table values(a)';
PREPARE stmt FROM @sql;
EXECUTE stmt;
DEALLOCATE PREPARE stmt;
```

In this example, there are no parameters that need to be bound in the user variable content.

## Compatibility

The SQL standard includes a PREPARE statement, but it is only for use in embedded SQL. This version of the PREPARE statement also uses a somewhat different syntax.

## See Also

DEALLOCATE, EXECUTE

---

# PREPARE TRANSACTION

PREPARE TRANSACTION — prepare the current transaction for two-phase commit

## Synopsis

```
PREPARE TRANSACTION transaction_id
```

## Description

PREPARE TRANSACTION prepares the current transaction for two-phase commit. After this command, the transaction is no longer associated with the current session; instead, its state is fully stored on disk, and there is a very high probability that it can be committed successfully, even if a database crash occurs before the commit is requested.

Once prepared, a transaction can later be committed or rolled back with COMMIT PREPARED or ROLLBACK PREPARED, respectively. Those commands can be issued from any session, not only the one that executed the original transaction.

From the point of view of the issuing session, PREPARE TRANSACTION is not unlike a ROLLBACK command: after executing it, there is no active current transaction, and the effects of the prepared transaction are no longer visible. (The effects will become visible again if the transaction is committed.)

If the PREPARE TRANSACTION command fails for any reason, it becomes a ROLLBACK: the current transaction is canceled.

## Parameters

*transaction\_id*

An arbitrary identifier that later identifies this transaction for COMMIT PREPARED or ROLLBACK PREPARED. The identifier must be written as a string literal, and must be less than 200 bytes long. It must not be the same as the identifier used for any currently prepared transaction.

## Notes

PREPARE TRANSACTION is not intended for use in applications or interactive sessions. Its purpose is to allow an external transaction manager to perform atomic global transactions across multiple databases or other transactional resources. Unless you're writing a transaction manager, you probably shouldn't be using PREPARE TRANSACTION.

This command must be used inside a transaction block. Use BEGIN to start one.

It is not currently allowed to PREPARE a transaction that has executed any operations involving temporary tables or the session's temporary namespace, created any cursors WITH HOLD, or executed LISTEN, UNLISTEN, or NOTIFY. Those features are too tightly tied to the current session to be useful in a transaction to be prepared.

If the transaction modified any run-time parameters with SET (without the LOCAL option), those effects persist after PREPARE TRANSACTION, and will not be affected by any later COMMIT PREPARED or ROLLBACK PREPARED. Thus, in this one respect PREPARE TRANSACTION acts more like COMMIT than ROLLBACK.

All currently available prepared transactions are listed in the pg\_prepared\_xacts system view.

### Caution

It is unwise to leave transactions in the prepared state for a long time. This will interfere with the ability of VACUUM to reclaim storage, and in extreme cases could cause the database to shut down to prevent transaction ID wraparound (see Section 22.1.5). Keep in mind also that the transaction continues to hold whatever locks it held. The intended usage of the feature is that a prepared transaction will normally be committed or rolled back as soon as an external transaction manager has verified that other databases are also prepared to commit.

If you have not set up an external transaction manager to track prepared transactions and ensure they get closed out promptly, it is best to keep the prepared-transaction feature disabled by setting `max_prepared_transactions` to zero. This will prevent accidental creation of prepared transactions that might then be forgotten and eventually cause problems.

## Examples

Prepare the current transaction for two-phase commit, using `foobar` as the transaction identifier:

```
PREPARE TRANSACTION 'foobar';
```

## Compatibility

PREPARE TRANSACTION is a LightDB extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

## See Also

COMMIT PREPARED, ROLLBACK PREPARED

---

# REASSIGN OWNED

REASSIGN OWNED — change the ownership of database objects owned by a database role

## Synopsis

```
REASSIGN OWNED BY { old_role | CURRENT_USER | SESSION_USER }  
[, ...]  
TO { new_role | CURRENT_USER | SESSION_USER }
```

## Description

REASSIGN OWNED instructs the system to change the ownership of database objects owned by any of the *old\_roles* to *new\_role*.

## Parameters

*old\_role*

The name of a role. The ownership of all the objects within the current database, and of all shared objects (databases, tablespaces), owned by this role will be reassigned to *new\_role*.

*new\_role*

The name of the role that will be made the new owner of the affected objects.

## Notes

REASSIGN OWNED is often used to prepare for the removal of one or more roles. Because REASSIGN OWNED does not affect objects within other databases, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

REASSIGN OWNED requires membership on both the source role(s) and the target role.

The DROP OWNED command is an alternative that simply drops all the database objects owned by one or more roles.

The REASSIGN OWNED command does not affect any privileges granted to the *old\_roles* on objects that are not owned by them. Likewise, it does not affect default privileges created with ALTER DEFAULT PRIVILEGES. Use DROP OWNED to revoke such privileges.

See Section 19.4 for more discussion.

## Compatibility

The REASSIGN OWNED command is a LightDB extension.

## See Also

DROP OWNED, DROP ROLE, ALTER DATABASE

---

# REFRESH MATERIALIZED VIEW

REFRESH MATERIALIZED VIEW — replace the contents of a materialized view

## Synopsis

```
REFRESH MATERIALIZED VIEW [ CONCURRENTLY ] name
    [ WITH [ NO ] DATA ]
```

## Description

REFRESH MATERIALIZED VIEW completely replaces the contents of a materialized view. To execute this command you must be the owner of the materialized view. The old contents are discarded. If WITH DATA is specified (or defaults) the backing query is executed to provide the new data, and the materialized view is left in a scannable state. If WITH NO DATA is specified no new data is generated and the materialized view is left in an unscannable state.

CONCURRENTLY and WITH NO DATA may not be specified together.

## Parameters

CONCURRENTLY

Refresh the materialized view without locking out concurrent selects on the materialized view. Without this option a refresh which affects a lot of rows will tend to use fewer resources and complete more quickly, but could block other connections which are trying to read from the materialized view. This option may be faster in cases where a small number of rows are affected.

This option is only allowed if there is at least one UNIQUE index on the materialized view which uses only column names and includes all rows; that is, it must not be an expression index or include a WHERE clause.

This option may not be used when the materialized view is not already populated.

Even with this option only one REFRESH at a time may run against any one materialized view.

*name*

The name (optionally schema-qualified) of the materialized view to refresh.

## Notes

If there is an ORDER BY clause in the materialized view's defining query, the original contents of the materialized view will be ordered that way; but REFRESH MATERIALIZED VIEW does not guarantee to preserve that ordering.

## Examples

This command will replace the contents of the materialized view called `order_summary` using the query from the materialized view's definition, and leave it in a scannable state:

```
REFRESH MATERIALIZED VIEW order_summary;
```

This command will free storage associated with the materialized view `annual_statistics_basis` and leave it in an unscannable state:

```
REFRESH MATERIALIZED VIEW annual_statistics_basis WITH NO DATA;
```

## Compatibility

`REFRESH MATERIALIZED VIEW` is a LightDB extension.

## See Also

`CREATE MATERIALIZED VIEW`, `ALTER MATERIALIZED VIEW`, `DROP MATERIALIZED VIEW`

---

# REINDEX

REINDEX — rebuild indexes

## Synopsis

```
REINDEX [ ( option [, ...] ) ] { INDEX | TABLE | SCHEMA | DATABASE  
| SYSTEM } [ CONCURRENTLY ] name
```

where *option* can be one of:

VERBOSE

## Description

REINDEX rebuilds an index using the data stored in the index's table, replacing the old copy of the index. There are several scenarios in which to use REINDEX:

- An index has become corrupted, and no longer contains valid data. Although in theory this should never happen, in practice indexes can become corrupted due to software bugs or hardware failures. REINDEX provides a recovery method.
- An index has become “bloated”, that is it contains many empty or nearly-empty pages. This can occur with B-tree indexes in LightDB under certain uncommon access patterns. REINDEX provides a way to reduce the space consumption of the index by writing a new version of the index without the dead pages. See Section 22.2 for more information.
- You have altered a storage parameter (such as fillfactor) for an index, and wish to ensure that the change has taken full effect.
- If an index build fails with the CONCURRENTLY option, this index is left as “invalid”. Such indexes are useless but it can be convenient to use REINDEX to rebuild them. Note that only REINDEX INDEX is able to perform a concurrent build on an invalid index.

## Parameters

INDEX

Recreate the specified index.

TABLE

Recreate all indexes of the specified table. If the table has a secondary “TOAST” table, that is reindexed as well.

SCHEMA

Recreate all indexes of the specified schema. If a table of this schema has a secondary “TOAST” table, that is reindexed as well. Indexes on shared system catalogs are also processed. This form of REINDEX cannot be executed inside a transaction block.

DATABASE

Recreate all indexes within the current database. Indexes on shared system catalogs are also processed. This form of REINDEX cannot be executed inside a transaction block.



**SYSTEM**

Recreate all indexes on system catalogs within the current database. Indexes on shared system catalogs are included. Indexes on user tables are not processed. This form of REINDEX cannot be executed inside a transaction block.

*name*

The name of the specific index, table, or database to be reindexed. Index and table names can be schema-qualified. Presently, REINDEX DATABASE and REINDEX SYSTEM can only reindex the current database, so their parameter must match the current database's name.

**CONCURRENTLY**

When this option is used, LightDB will rebuild the index without taking any locks that prevent concurrent inserts, updates, or deletes on the table; whereas a standard index rebuild locks out writes (but not reads) on the table until it's done. There are several caveats to be aware of when using this option — see Rebuilding Indexes Concurrently below.

For temporary tables, REINDEX is always non-concurrent, as no other session can access them, and non-concurrent reindex is cheaper.

**VERBOSE**

Prints a progress report as each index is reindexed.

## Notes

If you suspect corruption of an index on a user table, you can simply rebuild that index, or all indexes on the table, using REINDEX INDEX or REINDEX TABLE.

Things are more difficult if you need to recover from corruption of an index on a system table. In this case it's important for the system to not have used any of the suspect indexes itself. (Indeed, in this sort of scenario you might find that server processes are crashing immediately at start-up, due to reliance on the corrupted indexes.) To recover safely, the server must be started with the `-P` option, which prevents it from using indexes for system catalog lookups.

One way to do this is to shut down the server and start a single-user LightDB server with the `-P` option included on its command line. Then, REINDEX DATABASE, REINDEX SYSTEM, REINDEX TABLE, or REINDEX INDEX can be issued, depending on how much you want to reconstruct. If in doubt, use REINDEX SYSTEM to select reconstruction of all system indexes in the database. Then quit the single-user server session and restart the regular server. See the `lightdb` reference page for more information about how to interact with the single-user server interface.

Alternatively, a regular server session can be started with `-P` included in its command line options. The method for doing this varies across clients, but in all libpq-based clients, it is possible to set the `LTOPTIONS` environment variable to `-P` before starting the client. Note that while this method does not require locking out other clients, it might still be wise to prevent other users from connecting to the damaged database until repairs have been completed.

REINDEX is similar to a drop and recreate of the index in that the index contents are rebuilt from scratch. However, the locking considerations are rather different. REINDEX locks out writes but not reads of the index's parent table. It also takes an ACCESS EXCLUSIVE lock on the specific index being processed, which will block reads that attempt to use that index. In contrast, DROP INDEX momentarily takes an ACCESS EXCLUSIVE lock on the parent table, blocking both writes and reads. The subsequent CREATE INDEX locks out writes but not reads; since the index is not there, no read will attempt to use it, meaning that there will be no blocking but reads might be forced into expensive sequential scans.

Reindexing a single index or table requires being the owner of that index or table. Reindexing a schema or database requires being the owner of that schema or database. Note specifically that it's thus possible

for non-superusers to rebuild indexes of tables owned by other users. However, as a special exception, when `REINDEX DATABASE`, `REINDEX SCHEMA` or `REINDEX SYSTEM` is issued by a non-superuser, indexes on shared catalogs will be skipped unless the user owns the catalog (which typically won't be the case). Of course, superusers can always reindex anything.

Reindexing partitioned tables or partitioned indexes is not supported. Each individual partition can be reindexed separately instead.

## Rebuilding Indexes Concurrently

Rebuilding an index can interfere with regular operation of a database. Normally LightDB locks the table whose index is rebuilt against writes and performs the entire index build with a single scan of the table. Other transactions can still read the table, but if they try to insert, update, or delete rows in the table they will block until the index rebuild is finished. This could have a severe effect if the system is a live production database. Very large tables can take many hours to be indexed, and even for smaller tables, an index rebuild can lock out writers for periods that are unacceptably long for a production system.

LightDB supports rebuilding indexes with minimum locking of writes. This method is invoked by specifying the `CONCURRENTLY` option of `REINDEX`. When this option is used, LightDB must perform two scans of the table for each index that needs to be rebuilt and wait for termination of all existing transactions that could potentially use the index. This method requires more total work than a standard index rebuild and takes significantly longer to complete as it needs to wait for unfinished transactions that might modify the index. However, since it allows normal operations to continue while the index is being rebuilt, this method is useful for rebuilding indexes in a production environment. Of course, the extra CPU, memory and I/O load imposed by the index rebuild may slow down other operations.

The following steps occur in a concurrent reindex. Each step is run in a separate transaction. If there are multiple indexes to be rebuilt, then each step loops through all the indexes before moving to the next step.

1. A new transient index definition is added to the catalog `pg_index`. This definition will be used to replace the old index. A `SHARE UPDATE EXCLUSIVE` lock at session level is taken on the indexes being reindexed as well as their associated tables to prevent any schema modification while processing.
2. A first pass to build the index is done for each new index. Once the index is built, its flag `pg_index.indisready` is switched to “true” to make it ready for inserts, making it visible to other sessions once the transaction that performed the build is finished. This step is done in a separate transaction for each index.
3. Then a second pass is performed to add tuples that were added while the first pass was running. This step is also done in a separate transaction for each index.
4. All the constraints that refer to the index are changed to refer to the new index definition, and the names of the indexes are changed. At this point, `pg_index.indisvalid` is switched to “true” for the new index and to “false” for the old, and a cache invalidation is done causing all sessions that referenced the old index to be invalidated.
5. The old indexes have `pg_index.indisready` switched to “false” to prevent any new tuple insertions, after waiting for running queries that might reference the old index to complete.
6. The old indexes are dropped. The `SHARE UPDATE EXCLUSIVE` session locks for the indexes and the table are released.

If a problem arises while rebuilding the indexes, such as a uniqueness violation in a unique index, the `REINDEX` command will fail but leave behind an “invalid” new index in addition to the pre-existing one. This index will be ignored for querying purposes because it might be incomplete; however it will still consume update overhead. The `ltsql \d` command will report such an index as `INVALID`:

```
lightdb@postgres=# \d tab
      Table "public.tab"
  Column | Type      | Modifiers
-----+-----+-----
   col   | integer   |
Indexes:
    "idx" btree (col)
    "idx_ccnew" btree (col) INVALID
```

If the index marked `INVALID` is suffixed `ccnew`, then it corresponds to the transient index created during the concurrent operation, and the recommended recovery method is to drop it using `DROP INDEX`, then attempt `REINDEX CONCURRENTLY` again. If the invalid index is instead suffixed `ccold`, it corresponds to the original index which could not be dropped; the recommended recovery method is to just drop said index, since the rebuild proper has been successful.

Regular index builds permit other regular index builds on the same table to occur simultaneously, but only one concurrent index build can occur on a table at a time. In both cases, no other types of schema modification on the table are allowed meanwhile. Another difference is that a regular `REINDEX TABLE` or `REINDEX INDEX` command can be performed within a transaction block, but `REINDEX CONCURRENTLY` cannot.

Like any long-running transaction, `REINDEX` on a table can affect which tuples can be removed by concurrent `VACUUM` on any other table.

`REINDEX SYSTEM` does not support `CONCURRENTLY` since system catalogs cannot be reindexed concurrently.

Furthermore, indexes for exclusion constraints cannot be reindexed concurrently. If such an index is named directly in this command, an error is raised. If a table or database with exclusion constraint indexes is reindexed concurrently, those indexes will be skipped. (It is possible to reindex such indexes without the `CONCURRENTLY` option.)

## Examples

Rebuild a single index:

```
REINDEX INDEX my_index;
```

Rebuild all the indexes on the table `my_table`:

```
REINDEX TABLE my_table;
```

Rebuild all indexes in a particular database, without trusting the system indexes to be valid already:

```
$ export PGOPTIONS="-P"
$ ltsql broken_db
...
broken_db=> REINDEX DATABASE broken_db;
broken_db=> \q
```

Rebuild indexes for a table, without blocking read and write operations on involved relations while reindexing is in progress:

```
REINDEX TABLE CONCURRENTLY my_broken_table;
```

## Compatibility

There is no REINDEX command in the SQL standard.

## See Also

CREATE INDEX, DROP INDEX, reindexdb

---

# RELEASE SAVEPOINT

RELEASE SAVEPOINT — destroy a previously defined savepoint

## Synopsis

```
RELEASE [ SAVEPOINT ] savepoint_name
```

## Description

RELEASE SAVEPOINT destroys a savepoint previously defined in the current transaction.

Destroying a savepoint makes it unavailable as a rollback point, but it has no other user visible behavior. It does not undo the effects of commands executed after the savepoint was established. (To do that, see ROLLBACK TO SAVEPOINT.) Destroying a savepoint when it is no longer needed allows the system to reclaim some resources earlier than transaction end.

RELEASE SAVEPOINT also destroys all savepoints that were established after the named savepoint was established.

## Parameters

*savepoint\_name*

The name of the savepoint to destroy.

## Notes

Specifying a savepoint name that was not previously defined is an error.

It is not possible to release a savepoint when the transaction is in an aborted state.

If multiple savepoints have the same name, only the most recently defined unreleased one is released. Repeated commands will release progressively older savepoints.

## Examples

To establish and later destroy a savepoint:

```
BEGIN;  
  INSERT INTO table1 VALUES (3);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (4);  
  RELEASE SAVEPOINT my_savepoint;  
COMMIT;
```

The above transaction will insert both 3 and 4.

## Compatibility

This command conforms to the SQL standard. The standard specifies that the key word SAVEPOINT is mandatory, but LightDB allows it to be omitted.

## **See Also**

BEGIN, COMMIT, ROLLBACK, ROLLBACK TO SAVEPOINT, SAVEPOINT

---

# REPLACE INTO

REPLACE INTO — update rows in a table while primary key constraint conflict

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]  
REPLACE INTO table_name [ AS alias ] [ ( column_name [, ...] ) ]  
  [ OVERRIDING { SYSTEM | USER } VALUE ]  
  VALUES ( { expression | DEFAULT } [, ...] ) [, ...]  
  [ RETURNING * | output_expression [ [ AS ] output_name ]  
  [, ...] ]
```

## Description

REPLACE works exactly like INSERT, except that if an old row in the table has the same value as a new row for a PRIMARY KEY index, the old row is deleted before the new row is inserted.

### Note

REPLACE makes sense only if a table has a PRIMARY KEY index (UNIQUE index is not support now). Otherwise, it becomes equivalent to INSERT, because there is no index to be used to determine whether a new row duplicates another.

Values for all columns are taken from the values specified in the REPLACE statement. Any missing columns are set to their default values, just as happens for INSERT.

You must have both INSERT and UPDATE privileges on a table in order to replace into it.

## Parameters

### Replacing

This section covers parameters that may be used when only replacing new rows.

*with\_query*

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the REPLACE query. See Section 7.8 and SELECT for details.

*table\_name*

The name (optionally schema-qualified) of an existing table.

*alias*

A substitute name for *table\_name*. When an alias is provided, it completely hides the actual name of the table.

*column\_name*

The name of a column in the table named by *table\_name*. The column name can be qualified with a subfield name or array subscript, if needed. (replacing into only some fields of a composite column leaves the other fields null.)

**OVERRIDING SYSTEM VALUE**

If this clause is specified, then any values supplied for identity columns will override the default sequence-generated values.

For an identity column defined as `GENERATED ALWAYS`, it is an error to insert an explicit value (other than `DEFAULT`) without specifying either `OVERRIDING SYSTEM VALUE` or `OVERRIDING USER VALUE`. (For an identity column defined as `GENERATED BY DEFAULT`, `OVERRIDING SYSTEM VALUE` is the normal behavior and specifying it does nothing, but LightDB allows it as an extension.)

**OVERRIDING USER VALUE**

If this clause is specified, then any values supplied for identity columns are ignored and the default sequence-generated values are applied.

This clause is useful for example when copying values between tables. Writing `INSERT INTO tbl2 OVERRIDING USER VALUE SELECT * FROM tbl1` will copy from `tbl1` all columns that are not identity columns in `tbl2` while values for the identity columns in `tbl2` will be generated by the sequences associated with `tbl2`.

*expression*

An expression or value to assign to the corresponding column.

**DEFAULT**

The corresponding column will be filled with its default value. An identity column will be filled with a new value generated by the associated sequence. For a generated column, specifying this is permitted but merely specifies the normal behavior of computing the column from its generation expression.

*output\_expression*

An expression to be computed and returned by the `REPLACE` command after each row is inserted or updated. The expression can use any column names of the table named by *table\_name*. Write `*` to return all columns of the inserted or updated row(s).

*output\_name*

A name to use for a returned column.

## Outputs

On successful completion, an `REPLACE` command returns a command tag of the form

```
REPLACE oid count
```

The meaning of *count* and *oid* is same with `INSERT` command.

## Notes

If the specified table is a partitioned table, each row is routed to the appropriate partition and inserted into it. If the specified table is a partition, an error will occur if one of the input rows violates the partition constraint.

## Examples

Consider the table created by the following `CREATE TABLE` statement:



```
CREATE TABLE test (
  id INT NOT NULL,
  name CHAR(16),
  age INT DEFAULT 0,
  PRIMARY KEY(id)
);
```

When we create this table and run the statements shown in the ltsql client, the result is as follows:

```
lightdb@testdb=# REPLACE INTO test VALUES (1, 'Old name', '18');
INSERT 0 1
```

```
lightdb@testdb=# REPLACE INTO test VALUES (1, 'New name');
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
 id |      name      | age
----+-----+----
  1 | New name      |   0
(1 row)
```

Consider the table created by the following CREATE TABLE statement:

```
CREATE TABLE test (
  id INT NOT NULL,
  name CHAR(16),
  seq SERIAL,
  PRIMARY KEY(id)
);
```

When we create this table and run the statements shown in the ltsql client, the result is as follows, the value of 'seq' becomes 4 because primary key constraint conflict is happened:

```
lightdb@testdb=# REPLACE INTO test VALUES (1, 'Old name1'), (2,
'Old name2');
INSERT 0 2
```

```
lightdb@testdb=# SELECT * FROM test;
 id |      name      | seq
----+-----+----
  1 | Old name1     |   1
  2 | Old name2     |   2
(2 rows)
```

```
lightdb@testdb=# REPLACE INTO test VALUES (1, 'New name');
INSERT 0 1
```

```
lightdb@testdb=# SELECT * FROM test;
 id |      name      | seq
----+-----+----
  2 | Old name2     |   2
  1 | New name      |   4
(2 rows)
```

## Compatibility

REPLACE is a LightDB extension to the SQL standard. It either inserts, or deletes and inserts. REPLACE is only supported while the syntax compatible type of the database is mysql. See [lightdb\\_syntax\\_compatible\\_type](#) for details.

---

# RESET

RESET — restore the value of a run-time parameter to the default value

## Synopsis

```
RESET configuration_parameter
RESET ALL
```

## Description

RESET restores run-time parameters to their default values. RESET is an alternative spelling for

```
SET configuration_parameter TO DEFAULT
```

Refer to SET for details.

The default value is defined as the value that the parameter would have had, if no SET had ever been issued for it in the current session. The actual source of this value might be a compiled-in default, the configuration file, command-line options, or per-database or per-user default settings. This is subtly different from defining it as “the value that the parameter had at session start”, because if the value came from the configuration file, it will be reset to whatever is specified by the configuration file now. See Chapter 17 for details.

The transactional behavior of RESET is the same as SET: its effects will be undone by transaction rollback.

## Parameters

*configuration\_parameter*

Name of a settable run-time parameter. Available parameters are documented in Chapter 17 and on the SET reference page.

ALL

Resets all settable run-time parameters to default values.

## Examples

Set the `timezone` configuration variable to its default value:

```
RESET timezone;
```

## Compatibility

RESET is a LightDB extension.

## See Also

SET, SHOW

---

# REVOKE

REVOKE — remove access privileges

## Synopsis

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES |
      TRIGGER }
      [, ...] | ALL [ PRIVILEGES ] }
    ON { [ TABLE ] table_name [, ...]
        | ALL TABLES IN SCHEMA schema_name [, ...] }
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name
      [, ...] )
      [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
    ON [ TABLE ] table_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { USAGE | SELECT | UPDATE }
      [, ...] | ALL [ PRIVILEGES ] }
    ON { SEQUENCE sequence_name [, ...]
        | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL
      [ PRIVILEGES ] }
    ON DATABASE database_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON DOMAIN domain_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN DATA WRAPPER fdw_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN SERVER server_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { EXECUTE | ALL [ PRIVILEGES ] }
    ON { { FUNCTION | PROCEDURE | ROUTINE } function_name
    [ ( [ [ argmode ] [ arg_name ] arg_type [, ...] ) ] [, ...]
        | ALL { FUNCTIONS | PROCEDURES | ROUTINES } IN
    SCHEMA schema_name [, ...] }
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON LANGUAGE lang_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
    ON LARGE OBJECT loid [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
    ON SCHEMA schema_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { CREATE | ALL [ PRIVILEGES ] }
    ON TABLESPACE tablespace_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE type_name [, ...]
    FROM role_specification [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ ADMIN OPTION FOR ]
    role_name [, ...] FROM role_specification [, ...]
    [ GRANTED BY role_specification ]
    [ CASCADE | RESTRICT ]
```

where *role\_specification* can be:

```
[ GROUP ] role_name
| PUBLIC
| CURRENT_USER
| SESSION_USER
```

## Description

The REVOKE command revokes previously granted privileges from one or more roles. The key word PUBLIC refers to the implicitly defined group of all roles.

See the description of the GRANT command for the meaning of the privilege types.

Note that any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC. Thus, for example, revoking SELECT privilege from PUBLIC does not necessarily mean that all roles have lost SELECT privilege on the object: those who have it granted directly or via another role will still have it. Similarly, revoking SELECT from a user might not prevent that user from using SELECT if PUBLIC or another membership role still has SELECT rights.

If GRANT OPTION FOR is specified, only the grant option for the privilege is revoked, not the privilege itself. Otherwise, both the privilege and the grant option are revoked.

If a user holds a privilege with grant option and has granted it to other users then the privileges held by those other users are called dependent privileges. If the privilege or the grant option held by the first user is being revoked and dependent privileges exist, those dependent privileges are also revoked if CASCADE is specified; if it is not, the revoke action will fail. This recursive revocation only affects privileges that were granted through a chain of users that is traceable to the user that is the subject of this REVOKE command. Thus, the affected users might effectively keep the privilege if it was also granted through other users.

When revoking privileges on a table, the corresponding column privileges (if any) are automatically revoked on each column of the table, as well. On the other hand, if a role has been granted privileges on a table, then revoking the same privileges from individual columns will have no effect.

When revoking membership in a role, GRANT OPTION is instead called ADMIN OPTION, but the behavior is similar. This form of the command also allows a GRANTED BY option, but that option is currently ignored (except for checking the existence of the named role). Note also that this form of the command does not allow the noise word GROUP in *role\_specification*.

## Notes

A user can only revoke privileges that were granted directly by that user. If, for example, user A has granted a privilege with grant option to user B, and user B has in turn granted it to user C, then user A cannot revoke the privilege directly from C. Instead, user A could revoke the grant option from user B and use the CASCADE option so that the privilege is in turn revoked from user C. For another example, if both A and B have granted the same privilege to C, A can revoke their own grant but not B's grant, so C will still effectively have the privilege.

When a non-owner of an object attempts to REVOKE privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will revoke only those privileges for which the user has grant options. The REVOKE ALL PRIVILEGES forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

If a superuser chooses to issue a GRANT or REVOKE command, the command is performed as though it were issued by the owner of the affected object. Since all privileges ultimately come from the object owner (possibly indirectly via chains of grant options), it is possible for a superuser to revoke all privileges, but this might require use of CASCADE as stated above.

REVOKE can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges WITH GRANT OPTION on the object. In this case the command is performed as though it were issued by the containing role that actually owns the object or holds the privileges WITH GRANT OPTION. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can revoke privileges on `t1` that are recorded as being granted by `g1`. This would include grants made by `u1` as well as by other members of role `g1`.

If the role executing REVOKE holds privileges indirectly via more than one role membership path, it is unspecified which containing role will be used to perform the command. In such cases it is best practice to use SET ROLE to become the specific role you want to do the REVOKE as. Failure to do so might lead to revoking privileges other than the ones you intended, or not revoking anything at all.

See Section 5.7 for more information about specific privilege types, as well as how to inspect objects' privileges.

## Examples

Revoke insert privilege for the public on table `films`:

```
REVOKE INSERT ON films FROM PUBLIC;
```

Revoke all privileges from user `manuel` on view `kinds`:

```
REVOKE ALL PRIVILEGES ON kinds FROM manuel;
```

Note that this actually means “revoke all privileges that I granted”.

Revoke membership in role `admins` from user `joe`:

```
REVOKE admins FROM joe;
```

## Compatibility

The compatibility notes of the `GRANT` command apply analogously to `REVOKE`. The keyword `RESTRICT` or `CASCADE` is required according to the standard, but `LightDB` assumes `RESTRICT` by default.

## See Also

`GRANT`, `ALTER DEFAULT PRIVILEGES`

---

# ROLLBACK

ROLLBACK — abort the current transaction

## Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

## Description

ROLLBACK rolls back the current transaction and causes all the updates made by the transaction to be discarded.

## Parameters

WORK  
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

## Notes

Use COMMIT to successfully terminate a transaction.

Issuing ROLLBACK outside of a transaction block emits a warning and otherwise has no effect. ROLLBACK AND CHAIN outside of a transaction block is an error.

## Examples

To abort all changes:

```
ROLLBACK ;
```

## Compatibility

The command ROLLBACK conforms to the SQL standard. The form ROLLBACK TRANSACTION is a LightDB extension.

## See Also

BEGIN, COMMIT, ROLLBACK TO SAVEPOINT



---

# ROLLBACK PREPARED

ROLLBACK PREPARED — cancel a transaction that was earlier prepared for two-phase commit

## Synopsis

```
ROLLBACK PREPARED transaction_id
```

## Description

ROLLBACK PREPARED rolls back a transaction that is in prepared state.

## Parameters

```
transaction_id
```

The transaction identifier of the transaction that is to be rolled back.

## Notes

To roll back a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is rolled back immediately.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

## Examples

Roll back the transaction identified by the transaction identifier `foobar`:

```
ROLLBACK PREPARED 'foobar';
```

## Compatibility

ROLLBACK PREPARED is a LightDB extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

## See Also

PREPARE TRANSACTION, COMMIT PREPARED

---

# ROLLBACK TO SAVEPOINT

ROLLBACK TO SAVEPOINT — roll back to a savepoint

## Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] TO [ SAVEPOINT ] savepoint_name
```

## Description

Roll back all commands that were executed after the savepoint was established. The savepoint remains valid and can be rolled back to again later, if needed.

ROLLBACK TO SAVEPOINT implicitly destroys all savepoints that were established after the named savepoint.

## Parameters

*savepoint\_name*

The savepoint to roll back to.

## Notes

Use RELEASE SAVEPOINT to destroy a savepoint without discarding the effects of commands executed after it was established.

Specifying a savepoint name that has not been established is an error.

Cursors have somewhat non-transactional behavior with respect to savepoints. Any cursor that is opened inside a savepoint will be closed when the savepoint is rolled back. If a previously opened cursor is affected by a FETCH or MOVE command inside a savepoint that is later rolled back, the cursor remains at the position that FETCH left it pointing to (that is, the cursor motion caused by FETCH is not rolled back). Closing a cursor is not undone by rolling back, either. However, other side-effects caused by the cursor's query (such as side-effects of volatile functions called by the query) *are* rolled back if they occur during a savepoint that is later rolled back. A cursor whose execution causes a transaction to abort is put in a cannot-execute state, so while the transaction can be restored using ROLLBACK TO SAVEPOINT, the cursor can no longer be used.

## Examples

To undo the effects of the commands executed after `my_savepoint` was established:

```
ROLLBACK TO SAVEPOINT my_savepoint;
```

Cursor positions are not affected by savepoint rollback:

```
BEGIN;
```

```
DECLARE foo CURSOR FOR SELECT 1 UNION SELECT 2;
```

```
SAVEPOINT foo;
```

```
FETCH 1 FROM foo;  
?column?  
-----  
1
```

```
ROLLBACK TO SAVEPOINT foo;
```

```
FETCH 1 FROM foo;  
?column?  
-----  
2
```

```
COMMIT;
```

## Compatibility

The SQL standard specifies that the key word `SAVEPOINT` is mandatory, but LightDB and Oracle allow it to be omitted. SQL allows only `WORK`, not `TRANSACTION`, as a noise word after `ROLLBACK`. Also, SQL has an optional clause `AND [ NO ] CHAIN` which is not currently supported by LightDB. Otherwise, this command conforms to the SQL standard.

## See Also

`BEGIN`, `COMMIT`, `RELEASE SAVEPOINT`, `ROLLBACK`, `SAVEPOINT`

---

# SAVEPOINT

SAVEPOINT — define a new savepoint within the current transaction

## Synopsis

```
SAVEPOINT savepoint_name
```

## Description

SAVEPOINT establishes a new savepoint within the current transaction.

A savepoint is a special mark inside a transaction that allows all commands that are executed after it was established to be rolled back, restoring the transaction state to what it was at the time of the savepoint.

## Parameters

*savepoint\_name*

The name to give to the new savepoint. If savepoints with the same name already exist, they will be inaccessible until newer identically-named savepoints are released.

## Notes

Use ROLLBACK TO SAVEPOINT to rollback to a savepoint. Use RELEASE SAVEPOINT to destroy a savepoint, keeping the effects of commands executed after it was established.

Savepoints can only be established when inside a transaction block. There can be multiple savepoints defined within a transaction.

## Examples

To establish a savepoint and later undo the effects of all commands executed after it was established:

```
BEGIN;  
  INSERT INTO table1 VALUES (1);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (2);  
  ROLLBACK TO SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (3);  
COMMIT;
```

The above transaction will insert the values 1 and 3, but not 2.

To establish and later destroy a savepoint:

```
BEGIN;  
  INSERT INTO table1 VALUES (3);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (4);  
  RELEASE SAVEPOINT my_savepoint;
```

COMMIT;

The above transaction will insert both 3 and 4.

To use a single savepoint name:

```
BEGIN;
  INSERT INTO table1 VALUES (1);
  SAVEPOINT my_savepoint;
  INSERT INTO table1 VALUES (2);
  SAVEPOINT my_savepoint;
  INSERT INTO table1 VALUES (3);

  -- rollback to the second savepoint
  ROLLBACK TO SAVEPOINT my_savepoint;
  SELECT * FROM table1;           -- shows rows 1 and 2

  -- release the second savepoint
  RELEASE SAVEPOINT my_savepoint;

  -- rollback to the first savepoint
  ROLLBACK TO SAVEPOINT my_savepoint;
  SELECT * FROM table1;           -- shows only row 1
COMMIT;
```

The above transaction shows row 3 being rolled back first, then row 2.

## Compatibility

SQL requires a savepoint to be destroyed automatically when another savepoint with the same name is established. In LightDB, the old savepoint is kept, though only the more recent one will be used when rolling back or releasing. (Releasing the newer savepoint with `RELEASE SAVEPOINT` will cause the older one to again become accessible to `ROLLBACK TO SAVEPOINT` and `RELEASE SAVEPOINT`.) Otherwise, `SAVEPOINT` is fully SQL conforming.

## See Also

BEGIN, COMMIT, RELEASE SAVEPOINT, ROLLBACK, ROLLBACK TO SAVEPOINT

---

# SECURITY LABEL

SECURITY LABEL — define or change a security label applied to an object

## Synopsis

```
SECURITY LABEL [ FOR provider ] ON
{
  TABLE object_name |
  COLUMN table_name.column_name |
  AGGREGATE aggregate_name ( aggregate_signature ) |
  DATABASE object_name |
  DOMAIN object_name |
  EVENT TRIGGER object_name |
  FOREIGN TABLE object_name
  FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
  [ , ... ] ) ) ] |
  LARGE OBJECT large_object_oid |
  MATERIALIZED VIEW object_name |
  [ PROCEDURAL ] LANGUAGE object_name |
  PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
  [ , ... ] ) ) ] |
  PUBLICATION object_name |
  ROLE object_name |
  ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
  [ , ... ] ) ) ] |
  SCHEMA object_name |
  SEQUENCE object_name |
  SUBSCRIPTION object_name |
  TABLESPACE object_name |
  TYPE object_name |
  VIEW object_name
} IS 'label'
```

where *aggregate\_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

## Description

SECURITY LABEL applies a security label to a database object. An arbitrary number of security labels, one per label provider, can be associated with a given database object. Label providers are loadable modules which register themselves by using the function `register_label_provider`.

### Note

`register_label_provider` is not an SQL function; it can only be called from C code loaded into the backend.

The label provider determines whether a given label is valid and whether it is permissible to assign that label to a given object. The meaning of a given label is likewise at the discretion of the label provider. LightDB places no restrictions on whether or how a label provider must interpret security labels; it merely provides a mechanism for storing them. In practice, this facility is intended to allow integration with label-based mandatory access control (MAC) systems such as SELinux. Such systems make all access control decisions based on object labels, rather than traditional discretionary access control (DAC) concepts such as users and groups.

## Parameters

*object\_name*

*table\_name.column\_name*

*aggregate\_name*

*function\_name*

*procedure\_name*

*routine\_name*

The name of the object to be labeled. Names of tables, aggregates, domains, foreign tables, functions, procedures, routines, sequences, types, and views can be schema-qualified.

*provider*

The name of the provider with which this label is to be associated. The named provider must be loaded and must consent to the proposed labeling operation. If exactly one provider is loaded, the provider name may be omitted for brevity.

*argmode*

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that SECURITY LABEL does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

*argname*

The name of a function, procedure, or aggregate argument. Note that SECURITY LABEL does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

*argtype*

The data type of a function, procedure, or aggregate argument.

*large\_object\_oid*

The OID of the large object.

PROCEDURAL

This is a noise word.

*label*

The new security label, written as a string literal; or NULL to drop the security label.

## Examples

The following example shows how the security label of a table might be changed.

```
SECURITY LABEL FOR selinux ON TABLE mytable IS  
'system_u:object_r:sepgsql_table_t:s0';
```

## Compatibility

There is no SECURITY LABEL command in the SQL standard.

## See Also

sepgsql, src/test/modules/dummy\_seclabel



---

# SELECT

SELECT, TABLE, WITH — retrieve rows from a table or view

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    [ * | expression [ [ AS ] output_name ] [, ...] ]
    [ FROM from_item [, ...] ]
    [ { USE | IGNORE | FORCE } { INDEX | KEY } [ FOR { JOIN | ORDER
BY | GROUP BY } ] (index_list) ]
    [ WHERE condition ]
    [ START WITH start_expression ]
    [ CONNECT BY { PRIOR parent_expr = child_expr | child_expr =
PRIOR parent_expr } ]
    [ GROUP BY grouping_element [, ...] [WITH ROLLUP] ]
    [ HAVING condition ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT | MINUS } [ ALL |
DISTINCT ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
{ FIRST | LAST } ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } { ONLY | WITH
TIES } ]
    [ FOR { UPDATE | NO KEY UPDATE | SHARE | KEY SHARE }
[ OF table_name [, ...] ] [ NOWAIT | SKIP LOCKED ] [...] ]
```

where *from\_item* can be one of:

```
[ ONLY ] table_name [ * ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
    [ TABLESAMPLE sampling_method ( argument [, ...] )
[ REPEATABLE ( seed ) ] ]
[ LATERAL ] ( select ) [ AS ] alias [ ( column_alias
[, ...] ) ]
    with_query_name [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] )
        [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] ) [ AS ] alias
( column_definition [, ...] )
    [ LATERAL ] function_name ( [ argument [, ...] ] ) AS
( column_definition [, ...] )
    [ LATERAL ] ROWS FROM( function_name ( [ argument [, ...] ] ) )
[ AS ( column_definition [, ...] ) ] [, ...] )
    [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
[ ONLY ] table_name [ * ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ] opt_conversion_clause
    ( select ) [ AS ] alias [ ( column_alias
[, ...] ) ] opt_conversion_clause
```

---

```

    from_item [ NATURAL ] join_type from_item [ ON join_condition |
USING ( join_column [, ...] ) ]

```

and *grouping\_element* can be one of:

```

( )
expression
( expression [, ...] )
ROLLUP ( { expression | ( expression [, ...] ) } [, ...] )
CUBE ( { expression | ( expression [, ...] ) } [, ...] )
GROUPING SETS ( grouping_element [, ...] )

```

and *with\_query* is:

```

    with_query_name [ ( column_name [, ...] ) ] AS [ [ NOT ]
MATERIALIZED ] ( select | values | insert | update | delete )

```

```
TABLE [ ONLY ] table_name [ * ]
```

and *opt\_conversion\_clause* is:

```

    pivot_clause [ * ] [ AS ] alias

```

and *pivot\_clause* is:

```

    PIVOT ( function_name (argument) [ AS ] alias
    FOR columnref IN ( column_definition [, ...] ) )
[ AS ] alias

```

## Description

SELECT retrieves rows from zero or more tables. The general processing of SELECT is as follows:

1. All queries in the WITH list are computed. These effectively serve as temporary tables that can be referenced in the FROM list. A WITH query that is referenced more than once in FROM is computed only once, unless specified otherwise with NOT MATERIALIZED. (See WITH Clause below.)
2. All elements in the FROM list are computed. (Each element in the FROM list is a real or virtual table.) If more than one element is specified in the FROM list, they are cross-joined together. (See FROM Clause below.)
3. All elements in the USE/FORCE/IGNORE list are just syntax compatible. Future version will implement these features.
4. If the WHERE clause is specified, all rows that do not satisfy the condition are eliminated from the output. (See WHERE Clause below.)
5. You can use '(+)' in condition to specify outer join like Oracle. (See Oracle plus below.)
6. If the CONNECT BY clause is specified, then you can select rows in a hierarchical order. (See CONNECT BY Clause below.) For each row returned by a hierarchical query, the LEVEL pseudocolumn returns 1 for a root row, 2 for a child of a root, and so on. SYS\_CONNECT\_BY\_PATH is valid only in hierarchical queries. SYS\_CONNECT\_BY\_PATH(column, char) with column values separated by char for each row returned by CONNECT BY condition. CONNECT\_BY\_ROOT is a unary operator that is valid only in hierarchical queries. When you qualify a column with this operator, it returns the column value using data from the root row. CONNECT BY LEVEL < n displays all recursive results

below *n* levels. `CONNECT_BY_ISLEAF` is a pseudocolumn that is frequently used in conjunction with recursive queries using the `CONNECT BY` clause. It serves the purpose of identifying whether the current row in a hierarchical query is a leaf node (having no child nodes) or not. The `CONNECT_BY_ISLEAF` column returns a Boolean value - 1 if the current row is a leaf node (indicating true), and 0 if it is not a leaf node (indicating false).

7. If the `GROUP BY` clause is specified, or if there are aggregate function calls, the output is combined into groups of rows that match on one or more values, and the results of aggregate functions are computed. If the `HAVING` clause is present, it eliminates groups that do not satisfy the given condition. (See `GROUP BY Clause` and `HAVING Clause` below.)
8. The actual output rows are computed using the `SELECT` output expressions for each selected row or row group. (See `SELECT List` below.)
9. `SELECT DISTINCT` eliminates duplicate rows from the result. `SELECT DISTINCT ON` eliminates rows that match on all the specified expressions. `SELECT ALL` (the default) will return all candidate rows, including duplicates. (See `DISTINCT Clause` below.)
10. Using the operators `UNION`, `INTERSECT`, and `EXCEPT`, the output of more than one `SELECT` statement can be combined to form a single result set. The `UNION` operator returns all rows that are in one or both of the result sets. The `INTERSECT` operator returns all rows that are strictly in both result sets. The `EXCEPT` (`MINUS` is completely equivalent to `EXCEPT`, so won't repeat it later) operator returns the rows that are in the first result set but not in the second. In all three cases, duplicate rows are eliminated unless `ALL` is specified. The noise word `DISTINCT` can be added to explicitly specify eliminating duplicate rows. Notice that `DISTINCT` is the default behavior here, even though `ALL` is the default for `SELECT` itself. (See `UNION Clause`, `INTERSECT Clause`, and `EXCEPT Clause` below.)
11. If the `ORDER BY` clause is specified, the returned rows are sorted in the specified order. If `ORDER BY` is not given, the rows are returned in whatever order the system finds fastest to produce. (See `ORDER BY Clause` below.)
12. If the `LIMIT` (or `FETCH FIRST`) or `OFFSET` clause is specified, the `SELECT` statement only returns a subset of the result rows. (See `LIMIT Clause` below.)
13. If `FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE` or `FOR KEY SHARE` is specified, the `SELECT` statement locks the selected rows against concurrent updates. (See `The Locking Clause` below.)

You must have `SELECT` privilege on each column used in a `SELECT` command. The use of `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` or `FOR KEY SHARE` requires `UPDATE` privilege as well (for at least one column of each table so selected).

## Parameters

### WITH Clause

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the primary query. The subqueries effectively act as temporary tables or views for the duration of the primary query. Each subquery can be a `SELECT`, `TABLE`, `VALUES`, `INSERT`, `UPDATE` or `DELETE` statement. When writing a data-modifying statement (`INSERT`, `UPDATE` or `DELETE`) in `WITH`, it is usual to include a `RETURNING` clause. It is the output of `RETURNING`, *not* the underlying table that the statement modifies, that forms the temporary table that is read by the primary query. If `RETURNING` is omitted, the statement is still executed, but it produces no output so it cannot be referenced as a table by the primary query.

A name (without schema qualification) must be specified for each `WITH` query. Optionally, a list of column names can be specified; if this is omitted, the column names are inferred from the subquery.

If `RECURSIVE` is specified, it allows a `SELECT` subquery to reference itself by name. Such a subquery must have the form

```
non_recursive_term UNION [ ALL | DISTINCT ] recursive_term
```

where the recursive self-reference must appear on the right-hand side of the `UNION`. Only one recursive self-reference is permitted per query. Recursive data-modifying statements are not supported, but you can use the results of a recursive `SELECT` query in a data-modifying statement. See Section 7.8 for an example.

Another effect of `RECURSIVE` is that `WITH` queries need not be ordered: a query can reference another one that is later in the list. (However, circular references, or mutual recursion, are not implemented.) Without `RECURSIVE`, `WITH` queries can only reference sibling `WITH` queries that are earlier in the `WITH` list.

When there are multiple queries in the `WITH` clause, `RECURSIVE` should be written only once, immediately after `WITH`. It applies to all queries in the `WITH` clause, though it has no effect on queries that do not use recursion or forward references.

The primary query and the `WITH` queries are all (notionally) executed at the same time. This implies that the effects of a data-modifying statement in `WITH` cannot be seen from other parts of the query, other than by reading its `RETURNING` output. If two such data-modifying statements attempt to modify the same row, the results are unspecified.

A key property of `WITH` queries is that they are normally evaluated only once per execution of the primary query, even if the primary query refers to them more than once. In particular, data-modifying statements are guaranteed to be executed once and only once, regardless of whether the primary query reads all or any of their output.

However, a `WITH` query can be marked `NOT MATERIALIZED` to remove this guarantee. In that case, the `WITH` query can be folded into the primary query much as though it were a simple sub-`SELECT` in the primary query's `FROM` clause. This results in duplicate computations if the primary query refers to that `WITH` query more than once; but if each such use requires only a few rows of the `WITH` query's total output, `NOT MATERIALIZED` can provide a net savings by allowing the queries to be optimized jointly. `NOT MATERIALIZED` is ignored if it is attached to a `WITH` query that is recursive or is not side-effect-free (i.e., is not a plain `SELECT` containing no volatile functions).

By default, a side-effect-free `WITH` query is folded into the primary query if it is used exactly once in the primary query's `FROM` clause. This allows joint optimization of the two query levels in situations where that should be semantically invisible. However, such folding can be prevented by marking the `WITH` query as `MATERIALIZED`. That might be useful, for example, if the `WITH` query is being used as an optimization fence to prevent the planner from choosing a bad plan. LightDB versions before v12 never did such folding, so queries written for older versions might rely on `WITH` to act as an optimization fence.

See Section 7.8 for additional information.

## FROM Clause

The `FROM` clause specifies one or more source tables for the `SELECT`. If multiple sources are specified, the result is the Cartesian product (cross join) of all the sources. But usually qualification conditions are added (via `WHERE`) to restrict the returned rows to a small subset of the Cartesian product.

The `FROM` clause can contain the following elements:

```
table_name
```

The name (optionally schema-qualified) of an existing table or view. If `ONLY` is specified before the table name, only that table is scanned. If `ONLY` is not specified, the table and all its descendant

tables (if any) are scanned. Optionally, \* can be specified after the table name to explicitly indicate that descendant tables are included.

#### *alias*

A substitute name for the FROM item containing the alias. An alias is used for brevity or to eliminate ambiguity for self-joins (where the same table is scanned multiple times). When an alias is provided, it completely hides the actual name of the table or function; for example given FROM foo AS f, the remainder of the SELECT must refer to this FROM item as f not foo. If an alias is written, a column alias list can also be written to provide substitute names for one or more columns of the table.

```
TABLESAMPLE sampling_method ( argument [, ...] ) [ REPEATABLE ( seed ) ]
```

A TABLESAMPLE clause after a *table\_name* indicates that the specified *sampling\_method* should be used to retrieve a subset of the rows in that table. This sampling precedes the application of any other filters such as WHERE clauses. The standard LightDB distribution includes two sampling methods, BERNOULLI and SYSTEM, and other sampling methods can be installed in the database via extensions.

The BERNOULLI and SYSTEM sampling methods each accept a single *argument* which is the fraction of the table to sample, expressed as a percentage between 0 and 100. This argument can be any real-valued expression. (Other sampling methods might accept more or different arguments.) These two methods each return a randomly-chosen sample of the table that will contain approximately the specified percentage of the table's rows. The BERNOULLI method scans the whole table and selects or ignores individual rows independently with the specified probability. The SYSTEM method does block-level sampling with each block having the specified chance of being selected; all rows in each selected block are returned. The SYSTEM method is significantly faster than the BERNOULLI method when small sampling percentages are specified, but it may return a less-random sample of the table as a result of clustering effects.

The optional REPEATABLE clause specifies a *seed* number or expression to use for generating random numbers within the sampling method. The seed value can be any non-null floating-point value. Two queries that specify the same seed and *argument* values will select the same sample of the table, if the table has not been changed meanwhile. But different seed values will usually produce different samples. If REPEATABLE is not given then a new random sample is selected for each query, based upon a system-generated seed. Note that some add-on sampling methods do not accept REPEATABLE, and will always produce new samples on each use.

#### *select*

A sub-SELECT can appear in the FROM clause. This acts as though its output were created as a temporary table for the duration of this single SELECT command. Note that the sub-SELECT must be surrounded by parentheses, and an alias *must* be provided for it. A VALUES command can also be used here.

#### *with\_query\_name*

A WITH query is referenced by writing its name, just as though the query's name were a table name. (In fact, the WITH query hides any real table of the same name for the purposes of the primary query. If necessary, you can refer to a real table of the same name by schema-qualifying the table's name.) An alias can be provided in the same way as for a table.

#### *function\_name*

Function calls can appear in the FROM clause. (This is especially useful for functions that return result sets, but any function can be used.) This acts as though the function's output were created as a temporary table for the duration of this single SELECT command. If the function's result

type is composite (including the case of a function with multiple OUT parameters), each attribute becomes a separate column in the implicit table.

When the optional `WITH ORDINALITY` clause is added to the function call, an additional column of type `bigint` will be appended to the function's result column(s). This column numbers the rows of the function's result set, starting from 1. By default, this column is named `ordinality`.

An alias can be provided in the same way as for a table. If an alias is written, a column alias list can also be written to provide substitute names for one or more attributes of the function's composite return type, including the ordinality column if present.

Multiple function calls can be combined into a single `FROM`-clause item by surrounding them with `ROWS FROM( ... )`. The output of such an item is the concatenation of the first row from each function, then the second row from each function, etc. If some of the functions produce fewer rows than others, null values are substituted for the missing data, so that the total number of rows returned is always the same as for the function that produced the most rows.

If the function has been defined as returning the `record` data type, then an alias or the key word `AS` must be present, followed by a column definition list in the form ( `column_name data_type [ , ... ]`). The column definition list must match the actual number and types of columns returned by the function.

When using the `ROWS FROM( ... )` syntax, if one of the functions requires a column definition list, it's preferred to put the column definition list after the function call inside `ROWS FROM( ... )`. A column definition list can be placed after the `ROWS FROM( ... )` construct only if there's just a single function and no `WITH ORDINALITY` clause.

To use `ORDINALITY` together with a column definition list, you must use the `ROWS FROM( ... )` syntax and put the column definition list inside `ROWS FROM( ... )`.

### *join\_type*

One of

- `[ INNER ] JOIN`
- `LEFT [ OUTER ] JOIN`
- `RIGHT [ OUTER ] JOIN`
- `FULL [ OUTER ] JOIN`
- `CROSS JOIN`

For the `INNER` and `OUTER` join types, a join condition must be specified, namely exactly one of `NATURAL`, `ON join_condition`, or `USING (join_column [ , ... ])`. See below for the meaning. For `CROSS JOIN`, none of these clauses can appear.

A `JOIN` clause combines two `FROM` items, which for convenience we will refer to as “tables”, though in reality they can be any type of `FROM` item. Use parentheses if necessary to determine the order of nesting. In the absence of parentheses, `JOINS` nest left-to-right. In any case `JOIN` binds more tightly than the commas separating `FROM`-list items.

`CROSS JOIN` and `INNER JOIN` produce a simple Cartesian product, the same result as you get from listing the two tables at the top level of `FROM`, but restricted by the join condition (if any). `CROSS JOIN` is equivalent to `INNER JOIN ON (TRUE)`, that is, no rows are removed by qualification. These join types are just a notational convenience, since they do nothing you couldn't do with plain `FROM` and `WHERE`.

`LEFT OUTER JOIN` returns all rows in the qualified Cartesian product (i.e., all combined rows that pass its join condition), plus one copy of each row in the left-hand table for which there was no right-hand row that passed the join condition. This left-hand row is extended to the full width

of the joined table by inserting null values for the right-hand columns. Note that only the JOIN clause's own condition is considered while deciding which rows have matches. Outer conditions are applied afterwards.

Conversely, `RIGHT OUTER JOIN` returns all the joined rows, plus one row for each unmatched right-hand row (extended with nulls on the left). This is just a notational convenience, since you could convert it to a `LEFT OUTER JOIN` by switching the left and right tables.

`FULL OUTER JOIN` returns all the joined rows, plus one row for each unmatched left-hand row (extended with nulls on the right), plus one row for each unmatched right-hand row (extended with nulls on the left).

`ON join_condition`

*join\_condition* is an expression resulting in a value of type `boolean` (similar to a `WHERE` clause) that specifies which rows in a join are considered to match.

`USING ( join_column [, ...] )`

A clause of the form `USING ( a, b, ... )` is shorthand for `ON left_table.a = right_table.a AND left_table.b = right_table.b ...`. Also, `USING` implies that only one of each pair of equivalent columns will be included in the join output, not both.

`NATURAL`

`NATURAL` is shorthand for a `USING` list that mentions all columns in the two tables that have matching names. If there are no common column names, `NATURAL` is equivalent to `ON TRUE`.

`LATERAL`

The `LATERAL` key word can precede a sub-`SELECT FROM` item. This allows the sub-`SELECT` to refer to columns of `FROM` items that appear before it in the `FROM` list. (Without `LATERAL`, each sub-`SELECT` is evaluated independently and so cannot cross-reference any other `FROM` item.)

`LATERAL` can also precede a function-call `FROM` item, but in this case it is a noise word, because the function expression can refer to earlier `FROM` items in any case.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

The column source table(s) must be `INNER` or `LEFT` joined to the `LATERAL` item, else there would not be a well-defined set of rows from which to compute each set of rows for the `LATERAL` item. Thus, although a construct such as `X RIGHT JOIN LATERAL Y` is syntactically valid, it is not actually allowed for `Y` to reference `X`.

*opt\_conversion\_clause*

is

- `PIVOT`

`PIVOT` only supports single-clustering functions and single-column multi-group scenarios. As part of the `FROM` clause, it can be used in `JOIN`, `NATURAL`, `LATERAL` connections, - Complete the function of row to column.

`PIVOT` does not support the following five scenarios#

- XML and ANY keywords are not supported
- Multiple aggregate functions are not supported

```
PIVOT (  
  SUM(sale_amount),  
  COUNT(sale_amount)  
FOR customer_id  
IN (1, 2, 3, 4)  
);
```

- Multi-column grouping is not supported

```
PIVOT (  
  SUM(sale_amount)  
FOR (customer_id, prod_category)  
IN (  
  (1, 'furniture') AS furn1,  
  (2, 'furniture') AS furn2,  
  (1, 'electronics') AS elec1,  
  (2, 'electronics') AS elec2  
)
```

- IN() is not supported

```
select * from test123  
PIVOT (  
  SUM(score) as tc  
FOR course  
IN ());
```

- The aggregate function argument used in the PIVOT clause only supports field types, not numbers types and '\*'

## WHERE Clause

The optional WHERE clause has the general form

```
WHERE condition
```

where *condition* is any expression that evaluates to a result of type boolean. Any row that does not satisfy this condition will be eliminated from the output. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

## CONNECT BY Clause

The optional CONNECT BY clause has the general form

```
CONNECT BY { PRIOR parent_expr = child_expr |  
  child_expr = PRIOR parent_expr }.
```

CONNECT BY specifies the relationship between parent rows and child rows of the hierarchy. In a hierarchical query, one expression in condition must be qualified with the PRIOR operator to refer to the parent row.



## START Clause

The optional `START WITH` clause has the general form

```
[ START WITH start_expression ].
```

`START WITH` specifies the root row(s) of the hierarchy.

## GROUP BY Clause

The optional `GROUP BY` clause has the general form

```
GROUP BY grouping_element [, ...] [WITH ROLLUP]
```

`GROUP BY` will condense into a single row all selected rows that share the same values for the grouped expressions. An *expression* used inside a *grouping\_element* can be an input column name, or the name or ordinal number of an output column (`SELECT` list item), or an arbitrary expression formed from input-column values. In case of ambiguity, a `GROUP BY` name will be interpreted as an input-column name rather than an output column name.

If any of `GROUPING SETS`, `ROLLUP` or `CUBE` are present as grouping elements, then the `GROUP BY` clause as a whole defines some number of independent *grouping sets*. The effect of this is equivalent to constructing a `UNION ALL` between subqueries with the individual grouping sets as their `GROUP BY` clauses. For further details on the handling of grouping sets see Section 7.2.4.

Aggregate functions, if any are used, are computed across all rows making up each group, producing a separate value for each group. (If there are aggregate functions but no `GROUP BY` clause, the query is treated as having a single group comprising all the selected rows.) The set of rows fed to each aggregate function can be further filtered by attaching a `FILTER` clause to the aggregate function call; see Section 4.2.7 for more information. When a `FILTER` clause is present, only those rows matching it are included in the input to that aggregate function.

When `GROUP BY` is present, or any aggregate functions are present, it is not valid for the `SELECT` list expressions to refer to ungrouped columns except within aggregate functions or when the ungrouped column is functionally dependent on the grouped columns, since there would otherwise be more than one possible value to return for an ungrouped column. A functional dependency exists if the grouped columns (or a subset thereof) are the primary key of the table containing the ungrouped column.

Keep in mind that all aggregate functions are evaluated before evaluating any “scalar” expressions in the `HAVING` clause or `SELECT` list. This means that, for example, a `CASE` expression cannot be used to skip evaluation of an aggregate function; see Section 4.2.15.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `GROUP BY`.

`WITH ROLLUP` takes effect in `mysql` mode. The basic value used by `WITH ROLLUP` is to generate additional rows in the aggregate query to provide summary data.

## HAVING Clause

The optional `HAVING` clause has the general form

```
HAVING condition
```

where *condition* is the same as specified for the `WHERE` clause.

`HAVING` eliminates group rows that do not satisfy the condition. `HAVING` is different from `WHERE`: `WHERE` filters individual rows before the application of `GROUP BY`, while `HAVING` filters group rows

created by `GROUP BY`. Each column referenced in *condition* must unambiguously reference a grouping column, unless the reference appears within an aggregate function or the ungrouped column is functionally dependent on the grouping columns.

The presence of `HAVING` turns a query into a grouped query even if there is no `GROUP BY` clause. This is the same as what happens when the query contains aggregate functions but no `GROUP BY` clause. All the selected rows are considered to form a single group, and the `SELECT` list and `HAVING` clause can only reference table columns from within aggregate functions. Such a query will emit a single row if the `HAVING` condition is true, zero rows if it is not true.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `HAVING`.

## WINDOW Clause

The optional `WINDOW` clause has the general form

```
WINDOW window_name AS ( window_definition ) [, ...]
```

where *window\_name* is a name that can be referenced from `OVER` clauses or subsequent window definitions, and *window\_definition* is

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
  { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

If an *existing\_window\_name* is specified it must refer to an earlier entry in the `WINDOW` list; the new window copies its partitioning clause from that entry, as well as its ordering clause if any. In this case the new window cannot specify its own `PARTITION BY` clause, and it can specify `ORDER BY` only if the copied window does not have one. The new window always uses its own frame clause; the copied window must not specify a frame clause.

The elements of the `PARTITION BY` list are interpreted in much the same fashion as elements of a `GROUP BY` clause, except that they are always simple expressions and never the name or number of an output column. Another difference is that these expressions can contain aggregate function calls, which are not allowed in a regular `GROUP BY` clause. They are allowed here because windowing occurs after grouping and aggregation.

Similarly, the elements of the `ORDER BY` list are interpreted in much the same fashion as elements of a statement-level `ORDER BY` clause, except that the expressions are always taken as simple expressions and never the name or number of an output column.

The optional *frame\_clause* defines the *window frame* for window functions that depend on the frame (not all do). The window frame is a set of related rows for each row of the query (called the *current row*). The *frame\_clause* can be one of

```
{ RANGE | ROWS | GROUPS } frame_start [ frame_exclusion ]
{ RANGE | ROWS | GROUPS } BETWEEN frame_start AND frame_end
[ frame_exclusion ]
```

where *frame\_start* and *frame\_end* can be one of

```
UNBOUNDED PRECEDING
```

---

*offset* PRECEDING  
CURRENT ROW  
*offset* FOLLOWING  
UNBOUNDED FOLLOWING

and *frame\_exclusion* can be one of

EXCLUDE CURRENT ROW  
EXCLUDE GROUP  
EXCLUDE TIES  
EXCLUDE NO OTHERS

If *frame\_end* is omitted it defaults to CURRENT ROW. Restrictions are that *frame\_start* cannot be UNBOUNDED FOLLOWING, *frame\_end* cannot be UNBOUNDED PRECEDING, and the *frame\_end* choice cannot appear earlier in the above list of *frame\_start* and *frame\_end* options than the *frame\_start* choice does — for example RANGE BETWEEN CURRENT ROW AND *offset* PRECEDING is not allowed.

The default framing option is RANGE UNBOUNDED PRECEDING, which is the same as RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW; it sets the frame to be all rows from the partition start up through the current row's last *peer* (a row that the window's ORDER BY clause considers equivalent to the current row; all rows are peers if there is no ORDER BY). In general, UNBOUNDED PRECEDING means that the frame starts with the first row of the partition, and similarly UNBOUNDED FOLLOWING means that the frame ends with the last row of the partition, regardless of RANGE, ROWS or GROUPS mode. In ROWS mode, CURRENT ROW means that the frame starts or ends with the current row; but in RANGE or GROUPS mode it means that the frame starts or ends with the current row's first or last peer in the ORDER BY ordering. The *offset* PRECEDING and *offset* FOLLOWING options vary in meaning depending on the frame mode. In ROWS mode, the *offset* is an integer indicating that the frame starts or ends that many rows before or after the current row. In GROUPS mode, the *offset* is an integer indicating that the frame starts or ends that many peer groups before or after the current row's peer group, where a *peer group* is a group of rows that are equivalent according to the window's ORDER BY clause. In RANGE mode, use of an *offset* option requires that there be exactly one ORDER BY column in the window definition. Then the frame contains those rows whose ordering column value is no more than *offset* less than (for PRECEDING) or more than (for FOLLOWING) the current row's ordering column value. In these cases the data type of the *offset* expression depends on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an interval. In all these cases, the value of the *offset* must be non-null and non-negative. Also, while the *offset* does not have to be a simple constant, it cannot contain variables, aggregate functions, or window functions.

The *frame\_exclusion* option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. EXCLUDE CURRENT ROW excludes the current row from the frame. EXCLUDE GROUP excludes the current row and its ordering peers from the frame. EXCLUDE TIES excludes any peers of the current row from the frame, but not the current row itself. EXCLUDE NO OTHERS simply specifies explicitly the default behavior of not excluding the current row or its peers.

Beware that the ROWS mode can produce unpredictable results if the ORDER BY ordering does not order the rows uniquely. The RANGE and GROUPS modes are designed to ensure that rows that are peers in the ORDER BY ordering are treated alike: all rows of a given peer group will be in the frame or excluded from it.

The purpose of a WINDOW clause is to specify the behavior of *window functions* appearing in the query's SELECT list or ORDER BY clause. These functions can reference the WINDOW clause entries by name in their OVER clauses. A WINDOW clause entry does not have to be referenced anywhere, however; if it is not used in the query it is simply ignored. It is possible to use window functions without any WINDOW clause at all, since a window function call can specify its window definition directly

in its `OVER` clause. However, the `WINDOW` clause saves typing when the same window definition is needed for more than one window function.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `WINDOW`.

Window functions are described in detail in Section 3.5, Section 4.2.8, and Section 7.2.5.

## SELECT List

The `SELECT` list (between the key words `SELECT` and `FROM`) specifies expressions that form the output rows of the `SELECT` statement. The expressions can (and usually do) refer to columns computed in the `FROM` clause.

Just as in a table, every output column of a `SELECT` has a name. In a simple `SELECT` this name is just used to label the column for display, but when the `SELECT` is a sub-query of a larger query, the name is seen by the larger query as the column name of the virtual table produced by the sub-query. To specify the name to use for an output column, write `AS output_name` after the column's expression. (You can omit `AS`, but only if the desired output name does not match any LightDB keyword (see Appendix C). For protection against possible future keyword additions, it is recommended that you always either write `AS` or double-quote the output name.) If you do not specify a column name, a name is chosen automatically by LightDB. If the column's expression is a simple column reference then the chosen name is the same as that column's name. In more complex cases a function or type name may be used, or the system may fall back on a generated name such as `?column?`.

However, the output of columns's name are converted to lowercase even if we use `AS` to specify their alias name specially unless they are wrapped with double-quote or anti-quote. But it could keep case invariant in mysql mode which belongs to the database initied with parameter `lightdb_syntax_compatible_type mysql` accompanied with setting `lightdb_sql_mode` to 'uppercase\_identifier' in the meanwhile. Especially, the option 'uppercase\_identifier' is suggested to be setted in the `lightdb.conf` instead of enabling that on session because of this parameter is unexpected to be modified once it was setted. Lacking either condition above would disable the feature. For realized this feature, reaching the same effect as mysql, matching select's column name to storage's value should ignore the case, e.g. column "fOo" in select to be equaled to "FoO" which store on disk.

It is similarly but slightly different to mysql mode during oracle mode that the `guc` parameter 'lightdb\_oracle\_sql\_mode' could be setted on session with value 'show\_identifier\_uppercase' or ". If 'show\_identifier\_uppercase' is setted then the column name on displayed feedbacked by executed a select statement would be uppercase by default. Users only could wrapper that column name with double-quote to keep it invariant. Setting 'lightdb\_oracle\_sql\_mode' to " could disable this function and recovery the default state.

An output column's name can be used to refer to the column's value in `ORDER BY` and `GROUP BY` clauses, but not in the `WHERE` or `HAVING` clauses; there you must write out the expression instead.

Instead of an expression, `*` can be written in the output list as a shorthand for all the columns of the selected rows. Also, you can write `table_name.*` as a shorthand for the columns coming from just that table. In these cases it is not possible to specify new names with `AS`; the output column names will be the same as the table columns' names.

According to the SQL standard, the expressions in the output list should be computed before applying `DISTINCT`, `ORDER BY`, or `LIMIT`. This is obviously necessary when using `DISTINCT`, since otherwise it's not clear what values are being made distinct. However, in many cases it is convenient if output expressions are computed after `ORDER BY` and `LIMIT`; particularly if the output list contains any volatile or expensive functions. With that behavior, the order of function evaluations is more intuitive and there will not be evaluations corresponding to rows that never appear in the output. LightDB will effectively evaluate output expressions after sorting and limiting, so long as those expressions are not referenced in `DISTINCT`, `ORDER BY` or `GROUP BY`. (As a counterexample, `SELECT f(x) FROM tab ORDER BY 1` clearly must evaluate `f(x)` before sorting.) Output

expressions that contain set-returning functions are effectively evaluated after sorting and before limiting, so that `LIMIT` will act to cut off the output from a set-returning function.

### Note

LightDB versions before 9.6 did not provide any guarantees about the timing of evaluation of output expressions versus sorting and limiting; it depended on the form of the chosen query plan.

## DISTINCT Clause

If `SELECT DISTINCT` is specified, all duplicate rows are removed from the result set (one row is kept from each group of duplicates). `SELECT ALL` specifies the opposite: all rows are kept; that is the default.

`SELECT DISTINCT ON ( expression [ , ... ] )` keeps only the first row of each set of rows where the given expressions evaluate to equal. The `DISTINCT ON` expressions are interpreted using the same rules as for `ORDER BY` (see above). Note that the “first row” of each set is unpredictable unless `ORDER BY` is used to ensure that the desired row appears first. For example:

```
SELECT DISTINCT ON (location) location, time, report
  FROM weather_reports
  ORDER BY location, time DESC;
```

retrieves the most recent weather report for each location. But if we had not used `ORDER BY` to force descending order of time values for each location, we'd have gotten a report from an unpredictable time for each location.

The `DISTINCT ON` expression(s) must match the leftmost `ORDER BY` expression(s). The `ORDER BY` clause will normally contain additional expression(s) that determine the desired precedence of rows within each `DISTINCT ON` group.

`DISTINCT` supports use with `CONNECT BY`. For example:

```
select distinct test_area1.id, test_area1.name, test_area1.pid
  from test_area1 join test_area2
 on test_area1.id = test_area2.id
 connect by level < 3 order by test_area1.id;
```

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `DISTINCT`.

## UNION Clause

The `UNION` clause has this general form:

```
select_statement UNION [ ALL | DISTINCT ] select_statement
```

*select\_statement* is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause. (`ORDER BY` and `LIMIT` can be attached to a subexpression if it is enclosed in parentheses. Without parentheses, these clauses will be taken to apply to the result of the `UNION`, not to its right-hand input expression.)

The `UNION` operator computes the set union of the rows returned by the involved `SELECT` statements. A row is in the set union of two result sets if it appears in at least one of the result sets. The two

SELECT statements that represent the direct operands of the UNION must produce the same number of columns, and corresponding columns must be of compatible data types.

The result of UNION does not contain any duplicate rows unless the ALL option is specified. ALL prevents elimination of duplicates. (Therefore, UNION ALL is usually significantly quicker than UNION; use ALL when you can.) DISTINCT can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple UNION operators in the same SELECT statement are evaluated left to right, unless otherwise indicated by parentheses.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for a UNION result or for any input of a UNION.

## INTERSECT Clause

The INTERSECT clause has this general form:

```
select_statement INTERSECT [ ALL | DISTINCT ] select_statement
```

*select\_statement* is any SELECT statement without an ORDER BY, LIMIT, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, or FOR KEY SHARE clause.

The INTERSECT operator computes the set intersection of the rows returned by the involved SELECT statements. A row is in the intersection of two result sets if it appears in both result sets.

The result of INTERSECT does not contain any duplicate rows unless the ALL option is specified. With ALL, a row that has  $m$  duplicates in the left table and  $n$  duplicates in the right table will appear  $\min(m,n)$  times in the result set. DISTINCT can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple INTERSECT operators in the same SELECT statement are evaluated left to right, unless parentheses dictate otherwise. INTERSECT binds more tightly than UNION. That is, A UNION B INTERSECT C will be read as A UNION (B INTERSECT C).

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for an INTERSECT result or for any input of an INTERSECT.

## EXCEPT Clause

The EXCEPT clause has this general form:

```
select_statement EXCEPT [ ALL | DISTINCT ] select_statement
```

*select\_statement* is any SELECT statement without an ORDER BY, LIMIT, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, or FOR KEY SHARE clause.

The EXCEPT operator computes the set of rows that are in the result of the left SELECT statement but not in the result of the right one.

The result of EXCEPT does not contain any duplicate rows unless the ALL option is specified. With ALL, a row that has  $m$  duplicates in the left table and  $n$  duplicates in the right table will appear  $\max(m-n,0)$  times in the result set. DISTINCT can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple EXCEPT operators in the same SELECT statement are evaluated left to right, unless parentheses dictate otherwise. EXCEPT binds at the same level as UNION.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for an EXCEPT result or for any input of an EXCEPT.

## ORDER BY Clause

The optional `ORDER BY` clause has this general form:

```
ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST  
| LAST } ] [, ...]
```

The `ORDER BY` clause causes the result rows to be sorted according to the specified expression(s). If two rows are equal according to the leftmost expression, they are compared according to the next expression and so on. If they are equal according to all specified expressions, they are returned in an implementation-dependent order.

Each *expression* can be the name or ordinal number of an output column (`SELECT` list item), or it can be an arbitrary expression formed from input-column values.

The ordinal number refers to the ordinal (left-to-right) position of the output column. This feature makes it possible to define an ordering on the basis of a column that does not have a unique name. This is never absolutely necessary because it is always possible to assign a name to an output column using the `AS` clause.

It is also possible to use arbitrary expressions in the `ORDER BY` clause, including columns that do not appear in the `SELECT` output list. Thus the following statement is valid:

```
SELECT name FROM distributors ORDER BY code;
```

A limitation of this feature is that an `ORDER BY` clause applying to the result of a `UNION`, `INTERSECT`, or `EXCEPT` clause can only specify an output column name or number, not an expression.

If an `ORDER BY` expression is a simple name that matches both an output column name and an input column name, `ORDER BY` will interpret it as the output column name. This is the opposite of the choice that `GROUP BY` will make in the same situation. This inconsistency is made to be compatible with the SQL standard.

Optionally one can add the key word `ASC` (ascending) or `DESC` (descending) after any expression in the `ORDER BY` clause. If not specified, `ASC` is assumed by default. Alternatively, a specific ordering operator name can be specified in the `USING` clause. An ordering operator must be a less-than or greater-than member of some B-tree operator family. `ASC` is usually equivalent to `USING <` and `DESC` is usually equivalent to `USING >`. (But the creator of a user-defined data type can define exactly what the default sort ordering is, and it might correspond to operators with other names.)

If `NULLS LAST` is specified, null values sort after all non-null values; if `NULLS FIRST` is specified, null values sort before all non-null values. If neither is specified, the default behavior is `NULLS LAST` when `ASC` is specified or implied, and `NULLS FIRST` when `DESC` is specified (thus, the default is to act as though nulls are larger than non-nulls). When `USING` is specified, the default nulls ordering depends on whether the operator is a less-than or greater-than operator.

Note that ordering options apply only to the expression they follow; for example `ORDER BY x, y DESC` does not mean the same thing as `ORDER BY x DESC, y DESC`.

Character-string data is sorted according to the collation that applies to the column being sorted. That can be overridden at need by including a `COLLATE` clause in the *expression*, for example `ORDER BY mycolumn COLLATE "en_US"`. For more information see Section 4.2.10 and Section 21.2.

## LIMIT Clause

The `LIMIT` clause consists of two independent sub-clauses:

```
LIMIT { count | ALL }
OFFSET start
```

The parameter *count* specifies the maximum number of rows to return, while *start* specifies the number of rows to skip before starting to return rows. When both are specified, *start* rows are skipped before starting to count the *count* rows to be returned.

If the *count* expression evaluates to NULL, it is treated as LIMIT ALL, i.e., no limit. If *start* evaluates to NULL, it is treated the same as OFFSET 0.

SQL:2008 introduced a different syntax to achieve the same result, which LightDB also supports. It is:

```
OFFSET start { ROW | ROWS }
FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } { ONLY | WITH
  TIES }
```

In this syntax, the *start* or *count* value is required by the standard to be a literal constant, a parameter, or a variable name; as a LightDB extension, other expressions are allowed, but will generally need to be enclosed in parentheses to avoid ambiguity. If *count* is omitted in a FETCH clause, it defaults to 1. The WITH TIES option is used to return any additional rows that tie for the last place in the result set according to the ORDER BY clause; ORDER BY is mandatory in this case, and SKIP LOCKED is not allowed. ROW and ROWS as well as FIRST and NEXT are noise words that don't influence the effects of these clauses. According to the standard, the OFFSET clause must come before the FETCH clause if both are present; but LightDB is laxer and allows either order.

When using LIMIT, it is a good idea to use an ORDER BY clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows — you might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? You don't know what ordering unless you specify ORDER BY.

The query planner takes LIMIT into account when generating a query plan, so you are very likely to get different plans (yielding different row orders) depending on what you use for LIMIT and OFFSET. Thus, using different LIMIT/OFFSET values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with ORDER BY. This is not a bug; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless ORDER BY is used to constrain the order.

It is even possible for repeated executions of the same LIMIT query to return different subsets of the rows of a table, if there is not an ORDER BY to enforce selection of a deterministic subset. Again, this is not a bug; determinism of the results is simply not guaranteed in such a case.

## The Locking Clause

FOR UPDATE, FOR NO KEY UPDATE, FOR SHARE and FOR KEY SHARE are *locking clauses*; they affect how SELECT locks rows as they are obtained from the table.

The locking clause has the general form

```
FOR lock_strength [ OF table_name [, ...] ] [ NOWAIT | SKIP
  LOCKED ]
```

where *lock\_strength* can be one of

```
UPDATE
NO KEY UPDATE
SHARE
KEY SHARE
```

For more information on each row-level lock mode, refer to Section 13.3.2.



To prevent the operation from waiting for other transactions to commit, use either the `NOWAIT` or `SKIP LOCKED` option. With `NOWAIT`, the statement reports an error, rather than waiting, if a selected row cannot be locked immediately. With `SKIP LOCKED`, any selected rows that cannot be immediately locked are skipped. Skipping locked rows provides an inconsistent view of the data, so this is not suitable for general purpose work, but can be used to avoid lock contention with multiple consumers accessing a queue-like table. Note that `NOWAIT` and `SKIP LOCKED` apply only to the row-level lock(s) — the required `ROW SHARE` table-level lock is still taken in the ordinary way (see Chapter 13). You can use `LOCK` with the `NOWAIT` option first, if you need to acquire the table-level lock without waiting.

If specific tables are named in a locking clause, then only rows coming from those tables are locked; any other tables used in the `SELECT` are simply read as usual. A locking clause without a table list affects all tables used in the statement. If a locking clause is applied to a view or sub-query, it affects all tables used in the view or sub-query. However, these clauses do not apply to `WITH` queries referenced by the primary query. If you want row locking to occur within a `WITH` query, specify a locking clause within the `WITH` query.

Multiple locking clauses can be written if it is necessary to specify different locking behavior for different tables. If the same table is mentioned (or implicitly affected) by more than one locking clause, then it is processed as if it was only specified by the strongest one. Similarly, a table is processed as `NOWAIT` if that is specified in any of the clauses affecting it. Otherwise, it is processed as `SKIP LOCKED` if that is specified in any of the clauses affecting it.

The locking clauses cannot be used in contexts where returned rows cannot be clearly identified with individual table rows; for example they cannot be used with aggregation.

When a locking clause appears at the top level of a `SELECT` query, the rows that are locked are exactly those that are returned by the query; in the case of a join query, the rows locked are those that contribute to returned join rows. In addition, rows that satisfied the query conditions as of the query snapshot will be locked, although they will not be returned if they were updated after the snapshot and no longer satisfy the query conditions. If a `LIMIT` is used, locking stops once enough rows have been returned to satisfy the limit (but note that rows skipped over by `OFFSET` will get locked). Similarly, if a locking clause is used in a cursor's query, only rows actually fetched or stepped past by the cursor will be locked.

When a locking clause appears in a sub-`SELECT`, the rows locked are those returned to the outer query by the sub-query. This might involve fewer rows than inspection of the sub-query alone would suggest, since conditions from the outer query might be used to optimize execution of the sub-query. For example,

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss WHERE coll = 5;
```

will lock only rows having `coll = 5`, even though that condition is not textually within the sub-query.

### Caution

It is possible for a `SELECT` command running at the `READ COMMITTED` transaction isolation level and using `ORDER BY` and a locking clause to return rows out of order. This is because `ORDER BY` is applied first. The command sorts the result, but might then block trying to obtain a lock on one or more of the rows. Once the `SELECT` unblocks, some of the ordering column values might have been modified, leading to those rows appearing to be out of order (though they are in order in terms of the original column values). This can be worked around at need by placing the `FOR UPDATE/SHARE` clause in a sub-query, for example

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss
ORDER BY column1;
```

Note that this will result in locking all rows of `mytable`, whereas `FOR UPDATE` at the top level would lock only the actually returned rows. This can make for a significant performance difference, particularly if the `ORDER BY` is combined with `LIMIT` or other restrictions. So this technique is recommended only if concurrent updates of the ordering columns are expected and a strictly sorted result is required.

At the `REPEATABLE READ` or `SERIALIZABLE` transaction isolation level this would cause a serialization failure (with a `SQLSTATE` of `'40001'`), so there is no possibility of receiving rows out of order under these isolation levels.

## TABLE Command

The command

```
TABLE name
```

is equivalent to

```
SELECT * FROM name
```

It can be used as a top-level command or as a space-saving syntax variant in parts of complex queries. Only the `WITH`, `UNION`, `INTERSECT`, `EXCEPT`, `ORDER BY`, `LIMIT`, `OFFSET`, `FETCH` and `FOR` locking clauses can be used with `TABLE`; the `WHERE` clause and any form of aggregation cannot be used.

## Examples

To display the column's names invariant in `mysql` mode:

```
CREATE DATABASE films_distributors WITH
  lightdb_syntax_compatible_type mysql;
\c films_distributors;
-- it not suggest to set 'uppercase_identifier' on session to
  enable that as
-- 'set lightdb_sql_mode to uppercase_identifier;'. users should
  specify this
-- option in lightdb.conf instead, which follows by the current
  value of
-- 'lightdb_sql_mode' split with ','. Excuting 'lt_ctl --reload' to
  reload this
-- rule and don't modify it as far as possible.
```

```
SELECT Title as title, Did DiD, name, DATE_pROD, films.KIND
  FROM films;
```

title	DiD	name	DATE_pROD	KIND
The Third Man	101	British Lion	1949-12-23	Drama
The African Queen	101	British Lion	1951-08-11	Romantic
...				

To display the column's names in uppercase during oracle mode:

```
-- must ensure in oracle session
```

---

## SELECT

---

```
show lightdb_dblevel_syntax_compatible_type;
  lightdb_dblevel_syntax_compatible_type
-----
Oracle
(1 row)
set lightdb_oracle_sql_mode to 'show_identifier_uppercase';
show lightdb_oracle_sql_mode;
  lightdb_oracle_sql_mode
-----
show_identifier_uppercase
(1 row)

create table a(foo varchar(10));
-- foo in inner select not transform to upper case as follow:
select "foo" from (select foo as Foo from a) as temp;
  -- foo in show
  foo
-----
(0 rows)
select foo from (select foo as Foo from a) as temp;
  -- FOO in show
  FOO
-----
(0 rows)
select "foO" foo from (select foo as Foo from a) as temp;
  -- failed, column "foO" does not exist
ERROR: column "foO" does not exist
LINE 1: select "foO" foo from (select foo as Foo from a) as temp;
```

To join the table films with the table distributors:

```
SELECT f.title, f.did, d.name, f.date_prod, f.kind
  FROM distributors d, films f
 WHERE f.did = d.did
```

title	did	name	date_prod	kind
The Third Man	101	British Lion	1949-12-23	Drama
The African Queen	101	British Lion	1951-08-11	Romantic
...				

To sum the column len of all films and group the results by kind:

```
SELECT kind, sum(len) AS total FROM films GROUP BY kind;
```

kind	total
Action	07:34
Comedy	02:58
Drama	14:28
Musical	06:42
Romantic	04:38

To sum the column len of all films, group the results by kind and show those group totals that are less than 5 hours:

---

SELECT

---

```
SELECT kind, sum(len) AS total
  FROM films
  GROUP BY kind
  HAVING sum(len) < interval '5 hours';
```

kind	total
Comedy	02:58
Romantic	04:38

The following two examples are identical ways of sorting the individual results according to the contents of the second column (name):

```
SELECT * FROM distributors ORDER BY name;
SELECT * FROM distributors ORDER BY 2;
```

did	name
109	20th Century Fox
110	Bavaria Atelier
101	British Lion
107	Columbia
102	Jean Luc Godard
113	Luso films
104	Mosfilm
103	Paramount
106	Toho
105	United Artists
111	Walt Disney
112	Warner Bros.
108	Westward

The next example shows how to obtain the union of the tables `distributors` and `actors`, restricting the results to those that begin with the letter W in each table. Only distinct rows are wanted, so the key word `ALL` is omitted.

distributors:		actors:	
did	name	id	name
108	Westward	1	Woody Allen
111	Walt Disney	2	Warren Beatty
112	Warner Bros.	3	Walter Matthau
...		...	

```
SELECT distributors.name
  FROM distributors
  WHERE distributors.name LIKE 'W%'
UNION
SELECT actors.name
  FROM actors
  WHERE actors.name LIKE 'W%';
```

name
Walt Disney
Walter Matthau
Warner Bros.

```
Warren Beatty
Westward
Woody Allen
```

This example shows how to use a function in the FROM clause, both with and without a column definition list:

```
CREATE FUNCTION distributors(int) RETURNS SETOF distributors AS $$
    SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;
```

```
SELECT * FROM distributors(111);
 did | name
-----+-----
 111 | Walt Disney
```

```
CREATE FUNCTION distributors_2(int) RETURNS SETOF record AS $$
    SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;
```

```
SELECT * FROM distributors_2(111) AS (f1 int, f2 text);
 f1 | f2
-----+-----
 111 | Walt Disney
```

Here is an example of a function with an ordinality column added:

```
SELECT * FROM unnest(ARRAY['a','b','c','d','e','f']) WITH
    ORDINALITY;
 unnest | ordinality
-----+-----
 a      |          1
 b      |          2
 c      |          3
 d      |          4
 e      |          5
 f      |          6
(6 rows)
```

This example shows how to use a simple WITH clause:

```
WITH t AS (
    SELECT random() as x FROM generate_series(1, 3)
)
SELECT * FROM t
UNION ALL
SELECT * FROM t

      x
-----
0.534150459803641
0.520092216785997
0.0735620250925422
0.534150459803641
0.520092216785997
0.0735620250925422
```

Notice that the WITH query was evaluated only once, so that we got two sets of the same three random values.

This example uses WITH RECURSIVE to find all subordinates (direct or indirect) of the employee Mary, and their level of indirectness, from a table that shows only direct subordinates:

```
WITH RECURSIVE employee_recursive(distance, employee_name,
manager_name) AS (
    SELECT 1, employee_name, manager_name
    FROM employee
    WHERE manager_name = 'Mary'
    UNION ALL
    SELECT er.distance + 1, e.employee_name, e.manager_name
    FROM employee_recursive er, employee e
    WHERE er.employee_name = e.manager_name
)
SELECT distance, employee_name FROM employee_recursive;
```

Notice the typical form of recursive queries: an initial condition, followed by UNION, followed by the recursive part of the query. Be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. (See Section 7.8 for more examples.)

This example uses LATERAL to apply a set-returning function get\_product\_names() for each row of the manufacturers table:

```
SELECT m.name AS mname, pname
FROM manufacturers m, LATERAL get_product_names(m.id) pname;
```

Manufacturers not currently having any products would not appear in the result, since it is an inner join. If we wished to include the names of such manufacturers in the result, we could do:

```
SELECT m.name AS mname, pname
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id)
pname ON true;
```

This example uses the CONNECT BY clause to define the relationship between employees and managers, uses the LEVEL pseudocolumn to show parent and child rows and uses the START WITH clause to specify a root row for the hierarchy.

```
SELECT last_name, employee_id, manager_id, LEVEL
FROM employees
START WITH employee_id = 100
CONNECT BY PRIOR employee_id = manager_id;
```

LAST_NAME	EMPLOYEE_ID	MANAGER_ID	LEVEL
King	100		1
Cambrault	148	100	2
Bates	172	148	3
Bloom	169	148	3
Fox	170	148	3
Kumar	173	148	3
Ozer	168	148	3
Smith	171	148	3
De Haan	102	100	2
Hunold	103	102	3

SELECT

---

Austin	105	103	4
Ernst	104	103	4
Lorentz	107	103	4
Pataballa	106	103	4
Errazuriz	147	100	2
Ande	166	147	3
Banda	167	147	3

The following example returns the path of employee names from employee KING to all employees of KING (and their employees):

```
SELECT SYS_CONNECT_BY_PATH(last_name, '/') "Path"
FROM employees
START WITH last_name = 'KING'
CONNECT BY PRIOR employee_id = manager_id;
           Path
```

```
-----
/KING
/KING/JONES
/KING/BLAKE
/KING/CLARK
/KING/BLAKE/ALLEN
/KING/BLAKE/WARD
/KING/BLAKE/MARTIN
/KING/JONES/SCOTT
/KING/BLAKE/TURNER
/KING/BLAKE/JAMES
/KING/JONES/FORD
/KING/CLARK/MILLER
/KING/JONES/FORD/SMITH
/KING/JONES/SCOTT/ADAMS
(14 rows)
```

The following example returns the last name of each employee in department 110, each manager at the highest level above that employee in the hierarchy, the number of levels between manager and employee, and the path between the two:

```
SELECT last_name "Employee", CONNECT_BY_ROOT last_name "Manager",
LEVEL-1 "Pathlen", SYS_CONNECT_BY_PATH(last_name, '/') "Path"
FROM employees
WHERE LEVEL > 1 and department_id = 110
CONNECT BY PRIOR employee_id = manager_id
ORDER BY "Employee", "Manager", "Pathlen", "Path";
```

Employee	Manager	Pathlen	Path
Gietz	Higgins	1	/Higgins/Gietz
Gietz	King	3	/King/Kochhar/Higgins/
Gietz			
Gietz	Kochhar	2	/Kochhar/Higgins/Gietz
Higgins	King	2	/King/Kochhar/Higgins
Higgins	Kochhar	1	/Kochhar/Higgins

SELECT

The following example display all recursive results below n levels.

```
select * from staff_table connect by level < 2;
staff_id |          name          | manager_id
-----+-----+-----
    1001 | Michael North         |
    1002 | Megan Berry           |         1001
    1003 | Sarah Berry           |         1001
    1004 | Zoe Black              |         1001
    1005 | Tim James             |         1001
    1006 | Bella Tucker          |         1002
    1007 | Ryan Metcalfe         |         1002
    1008 | Max Mills             |         1002
    1009 | Benjamin Glover      |         1002
    1010 | Carolyn Henderson    |         1003
    1011 | Nicola Kelly          |         1003
    1012 | Alexandra Climo       |         1003
    1013 | Dominic King          |         1003
    1014 | Leonard Gray          |         1004
    1015 | Eric Rampling         |         1004
    1016 | Piers Paige          |         1007
    1017 | Ryan Henderson       |         1007
    1018 | Frank Tucker         |         1008
    1019 | Nathan Ferguson      |         1008
    1020 | Kevin Rampling       |         1008
```

The following example display employees if they are leaf nodes (no subordinates) or not.

```
SELECT staff_id, name, manager_id,
SYS_CONNECT_BY_PATH (name,'/'), connect_by_isleaf
FROM staff_table
START WITH staff_id = '1001'
CONNECT BY PRIOR staff_id = manager_id;
staff_id |          name          | manager_id |
sysconnectpath | connect_by_isleaf
-----+-----+-----+-----
+-----+-----+-----+-----
+-----+-----+-----+-----
    1001 | Michael North         |         1000 | /Michael North
                                                |         0
    1002 | Megan Berry           |         1001 | /Michael North/
Megan Berry |         |         0
    1003 | Sarah Berry           |         1001 | /Michael North/
Sarah Berry |         |         0
    1004 | Zoe Black              |         1001 | /Michael North/Zoe
Black |         |         0
    1005 | Tim James             |         1001 | /Michael North/Tim
James |         |         1
    1006 | Bella Tucker          |         1002 | /Michael North/
Megan Berry/Bella Tucker |         |         1
    1007 | Ryan Metcalfe         |         1002 | /Michael North/
Megan Berry/Ryan Metcalfe |         |         0
    1008 | Max Mills             |         1002 | /Michael North/
Megan Berry/Max Mills |         |         0
    1009 | Benjamin Glover      |         1002 | /Michael North/
Megan Berry/Benjamin Glover |         |         1
```



---

## SELECT

---

```
      1010 | Carolyn Henderson |      1003 | /Michael North/
Sarah Berry/Carolyn Henderson |      1
      1011 | Nicola Kelly |      1003 | /Michael North/
Sarah Berry/Nicola Kelly |      1
      1012 | Alexandra Climo |      1003 | /Michael North/
Sarah Berry/Alexandra Climo |      1
      1013 | Dominic King |      1003 | /Michael North/
Sarah Berry/Dominic King |      1
      1014 | Leonard Gray |      1004 | /Michael North/Zoe
Black/Leonard Gray |      1
      1015 | Eric Rampling |      1004 | /Michael North/Zoe
Black/Eric Rampling |      1
      1016 | Piers Paige |      1007 | /Michael North/
Megan Berry/Ryan Metcalfe/Piers Paige |      1
      1017 | Ryan Henderson |      1007 | /Michael North/
Megan Berry/Ryan Metcalfe/Ryan Henderson |      1
      1018 | Frank Tucker |      1008 | /Michael North/
Megan Berry/Max Mills/Frank Tucker |      1
      1019 | Nathan Ferguson |      1008 | /Michael North/
Megan Berry/Max Mills/Nathan Ferguson |      1
      1020 | Kevin Rampling |      1008 | /Michael North/
Megan Berry/Max Mills/Kevin Rampling |      1
(20 rows)
```

This example illustrate mysql index hint usage.

```
-- multiple index
select * from lt_test_mysql_ddl use
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);
select * from lt_test_mysql_ddl force
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);
select * from lt_test_mysql_ddl ignore
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);

-- multiple table join
select * from lt_test_mysql_ddl a use index for order
by(primary) join b using(id);
select * from lt_test_mysql_ddl a force index for order
by(pk_lt_test_mysql_ddl) join b using(id);
select * from lt_test_mysql_ddl a ignore index for order
by(primary,pk_lt_test_mysql_ddl) join b using(id);
select * from lt_test_mysql_ddl a ignore index for order
by(pk_lt_test_mysql_ddl) join b using(id);
```

## Compatibility

Of course, the SELECT statement is compatible with the SQL standard. But there are some extensions and some missing features.

## Omitted FROM Clauses

LightDB allows one to omit the FROM clause. It has a straightforward use to compute the results of simple expressions:

```
SELECT 2+2;  
  
?column?  
-----  
4
```

Some other SQL databases cannot do this except by introducing a dummy one-row table from which to do the `SELECT`.

Note that if a `FROM` clause is not specified, the query cannot reference any database tables. For example, the following query is invalid:

```
SELECT distributors.* WHERE distributors.name = 'Westward';
```

## Empty `SELECT` Lists

The list of output expressions after `SELECT` can be empty, producing a zero-column result table. This is not valid syntax according to the SQL standard. LightDB allows it to be consistent with allowing zero-column tables. However, an empty list is not allowed when `DISTINCT` is used.

## Omitting the `AS` Key Word

In the SQL standard, the optional key word `AS` can be omitted before an output column name whenever the new column name is a valid column name (that is, not the same as any reserved keyword). LightDB is slightly more restrictive: `AS` is required if the new column name matches any keyword at all, reserved or not. Recommended practice is to use `AS` or double-quote output column names, to prevent any possible conflict against future keyword additions.

In `FROM` items, both the standard and LightDB allow `AS` to be omitted before an alias that is an unreserved keyword. But this is impractical for output column names, because of syntactic ambiguities.

## `ONLY` and Inheritance

The SQL standard requires parentheses around the table name when writing `ONLY`, for example `SELECT * FROM ONLY (tab1), ONLY (tab2) WHERE ...`. LightDB considers these parentheses to be optional.

LightDB allows a trailing `*` to be written to explicitly specify the non-`ONLY` behavior of including child tables. The standard does not allow this.

(These points apply equally to all SQL commands supporting the `ONLY` option.)

## `TABLESAMPLE` Clause Restrictions

The `TABLESAMPLE` clause is currently accepted only on regular tables and materialized views. According to the SQL standard it should be possible to apply it to any `FROM` item.

## Function Calls in `FROM`

LightDB allows a function call to be written directly as a member of the `FROM` list. In the SQL standard it would be necessary to wrap such a function call in a sub-`SELECT`; that is, the syntax `FROM func(...) alias` is approximately equivalent to `FROM LATERAL (SELECT func(...)) alias`. Note that `LATERAL` is considered to be implicit; this is because the standard requires `LATERAL` semantics for an `UNNEST()` item in `FROM`. LightDB treats `UNNEST()` the same as other set-returning functions.

## Namespace Available to GROUP BY and ORDER BY

In the SQL-92 standard, an ORDER BY clause can only use output column names or numbers, while a GROUP BY clause can only use expressions based on input column names. LightDB extends each of these clauses to allow the other choice as well (but it uses the standard's interpretation if there is ambiguity). LightDB also allows both clauses to specify arbitrary expressions. Note that names appearing in an expression will always be taken as input-column names, not as output-column names.

SQL:1999 and later use a slightly different definition which is not entirely upward compatible with SQL-92. In most cases, however, LightDB will interpret an ORDER BY or GROUP BY expression the same way SQL:1999 does.

## Functional Dependencies

LightDB recognizes functional dependency (allowing columns to be omitted from GROUP BY) only when a table's primary key is included in the GROUP BY list. The SQL standard specifies additional conditions that should be recognized.

## LIMIT and OFFSET

The clauses LIMIT and OFFSET are LightDB-specific syntax, also used by MySQL. The SQL:2008 standard has introduced the clauses OFFSET ... FETCH {FIRST|NEXT} ... for the same functionality, as shown above in LIMIT Clause. This syntax is also used by IBM DB2. (Applications written for Oracle frequently use a workaround involving the automatically generated rownum column, which is not available in LightDB, to implement the effects of these clauses.)

## FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, FOR KEY SHARE

Although FOR UPDATE appears in the SQL standard, the standard allows it only as an option of DECLARE CURSOR. LightDB allows it in any SELECT query as well as in sub-SELECTs, but this is an extension. The FOR NO KEY UPDATE, FOR SHARE and FOR KEY SHARE variants, as well as the NOWAIT and SKIP LOCKED options, do not appear in the standard.

## Data-Modifying Statements in WITH

LightDB allows INSERT, UPDATE, and DELETE to be used as WITH queries. This is not found in the SQL standard.

## Nonstandard Clauses

DISTINCT ON ( ... ) is an extension of the SQL standard.

ROWS FROM( ... ) is an extension of the SQL standard.

The MATERIALIZED and NOT MATERIALIZED options of WITH are extensions of the SQL standard.

## oracle (+)

You can use '(+)' in where condition to specify outer join like oracle. An example is as follows:

```
select * from t1 a, t2 b where a.key1(+) = b.key1;
          QUERY PLAN
```

```
-----
Hash Right Join (cost=60.85..86.01 rows=2260 width=48)
  Hash Cond: (a.key1 = b.key1)
```

## SELECT

---

```
-> Seq Scan on t1 a (cost=0.00..22.00 rows=1200 width=40)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
    -> Seq Scan on t2 b (cost=0.00..32.60 rows=2260 width=8)
(5 rows)
```

The following describes the limitations of Oracle (+).

- The (+) operator can appear only in the WHERE clause and can be applied only to a column of a table or view.
- The (+) operator must match exactly without Spaces. oracle can have spaces.

```
select * from t1 a, t2 b where a.key1( +) = b.key1;
ERROR:  syntax error at or near ")"
LINE 1: explain select * from t1 a, t2 b where a.key1( +) =
         b.key1;
                                                ^
```

- If A and B are joined by multiple join conditions, you must use the (+) operator in all of these conditions. If you do not, LightDB will return only the rows resulting from a simple join, but without a warning or error to advise you that you do not have the results of an outer join.

```
explain select * from t1 a, t2 b where a.key1(+)=b.key1 and
a.key2=b.key2;
```

### QUERY PLAN

```
-----
Merge Join (cost=317.01..352.19 rows=128 width=16)
  Merge Cond: ((a.key1 = b.key1) AND (a.key2 = b.key2))
    -> Sort (cost=158.51..164.16 rows=2260 width=8)
        Sort Key: a.key1, a.key2
        -> Seq Scan on t1 a (cost=0.00..32.60 rows=2260
width=8)
    -> Sort (cost=158.51..164.16 rows=2260 width=8)
        Sort Key: b.key1, b.key2
        -> Seq Scan on t2 b (cost=0.00..32.60 rows=2260
width=8)
(8 rows)
```

- The (+) operator can be applied only to a column, not to an arbitrary expression. However, an arbitrary expression can contain a column marked with the (+) operator.

```
select * from t1 a, t2 b where mod(a.key1,10)(+)=b.key1;
ERROR:  syntax error at or near "(+)"
LINE 1: select * from t1 a, t2 b where mod(a.key1,10)(+)=b.key1;
                                                ^
```

```
select * from t1 a, t2 b where mod(a.key1(+),10)=b.key1;
 key1 | key2 | key1 | key2
-----+-----+-----+-----
(0 rows)
```

- A condition containing the (+) operator cannot be combined with another condition using the OR logical operator.

```
select * from t1 a, t2 b where a.key1(+)=b.key1 or
a.key2(+)=b.key2;
ERROR: Operator "(+)" is not allowed used with "OR" together
```

- A condition cannot compare any column marked with the (+) operator with a subquery.

```
select * from t1 a, t2 b where a.key1(+)=(select key1 from t3);
ERROR: Operator "(+)" can not be used in outer join with
SubQuery.
LINE 1: select * from t1 a, t2 b where a.key1(+)=(select key1
from t...
```

- The tables cannot outer join with each other by using (+).

```
select * from t1 a, t2 b where a.key1(+)=b.key1 and
b.key2(+)=a.key2;
ERROR: Relation can't outer join with each other.
```

- The (+) operator cannot be applied to column that belong to table in outer query block.

```
select * from t1 a where exists (select * from t2 b where
a.key1(+)=b.key1);
ERROR: Operator "(+)" can't specify on "a" which cannot be
referenced from this part of the query.
LINE 1: ...rom t1 a where exists (select * from t2 b where
a.key1(+)=...
```

- The (+) operator cannot be used in nested and/or expression. This is different from oracle, oracle support it.

```
#oracle also not support it, because it actually is or expression
after unnest.
select * from t1 a, t2 b where not (a.key1(+)= b.key1 and
a.key2(+)=b.key2);
ERROR: Operator "(+)" can not be used in nested and/or
expression.
LINE 1: select * from t1 a, t2 b where not (a.key1(+)= b.key1 and
a....
```

```
# oracle support 'not (a.key1(+)= b.key1 or a.key2(+)=b.key2)'
select * from t1 a, t2 b where not (a.key1(+)= b.key1 or
a.key2(+)=b.key2);
ERROR: Operator "(+)" can not be used in nested and/or
expression.
LINE 1: select * from t1 a, t2 b where not (a.key1(+)= b.key1 or
a.k...
```

- The (+) operator cannot be used with ansi join.

```
select * from t1 a join t2 b on a.key1=b.key1, t3 c, t4 d where
c.key1(+)=d.key1;
```

ERROR: Operator "(+)" and Join in FromClause can't be used together

- A table cannot outer join with multiple table. oracle supports this usage.

```
select * from t1 a, t2 b, t3 c where a.key1(+)=b.key1+c.key1;
ERROR: "a" can't outer join with more than one relation
HINT: "b", "c" are outer join with "a".
```

```
select * from t1 a, t2 b, t3 c where a.key1(+)=b.key1 and
a.key1(+)=c.key1;
ERROR: "a" can't outer join with more than one relation.
```

- The (+) operator cannot be used for full out join.

```
select * from t1 a, t2 b ,t3 c where a.key1(+) =b.key1(+);
ERROR: Operator "(+)" can't be specified on more than one
relation in one join condition
HINT: "a", "b"...are specified Operator "(+)" in one condition.
```

## pivot

Provide examples of how simple pivot can be used.

```
create table test123(name varchar(40),chinese int,math int, course
varchar(40), score int);
insert into test123 values('lisi',88,99,'math',99);
insert into test123 values('lisi',88,99,'chinese',88);
insert into test123 values('zhangsan',90,100,'chinese',90);
insert into test123 values('zhangsan',90,100,'math',100);
```

```
select * from test123 pivot (sum(score) for course
in('chinese','math'));
```

name	chinese	math	'chinese'	'math'
lisi	88	99	88	99
lisi	89	100		99
lisi	100	70	100	
zhangsan	76	89	99	
zhangsan	90	100	90	100
zhangsan	95	85		100

(6 rows)

```
drop table test123;
```

---

# SELECT INTO

SELECT INTO — define a new table from the results of a query

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    * | expression [ [ AS ] output_name ] [, ...]
    INTO [ TEMPORARY | TEMP | UNLOGGED ] [ TABLE ] new_table
    [ FROM from_item [, ...] ]
    [ WHERE condition ]
    [ GROUP BY expression [, ...] ]
    [ HAVING condition ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT } [ ALL | DISTINCT ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
{ FIRST | LAST } ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
    [ FOR { UPDATE | SHARE } [ OF table_name [, ...] ] [ NOWAIT ]
[ ... ] ]
```

## Description

SELECT INTO creates a new table and fills it with data computed by a query. The data is not returned to the client, as it is with a normal SELECT. The new table's columns have the names and data types associated with the output columns of the SELECT.

## Parameters

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

*new\_table*

The name (optionally schema-qualified) of the table to be created.

All other parameters are described in detail under SELECT.

## Notes

CREATE TABLE AS is functionally similar to SELECT INTO. CREATE TABLE AS is the recommended syntax, since this form of SELECT INTO is not available in ECPG or PL/pgSQL, because they interpret the INTO clause differently. Furthermore, CREATE TABLE AS offers a superset of the functionality provided by SELECT INTO.

In contrast to CREATE TABLE AS, SELECT INTO does not allow specifying properties like a table's access method with USING *method* or the table's tablespace with TABLESPACE

*tablespace\_name*. Use `CREATE TABLE AS` if necessary. Therefore, the default table access method is chosen for the new table. See `default_table_access_method` for more information.

## Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
SELECT * INTO films_recent FROM films WHERE date_prod >=
'2002-01-01';
```

## Compatibility

The SQL standard uses `SELECT INTO` to represent selecting values into scalar variables of a host program, rather than creating a new table. This indeed is the usage found in ECPG (see Chapter 34) and PL/pgSQL (see Chapter 41). The LightDB usage of `SELECT INTO` to represent table creation is historical. It is best to use `CREATE TABLE AS` for this purpose in new code.

## See Also

`CREATE TABLE AS`



---

# SET

SET — change a run-time parameter

## Synopsis

```
SET [ SESSION | LOCAL ] configuration_parameter { TO | = } { value
| 'value' | DEFAULT }
SET [ SESSION | LOCAL ] TIME ZONE { timezone | LOCAL | DEFAULT }
```

## Description

The SET command changes run-time configuration parameters. Many of the run-time parameters listed in Chapter 17 can be changed on-the-fly with SET. (But some require superuser privileges to change, and others cannot be changed after server or session start.) SET only affects the value used by the current session.

If SET (or equivalently SET SESSION) is issued within a transaction that is later aborted, the effects of the SET command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another SET.

The effects of SET LOCAL last only till the end of the current transaction, whether committed or not. A special case is SET followed by SET LOCAL within a single transaction: the SET LOCAL value will be seen until the end of the transaction, but afterwards (if the transaction is committed) the SET value will take effect.

The effects of SET or SET LOCAL are also canceled by rolling back to a savepoint that is earlier than the command.

If SET LOCAL is used within a function that has a SET option for the same variable (see CREATE FUNCTION), the effects of the SET LOCAL command disappear at function exit; that is, the value in effect when the function was called is restored anyway. This allows SET LOCAL to be used for dynamic or repeated changes of a parameter within a function, while still having the convenience of using the SET option to save and restore the caller's value. However, a regular SET command overrides any surrounding function's SET option; its effects will persist unless rolled back.

### Note

In LightDB versions 8.0 through 8.2, the effects of a SET LOCAL would be canceled by releasing an earlier savepoint, or by successful exit from a PL/pgSQL exception block. This behavior has been changed because it was deemed unintuitive.

## Parameters

SESSION

Specifies that the command takes effect for the current session. (This is the default if neither SESSION nor LOCAL appears.)

LOCAL

Specifies that the command takes effect for only the current transaction. After COMMIT or ROLLBACK, the session-level setting takes effect again. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

*configuration\_parameter*

Name of a settable run-time parameter. Available parameters are documented in Chapter 17 and below.

*value*

New value of parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. DEFAULT can be written to specify resetting the parameter to its default value (that is, whatever value it would have had if no SET had been executed in the current session).

Besides the configuration parameters documented in Chapter 17, there are a few that can only be adjusted using the SET command or that have a special syntax:

## SCHEMA

SET SCHEMA *value* is an alias for SET search\_path TO *value*. Only one schema can be specified using this syntax.

## NAMES

SET NAMES *value* is an alias for SET client\_encoding TO *value*.

## SEED

Sets the internal seed for the random number generator (the function random). Allowed values are floating-point numbers between -1 and 1 inclusive.

The seed can also be set by invoking the function setseed:

```
SELECT setseed(value);
```

## TIME ZONE

SET TIME ZONE *value* is an alias for SET timezone TO *value*. The syntax SET TIME ZONE allows special syntax for the time zone specification. Here are examples of valid values:

```
'PST8PDT'
```

The time zone for Berkeley, California.

```
'Europe/Rome'
```

The time zone for Italy.

```
-7
```

The time zone 7 hours west from UTC (equivalent to PDT). Positive values are east from UTC.

```
INTERVAL '-08:00' HOUR TO MINUTE
```

The time zone 8 hours west from UTC (equivalent to PST).

## LOCAL

## DEFAULT

Set the time zone to your local time zone (that is, the server's default value of timezone).

Timezone settings given as numbers or intervals are internally translated to POSIX timezone syntax. For example, after SET TIME ZONE -7, SHOW TIME ZONE would report <-07>+07.

See Section 8.5.3 for more information about time zones.

## Notes

The function `set_config` provides equivalent functionality; see Section 9.27.1. Also, it is possible to UPDATE the `pg_settings` system view to perform the equivalent of SET.

## Examples

Set the schema search path:

```
SET search_path TO my_schema, public;
```

Set the style of date to traditional POSTGRES with “day before month” input convention:

```
SET datestyle TO postgres, dmy;
```

Set the time zone for Berkeley, California:

```
SET TIME ZONE 'PST8PDT';
```

Set the time zone for Italy:

```
SET TIME ZONE 'Europe/Rome';
```

## Compatibility

SET TIME ZONE extends syntax defined in the SQL standard. The standard allows only numeric time zone offsets while LightDB allows more flexible time-zone specifications. All other SET features are LightDB extensions.

## See Also

RESET, SHOW

---

# SET CONSTRAINTS

SET CONSTRAINTS — set constraint check timing for the current transaction

## Synopsis

```
SET CONSTRAINTS { ALL | name [, ...] } { DEFERRED | IMMEDIATE }
```

## Description

SET CONSTRAINTS sets the behavior of constraint checking within the current transaction. IMMEDIATE constraints are checked at the end of each statement. DEFERRED constraints are not checked until transaction commit. Each constraint has its own IMMEDIATE or DEFERRED mode.

Upon creation, a constraint is given one of three characteristics: DEFERRABLE INITIALLY DEFERRED, DEFERRABLE INITIALLY IMMEDIATE, or NOT DEFERRABLE. The third class is always IMMEDIATE and is not affected by the SET CONSTRAINTS command. The first two classes start every transaction in the indicated mode, but their behavior can be changed within a transaction by SET CONSTRAINTS.

SET CONSTRAINTS with a list of constraint names changes the mode of just those constraints (which must all be deferrable). Each constraint name can be schema-qualified. The current schema search path is used to find the first matching name if no schema name is specified. SET CONSTRAINTS ALL changes the mode of all deferrable constraints.

When SET CONSTRAINTS changes the mode of a constraint from DEFERRED to IMMEDIATE, the new mode takes effect retroactively: any outstanding data modifications that would have been checked at the end of the transaction are instead checked during the execution of the SET CONSTRAINTS command. If any such constraint is violated, the SET CONSTRAINTS fails (and does not change the constraint mode). Thus, SET CONSTRAINTS can be used to force checking of constraints to occur at a specific point in a transaction.

Currently, only UNIQUE, PRIMARY KEY, REFERENCES (foreign key), and EXCLUDE constraints are affected by this setting. NOT NULL and CHECK constraints are always checked immediately when a row is inserted or modified (*not* at the end of the statement). Uniqueness and exclusion constraints that have not been declared DEFERRABLE are also checked immediately.

The firing of triggers that are declared as “constraint triggers” is also controlled by this setting — they fire at the same time that the associated constraint should be checked.

## Notes

Because LightDB does not require constraint names to be unique within a schema (but only per-table), it is possible that there is more than one match for a specified constraint name. In this case SET CONSTRAINTS will act on all matches. For a non-schema-qualified name, once a match or matches have been found in some schema in the search path, schemas appearing later in the path are not searched.

This command only alters the behavior of constraints within the current transaction. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

## Compatibility

This command complies with the behavior defined in the SQL standard, except for the limitation that, in LightDB, it does not apply to NOT NULL and CHECK constraints. Also, LightDB checks non-deferrable uniqueness constraints immediately, not at end of statement as the standard would suggest.

---

# SET ROLE

SET ROLE — set the current user identifier of the current session

## Synopsis

```
SET [ SESSION | LOCAL ] ROLE role_name
SET [ SESSION | LOCAL ] ROLE NONE
RESET ROLE
```

## Description

This command sets the current user identifier of the current SQL session to be *role\_name*. The role name can be written as either an identifier or a string literal. After SET ROLE, permissions checking for SQL commands is carried out as though the named role were the one that had logged in originally.

The specified *role\_name* must be a role that the current session user is a member of. (If the session user is a superuser, any role can be selected.)

The SESSION and LOCAL modifiers act the same as for the regular SET command.

SET ROLE NONE sets the current user identifier to the current session user identifier, as returned by session\_user. RESET ROLE sets the current user identifier to the connection-time setting specified by the command-line options, ALTER ROLE, or ALTER DATABASE, if any such settings exist. Otherwise, RESET ROLE sets the current user identifier to the current session user identifier. These forms can be executed by any user.

## Notes

Using this command, it is possible to either add privileges or restrict one's privileges. If the session user role has the INHERIT attribute, then it automatically has all the privileges of every role that it could SET ROLE to; in this case SET ROLE effectively drops all the privileges assigned directly to the session user and to the other roles it is a member of, leaving only the privileges available to the named role. On the other hand, if the session user role has the NOINHERIT attribute, SET ROLE drops the privileges assigned directly to the session user and instead acquires the privileges available to the named role.

In particular, when a superuser chooses to SET ROLE to a non-superuser role, they lose their superuser privileges.

SET ROLE has effects comparable to SET SESSION AUTHORIZATION, but the privilege checks involved are quite different. Also, SET SESSION AUTHORIZATION determines which roles are allowable for later SET ROLE commands, whereas changing roles with SET ROLE does not change the set of roles allowed to a later SET ROLE.

SET ROLE does not process session variables as specified by the role's ALTER ROLE settings; this only happens during login.

SET ROLE cannot be used within a SECURITY DEFINER function.

## Examples

```
SELECT SESSION_USER, CURRENT_USER;
```

```
session_user | current_user
-----+-----
peter        | peter
```

```
SET ROLE 'paul';
```

```
SELECT SESSION_USER, CURRENT_USER;
```

```
session_user | current_user
-----+-----
peter        | paul
```

## Compatibility

LightDB allows identifier syntax ("*rolename*"), while the SQL standard requires the role name to be written as a string literal. SQL does not allow this command during a transaction; LightDB does not make this restriction because there is no reason to. The `SESSION` and `LOCAL` modifiers are a LightDB extension, as is the `RESET` syntax.

## See Also

SET SESSION AUTHORIZATION

---

# SET SESSION AUTHORIZATION

SET SESSION AUTHORIZATION — set the session user identifier and the current user identifier of the current session

## Synopsis

```
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION user_name
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION DEFAULT
RESET SESSION AUTHORIZATION
```

## Description

This command sets the session user identifier and the current user identifier of the current SQL session to be *user\_name*. The user name can be written as either an identifier or a string literal. Using this command, it is possible, for example, to temporarily become an unprivileged user and later switch back to being a superuser.

The session user identifier is initially set to be the (possibly authenticated) user name provided by the client. The current user identifier is normally equal to the session user identifier, but might change temporarily in the context of SECURITY DEFINER functions and similar mechanisms; it can also be changed by SET ROLE. The current user identifier is relevant for permission checking.

The session user identifier can be changed only if the initial session user (the *authenticated user*) had the superuser privilege. Otherwise, the command is accepted only if it specifies the authenticated user name.

The SESSION and LOCAL modifiers act the same as for the regular SET command.

The DEFAULT and RESET forms reset the session and current user identifiers to be the originally authenticated user name. These forms can be executed by any user.

## Notes

SET SESSION AUTHORIZATION cannot be used within a SECURITY DEFINER function.

## Examples

```
SELECT SESSION_USER, CURRENT_USER;
```

```
  session_user | current_user
-----+-----
  peter       | peter
```

```
SET SESSION AUTHORIZATION 'paul';
```

```
SELECT SESSION_USER, CURRENT_USER;
```

```
  session_user | current_user
-----+-----
  paul        | paul
```

## Compatibility

The SQL standard allows some other expressions to appear in place of the literal *user\_name*, but these options are not important in practice. LightDB allows identifier syntax ("*username*"), which SQL does not. SQL does not allow this command during a transaction; LightDB does not make this restriction because there is no reason to. The `SESSION` and `LOCAL` modifiers are a LightDB extension, as is the `RESET` syntax.

The privileges necessary to execute this command are left implementation-defined by the standard.

## See Also

SET ROLE



---

# SET TRANSACTION

SET TRANSACTION — set the characteristics of the current transaction

## Synopsis

```
SET TRANSACTION transaction_mode [, ...]
SET TRANSACTION SNAPSHOT snapshot_id
SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode [, ...]
```

where *transaction\_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ
COMMITTED | READ UNCOMMITTED }
READ WRITE | READ ONLY
[ NOT ] DEFERRABLE
```

## Description

The SET TRANSACTION command sets the characteristics of the current transaction. It has no effect on any subsequent transactions. SET SESSION CHARACTERISTICS sets the default transaction characteristics for subsequent transactions of a session. These defaults can be overridden by SET TRANSACTION for an individual transaction.

The available transaction characteristics are the transaction isolation level, the transaction access mode (read/write or read-only), and the deferrable mode. In addition, a snapshot can be selected, though only for the current transaction, not as a session default.

The isolation level of a transaction determines what data the transaction can see when other transactions are running concurrently:

READ COMMITTED

A statement can only see rows committed before it began. This is the default.

REPEATABLE READ

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction.

SERIALIZABLE

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction. If a pattern of reads and writes among concurrent serializable transactions would create a situation which could not have occurred for any serial (one-at-a-time) execution of those transactions, one of them will be rolled back with a `serialization_failure` error.

The SQL standard defines one additional level, READ UNCOMMITTED. In LightDB READ UNCOMMITTED is treated as READ COMMITTED.

The transaction isolation level cannot be changed after the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of a transaction has been executed. See Chapter 13 for more information about transaction isolation and concurrency control.

The transaction access mode determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT,

UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table; all CREATE, ALTER, and DROP commands; COMMENT, GRANT, REVOKE, TRUNCATE; and EXPLAIN ANALYZE and EXECUTE if the command they would execute is among those listed. This is a high-level notion of read-only that does not prevent all writes to disk.

The DEFERRABLE transaction property has no effect unless the transaction is also SERIALIZABLE and READ ONLY. When all three of these properties are selected for a transaction, the transaction may block when first acquiring its snapshot, after which it is able to run without the normal overhead of a SERIALIZABLE transaction and without any risk of contributing to or being canceled by a serialization failure. This mode is well suited for long-running reports or backups.

The SET TRANSACTION SNAPSHOT command allows a new transaction to run with the same *snapshot* as an existing transaction. The pre-existing transaction must have exported its snapshot with the `pg_export_snapshot` function (see Section 9.27.5). That function returns a snapshot identifier, which must be given to SET TRANSACTION SNAPSHOT to specify which snapshot is to be imported. The identifier must be written as a string literal in this command, for example '000003A1-1'. SET TRANSACTION SNAPSHOT can only be executed at the start of a transaction, before the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of the transaction. Furthermore, the transaction must already be set to SERIALIZABLE or REPEATABLE READ isolation level (otherwise, the snapshot would be discarded immediately, since READ COMMITTED mode takes a new snapshot for each command). If the importing transaction uses SERIALIZABLE isolation level, then the transaction that exported the snapshot must also use that isolation level. Also, a non-read-only serializable transaction cannot import a snapshot from a read-only transaction.

## Notes

If SET TRANSACTION is executed without a prior START TRANSACTION or BEGIN, it emits a warning and otherwise has no effect.

It is possible to dispense with SET TRANSACTION by instead specifying the desired *transaction\_modes* in BEGIN or START TRANSACTION. But that option is not available for SET TRANSACTION SNAPSHOT.

The session default transaction modes can also be set or examined via the configuration parameters `default_transaction_isolation`, `default_transaction_read_only`, and `default_transaction_deferrable`. (In fact SET SESSION CHARACTERISTICS is just a verbose equivalent for setting these variables with SET.) This means the defaults can be set in the configuration file, via ALTER DATABASE, etc. Consult Chapter 17 for more information.

The current transaction's modes can similarly be set or examined via the configuration parameters `transaction_isolation`, `transaction_read_only`, and `transaction_deferrable`. Setting one of these parameters acts the same as the corresponding SET TRANSACTION option, with the same restrictions on when it can be done. However, these parameters cannot be set in the configuration file, or from any source other than live SQL.

## Examples

To begin a new transaction with the same snapshot as an already existing transaction, first export the snapshot from the existing transaction. That will return the snapshot identifier, for example:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SELECT pg_export_snapshot();
       pg_export_snapshot
-----
00000003-0000001B-1
(1 row)
```

Then give the snapshot identifier in a `SET TRANSACTION SNAPSHOT` command at the beginning of the newly opened transaction:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;  
SET TRANSACTION SNAPSHOT '00000003-0000001B-1';
```

## Compatibility

These commands are defined in the SQL standard, except for the `DEFERRABLE` transaction mode and the `SET TRANSACTION SNAPSHOT` form, which are LightDB extensions.

`SERIALIZABLE` is the default transaction isolation level in the standard. In LightDB the default is ordinarily `READ COMMITTED`, but you can change it as mentioned above.

In the SQL standard, there is one other transaction characteristic that can be set with these commands: the size of the diagnostics area. This concept is specific to embedded SQL, and therefore is not implemented in the LightDB server.

The SQL standard requires commas between successive *transaction\_modes*, but for historical reasons LightDB allows the commas to be omitted.

---

# SHOW

SHOW — show the value of a run-time parameter

## Synopsis

```
SHOW name
SHOW ALL
SHOW name%
SHOW %name
SHOW %name%
```

## Description

SHOW will display the current setting of run-time parameters. These variables can be set using the SET statement, by editing the `lightdb.conf` configuration file, through the `LTOPTIONS` environmental variable (when using libpq or a libpq-based application), or through command-line flags when starting the `lightdb` server. See Chapter 17 for details.

## Parameters

*name*

The name of a run-time parameter. Available parameters are documented in Chapter 17 and on the SET reference page. In addition, there are a few parameters that can be shown but not set:

SERVER\_VERSION

Shows the server's version number.

LIGHTDB\_SERVER\_VERSION

Shows the LightDB server's version number.

LIGHTDB\_SERVER\_VERSION\_NUM

Shows the LightDB server's version number, value is `major_version * 10000 + minor_version * 100`.

SERVER\_ENCODING

Shows the server-side character set encoding. At present, this parameter can be shown but not set, because the encoding is determined at database creation time.

LC\_COLLATE

Shows the database's locale setting for collation (text ordering). At present, this parameter can be shown but not set, because the setting is determined at database creation time.

LC\_CTYPE

Shows the database's locale setting for character classification. At present, this parameter can be shown but not set, because the setting is determined at database creation time.

IS\_SUPERUSER

True if the current role has superuser privileges.

ALL

Show the values of all configuration parameters, with descriptions.

name%

Show the values of all configuration parameters beginning with name, with descriptions.

%name

Show the values of all configuration parameters ending with name, with descriptions.

%name%

Show the values of all configuration parameters including with name, with descriptions.

## Notes

The function `current_setting` produces equivalent output; see Section 9.27.1. Also, the `pg_settings` system view produces the same information.

## Examples

Show the current setting of the parameter `DateStyle`:

```
SHOW DateStyle;
DateStyle
-----
ISO, MDY
(1 row)
```

Show the current setting of the parameter `geqo`:

```
SHOW geqo;
geqo
-----
on
(1 row)
```

Show `lightdb` server version:

```
SHOW lightdb_server_version;
lightdb_server_version
-----
13.8-23.4
(1 row)
```

Show `lightdb` server version number:

```
SHOW lightdb_server_version_num;
lightdb_server_version_num
-----
220400
(1 row)
```

Show all settings:

---

SHOW

---

SHOW ALL;

name	setting	description
allow_system_table_mods	off	Allows modifications of the structure of ...
.	.	.
xmloption	content	Sets whether XML data in implicit parsing ...
zero_damaged_pages	off	Continues processing past damaged page headers.

(196 rows)

Show all settings beginning with the parameter WAL%:

SHOW WAL%;

name	setting	description
wal_block_size	8192	Shows the block size in the write ahead log.
.	.	.
wal_writer_flush_after	1MB	Amount of WAL written out by WAL writer that triggers a flush.

(19 rows)

Show all settings ending with the parameter %LEVEL:

SHOW %LEVEL;

name	setting	description
auto_explain.log_level	log	Log level for the plan.
.	.	.
wal_level	replica	Set the level of information written to the WAL.

(7 rows)

Show all settings including with the parameter %\_FREEZE\_:

SHOW %\_FREEZE\_;

name	setting	description
------	---------	-------------

---

## SHOW

---

```
autovacuum_freeze_max_age          | 200000000 | Age at which to
autovacuum a table to prevent transaction ID wraparound.
.
.
.
vacuum_multixact_freeze_table_age   | 150000000 | Multixact age at
which VACUUM should scan whole table to freeze tuples.
(6 rows)
```

## Compatibility

The SHOW command is a LightDB extension.

## See Also

SET, RESET

---

# START TRANSACTION

START TRANSACTION — start a transaction block

## Synopsis

```
START TRANSACTION [ transaction_mode [, ...] ]
```

where *transaction\_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ  
COMMITTED | READ UNCOMMITTED }  
READ WRITE | READ ONLY  
[ NOT ] DEFERRABLE
```

## Description

This command begins a new transaction block. If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed. This is the same as the BEGIN command.

## Parameters

Refer to SET TRANSACTION for information on the meaning of the parameters to this statement.

## Compatibility

In the standard, it is not necessary to issue START TRANSACTION to start a transaction block: any SQL command implicitly begins a block. LightDB's behavior can be seen as implicitly issuing a COMMIT after each command that does not follow START TRANSACTION (or BEGIN), and it is therefore often called “autocommit”. Other relational database systems might offer an autocommit feature as a convenience.

The DEFERRABLE *transaction\_mode* is a LightDB language extension.

The SQL standard requires commas between successive *transaction\_modes*, but for historical reasons LightDB allows the commas to be omitted.

See also the compatibility section of SET TRANSACTION.

## See Also

BEGIN, COMMIT, ROLLBACK, SAVEPOINT, SET TRANSACTION



---

# TRUNCATE

TRUNCATE — empty a table or set of tables

## Synopsis

```
TRUNCATE [ TABLE ] [ ONLY ] name [ * ] [ , ... ]  
        [ RESTART IDENTITY | CONTINUE IDENTITY ] [ CASCADE | RESTRICT ]
```

## Description

TRUNCATE quickly removes all rows from a set of tables. It has the same effect as an unqualified DELETE on each table, but since it does not actually scan the tables it is faster. Furthermore, it reclaims disk space immediately, rather than requiring a subsequent VACUUM operation. This is most useful on large tables.

## Parameters

*name*

The name (optionally schema-qualified) of a table to truncate. If ONLY is specified before the table name, only that table is truncated. If ONLY is not specified, the table and all its descendant tables (if any) are truncated. Optionally, \* can be specified after the table name to explicitly indicate that descendant tables are included.

RESTART IDENTITY

Automatically restart sequences owned by columns of the truncated table(s).

CONTINUE IDENTITY

Do not change the values of sequences. This is the default.

CASCADE

Automatically truncate all tables that have foreign-key references to any of the named tables, or to any tables added to the group due to CASCADE.

RESTRICT

Refuse to truncate if any of the tables have foreign-key references from tables that are not listed in the command. This is the default.

## Notes

You must have the TRUNCATE privilege on a table to truncate it.

TRUNCATE acquires an ACCESS EXCLUSIVE lock on each table it operates on, which blocks all other concurrent operations on the table. When RESTART IDENTITY is specified, any sequences that are to be restarted are likewise locked exclusively. If concurrent access to a table is required, then the DELETE command should be used instead.

TRUNCATE cannot be used on a table that has foreign-key references from other tables, unless all such tables are also truncated in the same command. Checking validity in such cases would require table scans, and the whole point is not to do one. The CASCADE option can be used to automatically include

all dependent tables — but be very careful when using this option, or else you might lose data you did not intend to! Note in particular that when the table to be truncated is a partition, siblings partitions are left untouched, but cascading occurs to all referencing tables and all their partitions with no distinction.

TRUNCATE will not fire any ON DELETE triggers that might exist for the tables. But it will fire ON TRUNCATE triggers. If ON TRUNCATE triggers are defined for any of the tables, then all BEFORE TRUNCATE triggers are fired before any truncation happens, and all AFTER TRUNCATE triggers are fired after the last truncation is performed and any sequences are reset. The triggers will fire in the order that the tables are to be processed (first those listed in the command, and then any that were added due to cascading).

TRUNCATE is not MVCC-safe. After truncation, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the truncation occurred. See Section 13.5 for more details.

TRUNCATE is transaction-safe with respect to the data in the tables: the truncation will be safely rolled back if the surrounding transaction does not commit.

When RESTART IDENTITY is specified, the implied ALTER SEQUENCE RESTART operations are also done transactionally; that is, they will be rolled back if the surrounding transaction does not commit. Be aware that if any additional sequence operations are done on the restarted sequences before the transaction rolls back, the effects of these operations on the sequences will be rolled back, but not their effects on `currval()`; that is, after the transaction `currval()` will continue to reflect the last sequence value obtained inside the failed transaction, even though the sequence itself may no longer be consistent with that. This is similar to the usual behavior of `currval()` after a failed transaction.

TRUNCATE is not currently supported for foreign tables. This implies that if a specified table has any descendant tables that are foreign, the command will fail.

## Examples

Truncate the tables `bigtable` and `fattable`:

```
TRUNCATE bigtable, fattable;
```

The same, and also reset any associated sequence generators:

```
TRUNCATE bigtable, fattable RESTART IDENTITY;
```

Truncate the table `othertable`, and cascade to any tables that reference `othertable` via foreign-key constraints:

```
TRUNCATE othertable CASCADE;
```

## Compatibility

The SQL:2008 standard includes a TRUNCATE command with the syntax `TRUNCATE TABLE tablename`. The clauses `CONTINUE IDENTITY/RESTART IDENTITY` also appear in that standard, but have slightly different though related meanings. Some of the concurrency behavior of this command is left implementation-defined by the standard, so the above notes should be considered and compared with other implementations if necessary.

## See Also

DELETE

---

# UNLISTEN

UNLISTEN — stop listening for a notification

## Synopsis

```
UNLISTEN { channel | * }
```

## Description

UNLISTEN is used to remove an existing registration for NOTIFY events. UNLISTEN cancels any existing registration of the current LightDB session as a listener on the notification channel named *channel*. The special wildcard \* cancels all listener registrations for the current session.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

## Parameters

*channel*

Name of a notification channel (any identifier).

\*

All current listen registrations for this session are cleared.

## Notes

You can unlisten something you were not listening for; no warning or error will appear.

At the end of each session, UNLISTEN \* is automatically executed.

A transaction that has executed UNLISTEN cannot be prepared for two-phase commit.

## Examples

To make a registration:

```
LISTEN virtual;  
NOTIFY virtual;  
Asynchronous notification "virtual" received from server process  
with PID 8448.
```

Once UNLISTEN has been executed, further NOTIFY messages will be ignored:

```
UNLISTEN virtual;  
NOTIFY virtual;  
-- no NOTIFY event is received
```

## Compatibility

There is no UNLISTEN command in the SQL standard.

## See Also

LISTEN, NOTIFY

---

# UPDATE

UPDATE — update rows of a table

## Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
UPDATE [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    SET { column_name = { expression | DEFAULT } |
        ( column_name [, ...] ) = [ ROW ] ( { expression |
DEFAULT } [, ...] ) |
        ( column_name [, ...] ) = ( sub-SELECT )
    } [, ...]
    [ FROM from_item [, ...] ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
{ FIRST | LAST } ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ {RETURNING|RETURN} * | output_expression [ [ AS ] output_name
] [, ...] ]
```

## Description

UPDATE changes the values of the specified columns in all rows that satisfy the condition. Only the columns to be modified need be mentioned in the SET clause; columns not explicitly modified retain their previous values.

There are two ways to modify a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the FROM clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes UPDATE to compute and return value(s) based on each row actually updated. Any expression using the table's columns, and/or columns of other tables mentioned in FROM, can be computed. The new (post-update) values of the table's columns are used. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the UPDATE privilege on the table, or at least on the column(s) that are listed to be updated. You must also have the SELECT privilege on any column whose values are read in the *expressions* or *condition*.

If the ORDER BY clause is specified, you can update rows in the specified order. It's semantic like SELECT ORDER BY clause. Notice, do not support update inherit table with ORDER BY clause, not support canopy also.

If the LIMIT or OFFSET clause is specified, you can update a subset of rows. It's semantic like SELECT LIMIT clause. Notice, do not support update inherit table with LIMIT or OFFSET clause, not support canopy also.

## Parameters

*with\_query*

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the UPDATE query. See Section 7.8 and SELECT for details.

*table\_name*

The name (optionally schema-qualified) of the table to update. If `ONLY` is specified before the table name, matching rows are updated in the named table only. If `ONLY` is not specified, matching rows are also updated in any tables inheriting from the named table. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

*alias*

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `UPDATE foo AS f`, the remainder of the `UPDATE` statement must refer to this table as `f` not `foo`.

*column\_name*

The name of a column in the table named by *table\_name*. The column name can be qualified with a subfield name or array subscript, if needed. It can also use alias to qualify name. For example, `UPDATE table_name AS t SET t.col = 1`. Do not include the table's name in the specification of a target column — for example, `UPDATE table_name SET table_name.col = 1` is invalid.

*expression*

An expression to assign to the column. The expression can use the old values of this and other columns in the table.

## DEFAULT

Set the column to its default value (which will be `NULL` if no specific default expression has been assigned to it). If the expression references other columns, `DEFAULT` is not allowed. An identity column will be set to a new value generated by the associated sequence. For a generated column, specifying this is permitted but merely specifies the normal behavior of computing the column from its generation expression.

*sub-SELECT*

A `SELECT` sub-query that produces as many output columns as are listed in the parenthesized column list preceding it. The sub-query must yield no more than one row when executed. If it yields one row, its column values are assigned to the target columns; if it yields no rows, `NULL` values are assigned to the target columns. The sub-query can refer to old values of the current row of the table being updated.

*from\_item*

A table expression allowing columns from other tables to appear in the `WHERE` condition and update expressions. This uses the same syntax as the `FROM` clause of a `SELECT` statement; for example, an alias for the table name can be specified. Do not repeat the target table as a *from\_item* unless you intend a self-join (in which case it must appear with an alias in the *from\_item*).

*condition*

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated.

*cursor\_name*

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be updated is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `UPDATE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with

a Boolean condition. See DECLARE for more information about using cursors with WHERE CURRENT OF.

*output\_expression*

An expression to be computed and returned by the UPDATE command after each row is updated. The expression can use any column names of the table named by *table\_name* or table(s) listed in FROM. Write \* to return all columns.

*output\_name*

A name to use for a returned column.

## Outputs

On successful completion, an UPDATE command returns a command tag of the form

UPDATE *count*

The *count* is the number of rows updated, including matched rows whose values did not change. Note that the number may be less than the number of rows that matched the *condition* when updates were suppressed by a BEFORE UPDATE trigger. If *count* is 0, no rows were updated by the query (this is not considered an error).

If the UPDATE command contains a RETURNING clause, the result will be similar to that of a SELECT statement containing the columns and values defined in the RETURNING list, computed over the row(s) updated by the command.

## Notes

When a FROM clause is present, what essentially happens is that the target table is joined to the tables mentioned in the *from\_item* list, and each output row of the join represents an update operation for the target table. When using FROM you should ensure that the join produces at most one output row for each row to be modified. In other words, a target row shouldn't join to more than one row from the other table(s). If it does, then only one of the join rows will be used to update the target row, but which one will be used is not readily predictable.

Because of this indeterminacy, referencing other tables only within sub-selects is safer, though often harder to read and slower than using a join.

In the case of a partitioned table, updating a row might cause it to no longer satisfy the partition constraint of the containing partition. In that case, if there is some other partition in the partition tree for which this row satisfies its partition constraint, then the row is moved to that partition. If there is no such partition, an error will occur. Behind the scenes, the row movement is actually a DELETE and INSERT operation.

There is a possibility that a concurrent UPDATE or DELETE on the row being moved will get a serialization failure error. Suppose session 1 is performing an UPDATE on a partition key, and meanwhile a concurrent session 2 for which this row is visible performs an UPDATE or DELETE operation on this row. In such case, session 2's UPDATE or DELETE will detect the row movement and raise a serialization failure error (which always returns with an SQLSTATE code '40001'). Applications may wish to retry the transaction if this occurs. In the usual case where the table is not partitioned, or where there is no row movement, session 2 would have identified the newly updated row and carried out the UPDATE/DELETE on this new row version.

Note that while rows can be moved from local partitions to a foreign-table partition (provided the foreign data wrapper supports tuple routing), they cannot be moved from a foreign-table partition to another partition.

## Examples

Change the word Drama to Dramatic in the column kind of the table films:

```
UPDATE films SET kind = 'Dramatic' WHERE kind = 'Drama';
```

Adjust temperature entries and reset precipitation to its default value in one row of the table weather:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp
= DEFAULT
WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Perform the same operation and return the updated entries:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp
= DEFAULT
WHERE city = 'San Francisco' AND date = '2003-07-03'
RETURNING temp_lo, temp_hi, prcp;
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp
= DEFAULT
WHERE city = 'San Francisco' AND date = '2003-07-03'
RETURN temp_lo, temp_hi, prcp;
```

Use the alternative column-list syntax to do the same update:

```
UPDATE weather SET (temp_lo, temp_hi, prcp) = (temp_lo+1, temp_lo
+15, DEFAULT)
WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, using the FROM clause syntax:

```
UPDATE employees SET sales_count = sales_count + 1 FROM accounts
WHERE accounts.name = 'Acme Corporation'
AND employees.id = accounts.sales_person;
```

Perform the same operation, using a sub-select in the WHERE clause:

```
UPDATE employees SET sales_count = sales_count + 1 WHERE id =
(SELECT sales_person FROM accounts WHERE name = 'Acme
Corporation');
```

Update contact names in an accounts table to match the currently assigned salesmen:

```
UPDATE accounts SET (contact_first_name, contact_last_name) =
(SELECT first_name, last_name FROM salesmen
WHERE salesmen.id = accounts.sales_id);
```

A similar result could be accomplished with a join:

```
UPDATE accounts SET contact_first_name = first_name,
contact_last_name = last_name
```



```
FROM salesmen WHERE salesmen.id = accounts.sales_id;
```

However, the second query may give unexpected results if `salesmen.id` is not a unique key, whereas the first query is guaranteed to raise an error if there are multiple `id` matches. Also, if there is no match for a particular `accounts.sales_id` entry, the first query will set the corresponding name fields to `NULL`, whereas the second query will not update that row at all.

Update statistics in a summary table to match the current data:

```
UPDATE summary s SET (sum_x, sum_y, avg_x, avg_y) =
    (SELECT sum(x), sum(y), avg(x), avg(y) FROM data d
     WHERE d.group_id = s.group_id);
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. To do this without failing the entire transaction, use savepoints:

```
BEGIN;
-- other operations
SAVEPOINT sp1;
INSERT INTO wines VALUES('Chateau Lafite 2003', '24');
-- Assume the above fails because of a unique key violation,
-- so now we issue these commands:
ROLLBACK TO sp1;
UPDATE wines SET stock = stock + 24 WHERE winename = 'Chateau
Lafite 2003';
-- continue with other operations, and eventually
COMMIT;
```

Change the kind column of the table `films` in the row on which the cursor `c_films` is currently positioned:

```
UPDATE films SET kind = 'Dramatic' WHERE CURRENT OF c_films;
```

Change the name column of table `citys` order by `id` limit 5 .

```
UPDATE citys SET name = 'null' order by id LIMIT 5;
```

## Compatibility

This command conforms to the SQL standard, except that the `FROM` and `RETURNING` clauses are LightDB extensions, as is the ability to use `WITH` with `UPDATE`.

Some other database systems offer a `FROM` option in which the target table is supposed to be listed again within `FROM`. That is not how LightDB interprets `FROM`. Be careful when porting applications that use this extension.

According to the standard, the source value for a parenthesized sub-list of target column names can be any row-valued expression yielding the correct number of columns. LightDB only allows the source value to be a row constructor or a sub-`SELECT`. An individual column's updated value can be specified as `DEFAULT` in the row-constructor case, but not inside a sub-`SELECT`.

In Oracle compatible mode, a column update on a partitioned table would result in rows be moved from the original partition to the target partition if the column is included in partition key.

---

# VACUUM

VACUUM — garbage-collect and optionally analyze a database

## Synopsis

```
VACUUM [ ( option [, ...] ) ] [ table_and_columns [, ...] ]  
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] [ ANALYZE ]  
    [ table_and_columns [, ...] ]
```

where *option* can be one of:

```
FULL [ boolean ]  
FREEZE [ boolean ]  
VERBOSE [ boolean ]  
ANALYZE [ boolean ]  
DISABLE_PAGE_SKIPPING [ boolean ]  
SKIP_LOCKED [ boolean ]  
INDEX_CLEANUP [ boolean ]  
TRUNCATE [ boolean ]  
PARALLEL integer
```

and *table\_and\_columns* is:

```
table_name [ ( column_name [, ...] ) ]
```

## Description

VACUUM reclaims storage occupied by dead tuples. In normal LightDB operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present until a VACUUM is done. Therefore it's necessary to do VACUUM periodically, especially on frequently-updated tables.

Without a *table\_and\_columns* list, VACUUM processes every table and materialized view in the current database that the current user has permission to vacuum. With a list, VACUUM processes only those table(s).

VACUUM ANALYZE performs a VACUUM and then an ANALYZE for each selected table. This is a handy combination form for routine maintenance scripts. See ANALYZE for more details about its processing.

Plain VACUUM (without FULL) simply reclaims space and makes it available for re-use. This form of the command can operate in parallel with normal reading and writing of the table, as an exclusive lock is not obtained. However, extra space is not returned to the operating system (in most cases); it's just kept available for re-use within the same table. It also allows us to leverage multiple CPUs in order to process indexes. This feature is known as *parallel vacuum*. To disable this feature, one can use PARALLEL option and specify parallel workers as zero. VACUUM FULL rewrites the entire contents of the table into a new disk file with no extra space, allowing unused space to be returned to the operating system. This form is much slower and requires an ACCESS EXCLUSIVE lock on each table while it is being processed.

When the option list is surrounded by parentheses, the options can be written in any order. Without parentheses, options must be specified in exactly the order shown above. The parenthesized syntax was added in LightDB 9.0; the unparenthesized syntax is deprecated.

## Parameters

### FULL

Selects “full” vacuum, which can reclaim more space, but takes much longer and exclusively locks the table. This method also requires extra disk space, since it writes a new copy of the table and doesn't release the old copy until the operation is complete. Usually this should only be used when a significant amount of space needs to be reclaimed from within the table.

### FREEZE

Selects aggressive “freezing” of tuples. Specifying `FREEZE` is equivalent to performing `VACUUM` with the `vacuum_freeze_min_age` and `vacuum_freeze_table_age` parameters set to zero. Aggressive freezing is always performed when the table is rewritten, so this option is redundant when `FULL` is specified.

### VERBOSE

Prints a detailed vacuum activity report for each table.

### ANALYZE

Updates statistics used by the planner to determine the most efficient way to execute a query.

### DISABLE\_PAGE\_SKIPPING

Normally, `VACUUM` will skip pages based on the visibility map. Pages where all tuples are known to be frozen can always be skipped, and those where all tuples are known to be visible to all transactions may be skipped except when performing an aggressive vacuum. Furthermore, except when performing an aggressive vacuum, some pages may be skipped in order to avoid waiting for other sessions to finish using them. This option disables all page-skipping behavior, and is intended to be used only when the contents of the visibility map are suspect, which should happen only if there is a hardware or software issue causing database corruption.

### SKIP\_LOCKED

Specifies that `VACUUM` should not wait for any conflicting locks to be released when beginning work on a relation: if a relation cannot be locked immediately without waiting, the relation is skipped. Note that even with this option, `VACUUM` may still block when opening the relation's indexes. Additionally, `VACUUM ANALYZE` may still block when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while `VACUUM` ordinarily processes all partitions of specified partitioned tables, this option will cause `VACUUM` to skip all partitions if there is a conflicting lock on the partitioned table.

### INDEX\_CLEANUP

Specifies that `VACUUM` should attempt to remove index entries pointing to dead tuples. This is normally the desired behavior and is the default unless the `vacuum_index_cleanup` option has been set to false for the table to be vacuumed. Setting this option to false may be useful when it is necessary to make vacuum run as quickly as possible, for example to avoid imminent transaction ID wraparound (see Section 22.1.5). However, if index cleanup is not performed regularly, performance may suffer, because as the table is modified, indexes will accumulate dead tuples and the table itself will accumulate dead line pointers that cannot be removed until index cleanup is completed. This option has no effect for tables that do not have an index and is ignored if the `FULL` option is used.

### TRUNCATE

Specifies that `VACUUM` should attempt to truncate off any empty pages at the end of the table and allow the disk space for the truncated pages to be returned to the operating system. This

is normally the desired behavior and is the default unless the `vacuum_truncate` option has been set to `false` for the table to be vacuumed. Setting this option to `false` may be useful to avoid `ACCESS EXCLUSIVE` lock on the table that the truncation requires. This option is ignored if the `FULL` option is used.

#### PARALLEL

Perform index vacuum and index cleanup phases of `VACUUM` in parallel using *integer* background workers (for the details of each vacuum phase, please refer to Table 25.37). The number of workers used to perform the operation is equal to the number of indexes on the relation that support parallel vacuum which is limited by the number of workers specified with `PARALLEL` option if any which is further limited by `max_parallel_maintenance_workers`. An index can participate in parallel vacuum if and only if the size of the index is more than `min_parallel_index_scan_size`. Please note that it is not guaranteed that the number of parallel workers specified in *integer* will be used during execution. It is possible for a vacuum to run with fewer workers than specified, or even with no workers at all. Only one worker can be used per index. So parallel workers are launched only when there are at least 2 indexes in the table. Workers for vacuum are launched before the start of each phase and exit at the end of the phase. These behaviors might change in a future release. This option can't be used with the `FULL` option.

#### *boolean*

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

#### *integer*

Specifies a non-negative integer value passed to the selected option.

#### *table\_name*

The name (optionally schema-qualified) of a specific table or materialized view to vacuum. If the specified table is a partitioned table, all of its leaf partitions are vacuumed.

#### *column\_name*

The name of a specific column to analyze. Defaults to all columns. If a column list is specified, `ANALYZE` must also be specified.

## Outputs

When `VERBOSE` is specified, `VACUUM` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

## Notes

To vacuum a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to vacuum all tables in their databases, except shared catalogs. (The restriction for shared catalogs means that a true database-wide `VACUUM` can only be performed by a superuser.) `VACUUM` will skip over any tables that the calling user does not have permission to vacuum.

`VACUUM` cannot be executed inside a transaction block.

For tables with GIN indexes, `VACUUM` (in any form) also completes any pending index insertions, by moving pending index entries to the appropriate places in the main GIN index structure. See Section 62.4.1 for details.

We recommend that active production databases be vacuumed frequently (at least nightly), in order to remove dead rows. After adding or deleting a large number of rows, it might be a good idea to

issue a `VACUUM ANALYZE` command for the affected table. This will update the system catalogs with the results of all recent changes, and allow the LightDB query planner to make better choices in planning queries.

The `FULL` option is not recommended for routine use, but might be useful in special cases. An example is when you have deleted or updated most of the rows in a table and would like the table to physically shrink to occupy less disk space and allow faster table scans. `VACUUM FULL` will usually shrink the table more than a plain `VACUUM` would.

The `PARALLEL` option is used only for vacuum purposes. If this option is specified with the `ANALYZE` option, it does not affect `ANALYZE`.

`VACUUM` causes a substantial increase in I/O traffic, which might cause poor performance for other active sessions. Therefore, it is sometimes advisable to use the cost-based vacuum delay feature. For parallel vacuum, each worker sleeps in proportion to the work done by that worker. See Section 17.4.4 for details.

LightDB includes an “autovacuum” facility which can automate routine vacuum maintenance. For more information about automatic and manual vacuuming, see Section 22.1.

## Examples

To clean a single table `onek`, analyze it for the optimizer and print a detailed vacuum activity report:

```
VACUUM (VERBOSE, ANALYZE) onek;
```

## Compatibility

There is no `VACUUM` statement in the SQL standard.

## See Also

`vacuumdb`, Section 17.4.4, Section 22.1.6

---

# VALUES

VALUES — compute a set of rows

## Synopsis

```
VALUES ( expression [, ...] ) [, ...]  
  [ ORDER BY sort_expression [ ASC | DESC | USING operator ]  
  [, ...] ]  
  [ LIMIT { count | ALL } ]  
  [ OFFSET start [ ROW | ROWS ] ]  
  [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
```

## Description

VALUES computes a row value or set of row values specified by value expressions. It is most commonly used to generate a “constant table” within a larger command, but it can be used on its own.

When more than one row is specified, all the rows must have the same number of elements. The data types of the resulting table's columns are determined by combining the explicit or inferred types of the expressions appearing in that column, using the same rules as for UNION (see Section 10.5).

Within larger commands, VALUES is syntactically allowed anywhere that SELECT is. Because it is treated like a SELECT by the grammar, it is possible to use the ORDER BY, LIMIT (or equivalently FETCH FIRST), and OFFSET clauses with a VALUES command.

## Parameters

*expression*

A constant or expression to compute and insert at the indicated place in the resulting table (set of rows). In a VALUES list appearing at the top level of an INSERT, an *expression* can be replaced by DEFAULT to indicate that the destination column's default value should be inserted. DEFAULT cannot be used when VALUES appears in other contexts.

*sort\_expression*

An expression or integer constant indicating how to sort the result rows. This expression can refer to the columns of the VALUES result as *column1*, *column2*, etc. For more details see ORDER BY Clause in the SELECT documentation.

*operator*

A sorting operator. For details see ORDER BY Clause in the SELECT documentation.

*count*

The maximum number of rows to return. For details see LIMIT Clause in the SELECT documentation.

*start*

The number of rows to skip before starting to return rows. For details see LIMIT Clause in the SELECT documentation.

## Notes

VALUES lists with very large numbers of rows should be avoided, as you might encounter out-of-memory failures or poor performance. VALUES appearing within INSERT is a special case (because the desired column types are known from the INSERT's target table, and need not be inferred by scanning the VALUES list), so it can handle larger lists than are practical in other contexts.

## Examples

A bare VALUES command:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

This will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

More usually, VALUES is used within a larger SQL command. The most common use is in INSERT:

```
INSERT INTO films (code, title, did, date_prod, kind)
VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

In the context of INSERT, entries of a VALUES list can be DEFAULT to indicate that the column default should be used here instead of specifying a value:

```
INSERT INTO films VALUES
('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes'),
('T_601', 'Yojimbo', 106, DEFAULT, 'Drama', DEFAULT);
```

VALUES can also be used where a sub-SELECT might be written, for example in a FROM clause:

```
SELECT f.*
FROM films f, (VALUES('MGM', 'Horror'), ('UA', 'Sci-Fi')) AS t
(studio, kind)
WHERE f.studio = t.studio AND f.kind = t.kind;
```

```
UPDATE employees SET salary = salary * v.increase
FROM (VALUES(1, 200000, 1.2), (2, 400000, 1.4)) AS v (depno,
target, increase)
WHERE employees.depno = v.depno AND employees.sales >= v.target;
```

Note that an AS clause is required when VALUES is used in a FROM clause, just as is true for SELECT. It is not required that the AS clause specify names for all the columns, but it's good practice to do so. (The default column names for VALUES are column1, column2, etc in LightDB, but these names might be different in other database systems.)

When VALUES is used in INSERT, the values are all automatically coerced to the data type of the corresponding destination column. When it's used in other contexts, it might be necessary to specify the correct data type. If the entries are all quoted literal constants, coercing the first is sufficient to determine the assumed type for all:

```
SELECT * FROM machines
WHERE ip_address IN (VALUES('192.168.0.1'::inet), ('192.168.0.10'),
('192.168.1.43'));
```

**Tip**

For simple IN tests, it's better to rely on the list-of-scalars form of IN than to write a VALUES query as shown above. The list of scalars method requires less writing and is often more efficient.

## Compatibility

VALUES conforms to the SQL standard. LIMIT and OFFSET are LightDB extensions; see also under SELECT.

## See Also

INSERT, SELECT



---

# LightDB Client Applications

This part contains reference information for LightDB client applications and utilities. Not all of these commands are of general utility; some might require special privileges. The common feature of these applications is that they can be run on any host, independent of where the database server resides.

When specified on the command line, user and database names have their case preserved — the presence of spaces or special characters might require quoting. Table names and other identifiers do not have their case preserved, except where documented, and might require quoting.

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---

# clusterdb

clusterdb — cluster a LightDB database

## Synopsis

```
clusterdb [connection-option...] [ --verbose | -v ] [ --table | -t table ] ...  
[dbname]
```

```
clusterdb [connection-option...] [ --verbose | -v ] --all | -a
```

## Description

clusterdb is a utility for reclustering tables in a LightDB database. It finds tables that have previously been clustered, and clusters them again on the same index that was last used. Tables that have never been clustered are not affected.

clusterdb is a wrapper around the SQL command CLUSTER. There is no effective difference between clustering databases via this utility and via other methods for accessing the server.

## Options

clusterdb accepts the following command-line arguments:

-a  
--all

Cluster all databases.

[-d] *dbname*  
[--dbname=] *dbname*

Specifies the name of the database to be clustered, when -a/--all is not used. If this is not specified, the database name is read from the environment variable LTDATABASE. If that is not set, the user name specified for the connection is used. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options.

-e  
--echo

Echo the commands that clusterdb generates and sends to the server.

-q  
--quiet

Do not display progress messages.

-t *table*  
--table=*table*

Cluster *table* only. Multiple tables can be clustered by writing multiple -t switches.

-v  
--verbose

Print detailed information during processing.

`-V`  
`--version`

Print the clusterdb version and exit.

`-?`  
`--help`

Show help about clusterdb command line arguments, and exit.

clusterdb also accepts the following command-line arguments for connection parameters:

`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force clusterdb to prompt for a password before connecting to a database.

This option is never essential, since clusterdb will automatically prompt for a password if the server demands password authentication. However, clusterdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to to discover which databases should be clustered, when `-a/--all` is used. If not specified, the `postgres` database will be used, or if that does not exist, `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options. Also, connection string parameters other than the database name itself will be re-used when connecting to other databases.

## Environment

LTDATABASE  
LTHOST  
LTPORT  
LTUSER

Default connection parameters

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see `CLUSTER` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

## Examples

To cluster the database `test`:

```
$ clusterdb test
```

To cluster a single table `foo` in a database named `xyzyz`:

```
$ clusterdb --table=foo xyzyz
```

## See Also

`CLUSTER`

---

# createdb

createdb — create a new LightDB database

## Synopsis

```
createdb [connection-option...] [option...] [dbname [description]]
```

## Description

createdb creates a new LightDB database.

Normally, the database user who executes this command becomes the owner of the new database. However, a different owner can be specified via the `-O` option, if the executing user has appropriate privileges.

createdb is a wrapper around the SQL command CREATE DATABASE. There is no effective difference between creating databases via this utility and via other methods for accessing the server.

## Options

createdb accepts the following command-line arguments:

*dbname*

Specifies the name of the database to be created. The name must be unique among all LightDB databases in this cluster. The default is to create a database with the same name as the current system user.

*description*

Specifies a comment to be associated with the newly created database.

`-D tablespace`

`--tablespace=tablespace`

Specifies the default tablespace for the database. (This name is processed as a double-quoted identifier.)

`-e`

`--echo`

Echo the commands that createdb generates and sends to the server.

`-E encoding`

`--encoding=encoding`

Specifies the character encoding scheme to be used in this database. The character sets supported by the LightDB server are described in Section 21.3.1.

`-l locale`

`--locale=locale`

Specifies the locale to be used in this database. This is equivalent to specifying both `--lc-collate` and `--lc-ctype`.

`--lc-collate=locale`

Specifies the LC\_COLLATE setting to be used in this database.

`--lc-ctype=locale`

Specifies the LC\_CTYPE setting to be used in this database.

`-O owner`

`--owner=owner`

Specifies the database user who will own the new database. (This name is processed as a double-quoted identifier.)

`-T template`

`--template=template`

Specifies the template database from which to build this database. (This name is processed as a double-quoted identifier.)

`-V`

`--version`

Print the createdb version and exit.

`-?`

`--help`

Show help about createdb command line arguments, and exit.

The options `-D`, `-l`, `-E`, `-O`, and `-T` correspond to options of the underlying SQL command `CREATE DATABASE`; see there for more information about them.

createdb also accepts the following command-line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`

`--port=port`

Specifies the TCP port or the local Unix domain socket file extension on which the server is listening for connections.

`-U username`

`--username=username`

User name to connect as.

`-w`

`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

`--password`

Force createdb to prompt for a password before connecting to a database.

This option is never essential, since createdb will automatically prompt for a password if the server demands password authentication. However, createdb will waste a connection attempt finding out

that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to when creating the new database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the new database being created), `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options.

`--mysql-lower-case=value`

In MySQL compatibility mode, whether to enable the all-lowercase feature of table names. The value is one of (1, true, on, 0, false, off), the default value is 1. (1,true,on): enable (0,false,off): disable

`--compatible-type=type`

Database compatible type is a database level GUC parameter, used to identify the compatible type of the database.

For more information about database compatible type, please refer to GUC `lightdb_syntax_compatible_type`, See `lightdb_syntax_compatible_type`

`--ascii-zero-store-value=value`

`lightdb_ascii_zero_store_value` is a new GUC parameter of LightDB since release 23.3, the value is used to replace ASCII zero character in text if the compatible mode is set to Oracle or Mysql.

For more information about this feature, please refer to GUC `lightdb_ascii_zero_store_value`, See `lightdb_ascii_zero_store_value`

## Environment

`LTDATABASE`

If set, the name of the database to create, unless overridden on the command line.

`LTHOST`

`LTPORT`

`LTUSER`

Default connection parameters. `LTUSER` also determines the name of the database to create, if it is not specified on the command line or by `LTDATABASE`.

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

## Diagnostics

In case of difficulty, see `CREATE DATABASE` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

## Examples

To create the database demo using the default database server:

```
$ createdb demo
```

To create the database demo using the server on host eden, port 5000, using the template0 template database, here is the command-line command and the underlying SQL command:

```
$ createdb -p 5000 -h eden -T template0 -e demo  
CREATE DATABASE demo TEMPLATE template0;
```

## See Also

dropdb, CREATE DATABASE



---

# lt\_createdb

lt\_createdb — creates a new LightDB database.

## Synopsis

```
lt_createdb [connection-option...] [option...] [dbname [description]]
```

## Description

lt\_createdb is a tool to create a LightDB database.

lt\_createdb is a wrapper for the createdb command. It is equivalent to creating a database using the createdb command directly. However, in a distributed environment (Canopy), it automatically creates the database on all nodes, and these databases together form a distributed cluster.

Note: Canopy is related to databases. This tool only checks the deployment status of Canopy in the LightDB database, retrieves the list of Canopy nodes from the LightDB database, and then creates a database with the same name on each node.

## Options

lt\_createdb accepts the following command-line arguments:

*dbname*

Specifies the name of the database to be created. The name must be unique among all LightDB databases in this cluster. The default is to create a database with the same name as the current system user.

`-D tablespace`

`--tablespace=tablespace`

Specifies the default tablespace for the database. (This name is processed as a double-quoted identifier.)

`-e`

`--echo`

Echo the commands that lt\_createdb generates and sends to the server.

`-E encoding`

`--encoding=encoding`

Specifies the character encoding scheme to be used in this database. The character sets supported by the LightDB server are described in Section 21.3.1.

`-l locale`

`--locale=locale`

Specifies the locale to be used in this database. This is equivalent to specifying both `--lc-collate` and `--lc-ctype`.

`--lc-collate=locale`

Specifies the LC\_COLLATE setting to be used in this database.

`--lc-ctype=locale`

Specifies the LC\_CTYPE setting to be used in this database.

-O *owner*  
 --owner=*owner*

Specifies the database user who will own the new database. (This name is processed as a double-quoted identifier.)

-T *template*  
 --template=*template*

Specifies the template database from which to build this database. (This name is processed as a double-quoted identifier.)

--compatible-type=*compatible-type*

compatible type. TYPE=off: not compatible with other database features. off, mysql and oracle can be set.

--mysql-lower-case=*mysql-lower-case*

Whether to enable the all-lowercase feature in MySQL compatibility mode. The value is one of (1, true, on, 0, false, off), the default value is 1.

--ascii-zero-store-value=*ascii-zero-store-value*

Whether to store another ASCII value for ASCII ZERO. Available value range from 0 to 32 (including 0 and 32).

-V  
 --version

Print the lt\_createdb version and exit.

-?  
 --help

Show help about lt\_createdb command line arguments, and exit.

lt\_createdb also accepts the following command-line arguments for connection parameters:

-h *host*  
 --host=*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

-p *port*  
 --port=*port*

Specifies the TCP port or the local Unix domain socket file extension on which the server is listening for connections.

-U *username*  
 --username=*username*

User name to connect as.

-w  
 --no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force `lt_createdb` to prompt for a password before connecting to a database.

This option is never essential, since `lt_createdb` will automatically prompt for a password if the server demands password authentication. However, `lt_createdb` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to when creating the new database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the new database being created), `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options.

## Environment

`LTDATABASE`

If set, the name of the database to create, unless overridden on the command line.

`LTHOST`  
`LTPORT`  
`LTUSER`

Default connection parameters. `LTUSER` also determines the name of the database to create, if it is not specified on the command line or by `LTDATABASE`.

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

## Examples

Execute on a `cn` node to create a distributed database named `demo`:

```
$ lt_createdb demo
```

To create a non-distributed database named `demo` using the `template1` template database on a non-`cn` node host `eden` with port 5000, here are the command-line command:

```
$ lt_createdb -p 5000 -h eden -T template1 -e demo
```

---

# createuser

createuser — define a new LightDB user account

## Synopsis

```
createuser [connection-option...] [option...] [username]
```

## Description

createuser creates a new LightDB user (or more precisely, a role). Only superusers and users with CREATEROLE privilege can create new users, so createuser must be invoked by someone who can connect as a superuser or a user with CREATEROLE privilege.

If you wish to create a new superuser, you must connect as a superuser, not merely with CREATEROLE privilege. Being a superuser implies the ability to bypass all access permission checks within the database, so superuser access should not be granted lightly.

createuser is a wrapper around the SQL command CREATE ROLE. There is no effective difference between creating users via this utility and via other methods for accessing the server.

## Options

createuser accepts the following command-line arguments:

*username*

Specifies the name of the LightDB user to be created. This name must be different from all existing roles in this LightDB installation.

-c *number*

--connection-limit=*number*

Set a maximum number of connections for the new user. The default is to set no limit.

-d

--createdb

The new user will be allowed to create databases.

-D

--no-createdb

The new user will not be allowed to create databases. This is the default.

-e

--echo

Echo the commands that createuser generates and sends to the server.

-E

--encrypted

This option is obsolete but still accepted for backward compatibility.

-g *role*

--role=*role*

Indicates role to which this role will be added immediately as a new member. Multiple roles to which this role will be added as a member can be specified by writing multiple -g switches.

`-i`  
`--inherit`

The new role will automatically inherit privileges of roles it is a member of. This is the default.

`-I`  
`--no-inherit`

The new role will not automatically inherit privileges of roles it is a member of.

`--interactive`

Prompt for the user name if none is specified on the command line, and also prompt for whichever of the options `-d/-D`, `-r/-R`, `-s/-S` is not specified on the command line. (This was the default behavior up to LightDB 9.1.)

`-l`  
`--login`

The new user will be allowed to log in (that is, the user name can be used as the initial session user identifier). This is the default.

`-L`  
`--no-login`

The new user will not be allowed to log in. (A role without login privilege is still useful as a means of managing database permissions.)

`-P`  
`--pwprompt`

If given, `createuser` will issue a prompt for the password of the new user. This is not necessary if you do not plan on using password authentication.

`-r`  
`--createrole`

The new user will be allowed to create new roles (that is, this user will have `CREATEROLE` privilege).

`-R`  
`--no-createrole`

The new user will not be allowed to create new roles. This is the default.

`-s`  
`--superuser`

The new user will be a superuser.

`-S`  
`--no-superuser`

The new user will not be a superuser. This is the default.

`-V`  
`--version`

Print the `createuser` version and exit.

`--replication`

The new user will have the `REPLICATION` privilege, which is described more fully in the documentation for `CREATE ROLE`.

`--no-replication`

The new user will not have the `REPLICATION` privilege, which is described more fully in the documentation for `CREATE ROLE`.

`-?`

`--help`

Show help about createuser command line arguments, and exit.

createuser also accepts the following command-line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`

`--username=username`

User name to connect as (not the user name to create).

`-w`

`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

`--password`

Force createuser to prompt for a password (for connecting to the server, not for the password of the new user).

This option is never essential, since createuser will automatically prompt for a password if the server demands password authentication. However, createuser will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

## Environment

`LTHOST`

`LTPORT`

`LTUSER`

Default connection parameters

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see CREATE ROLE and ltsql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

## Examples

To create a user `joe` on the default database server:

```
$ createuser joe
```

To create a user `joe` on the default database server with prompting for some additional attributes:

```
$ createuser --interactive joe
Shall the new role be a superuser? (y/n) n
Shall the new role be allowed to create databases? (y/n) n
Shall the new role be allowed to create more new roles? (y/n) n
```

To create the same user `joe` using the server on host `eden`, port `5000`, with attributes explicitly specified, taking a look at the underlying command:

```
$ createuser -h eden -p 5000 -s -D -R -e joe
CREATE ROLE joe NOSUPERUSER NOCREATEDB NOCREATEROLE INHERIT LOGIN;
```

To create the user `joe` as a superuser, and assign a password immediately:

```
$ createuser -P -s -e joe
Enter password for new role: xyzzy
Enter it again: xyzzy
CREATE ROLE joe PASSWORD 'md5b5f5ba1a423792b526f799ae4eb3d59e'
SUPERUSER CREATEDB CREATEROLE INHERIT LOGIN;
```

In the above example, the new password isn't actually echoed when typed, but we show what was typed for clarity. As you see, the password is encrypted before it is sent to the client.

## See Also

dropuser, CREATE ROLE

---

# dropdb

dropdb — remove a LightDB database

## Synopsis

```
dropdb [connection-option...] [option...] dbname
```

## Description

dropdb destroys an existing LightDB database. The user who executes this command must be a database superuser or the owner of the database.

dropdb is a wrapper around the SQL command DROP DATABASE. There is no effective difference between dropping databases via this utility and via other methods for accessing the server.

## Options

dropdb accepts the following command-line arguments:

*dbname*

Specifies the name of the database to be removed.

-e  
--echo

Echo the commands that dropdb generates and sends to the server.

-f  
--force

Attempt to terminate all existing connections to the target database before dropping it. See DROP DATABASE for more information on this option.

-i  
--interactive

Issues a verification prompt before doing anything destructive.

-V  
--version

Print the dropdb version and exit.

--if-exists

Do not throw an error if the database does not exist. A notice is issued in this case.

-?  
--help

Show help about dropdb command line arguments, and exit.

dropdb also accepts the following command-line arguments for connection parameters:



`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force dropdb to prompt for a password before connecting to a database.

This option is never essential, since dropdb will automatically prompt for a password if the server demands password authentication. However, dropdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to in order to drop the target database. If not specified, the `postgres` database will be used; if that does not exist (or is the database being dropped), `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options.

## Environment

LTHOST  
LTPORT  
LTUSER

Default connection parameters

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see `DROP DATABASE` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

## Examples

To destroy the database demo on the default database server:

```
$ dropdb demo
```

To destroy the database demo using the server on host eden, port 5000, with verification and a peek at the underlying command:

```
$ dropdb -p 5000 -h eden -i -e demo
Database "demo" will be permanently deleted.
Are you sure? (y/n) y
DROP DATABASE demo;
```

## See Also

createdb, DROP DATABASE

---

# dropuser

dropuser — remove a LightDB user account

## Synopsis

```
dropuser [connection-option...] [option...] [username]
```

## Description

dropuser removes an existing LightDB user. Only superusers and users with the CREATEROLE privilege can remove LightDB users. (To remove a superuser, you must yourself be a superuser.)

dropuser is a wrapper around the SQL command DROP ROLE. There is no effective difference between dropping users via this utility and via other methods for accessing the server.

## Options

dropuser accepts the following command-line arguments:

*username*

Specifies the name of the LightDB user to be removed. You will be prompted for a name if none is specified on the command line and the `-i/--interactive` option is used.

`-e`  
`--echo`

Echo the commands that dropuser generates and sends to the server.

`-i`  
`--interactive`

Prompt for confirmation before actually removing the user, and prompt for the user name if none is specified on the command line.

`-V`  
`--version`

Print the dropuser version and exit.

`--if-exists`

Do not throw an error if the user does not exist. A notice is issued in this case.

`-?`  
`--help`

Show help about dropuser command line arguments, and exit.

dropuser also accepts the following command-line arguments for connection parameters:

`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`  
`--username=username`

User name to connect as (not the user name to drop).

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force dropuser to prompt for a password before connecting to a database.

This option is never essential, since dropuser will automatically prompt for a password if the server demands password authentication. However, dropuser will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

## Environment

LTHOST  
LTPORT  
LTUSER

Default connection parameters

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see `DROP ROLE` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

## Examples

To remove user `joe` from the default database server:

```
$ dropuser joe
```

To remove user `joe` using the server on host `eden`, port `5000`, with verification and a peek at the underlying command:

```
$ dropuser -p 5000 -h eden -i -e joe
Role "joe" will be permanently removed.
Are you sure? (y/n) y
DROP ROLE joe;
```

## See Also

createuser, DROP ROLE

---

# ecpg

ecpg — embedded SQL C preprocessor

## Synopsis

ecpg [*option...*] *file...*

## Description

ecpg is the embedded SQL preprocessor for C programs. It converts C programs with embedded SQL statements to normal C code by replacing the SQL invocations with special function calls. The output files can then be processed with any C compiler tool chain.

ecpg will convert each input file given on the command line to the corresponding C output file. If an input file name does not have any extension, .pgc is assumed. The file's extension will be replaced by .c to construct the output file name. But the output file name can be overridden using the -o option.

If an input file name is just -, ecpg reads the program from standard input (and writes to standard output, unless that is overridden with -o).

This reference page does not describe the embedded SQL language. See Chapter 34 for more information on that topic.

## Options

ecpg accepts the following command-line arguments:

-c

Automatically generate certain C code from SQL code. Currently, this works for EXEC SQL TYPE.

-C *mode*

Set a compatibility mode. *mode* can be INFORMIX, INFORMIX\_SE, or ORACLE.

-D *symbol*

Define a C preprocessor symbol.

-h

Process header files. When this option is specified, the output file extension becomes .h not .c, and the default input file extension is .pgh not .pgc. Also, the -c option is forced on.

-i

Parse system include files as well.

-I *directory*

Specify an additional include path, used to find files included via EXEC SQL INCLUDE. Defaults are . (current directory), /usr/local/include, the LightDB include directory which is defined at compile time (default: /usr/local/lightdb-x/include), and /usr/include, in that order.

`-o filename`

Specifies that `ecpg` should write all its output to the given `filename`. Write `-o -` to send all output to standard output.

`-r option`

Selects run-time behavior. `Option` can be one of the following:

`no_indicator`

Do not use indicators but instead use special values to represent null values. Historically there have been databases using this approach.

`prepare`

Prepare all statements before using them. Libecpg will keep a cache of prepared statements and reuse a statement if it gets executed again. If the cache runs full, libecpg will free the least used statement.

`questionmarks`

Allow question mark as placeholder for compatibility reasons. This used to be the default long ago.

`-t`

Turn on autocommit of transactions. In this mode, each SQL command is automatically committed unless it is inside an explicit transaction block. In the default mode, commands are committed only when `EXEC SQL COMMIT` is issued.

`-v`

Print additional information including the version and the "include" path.

`--version`

Print the `ecpg` version and exit.

`-?`

`--help`

Show help about `ecpg` command line arguments, and exit.

## Notes

When compiling the preprocessed C code files, the compiler needs to be able to find the ECPG header files in the LightDB include directory. Therefore, you might have to use the `-I` option when invoking the compiler (e.g., `-I/usr/local/lightdb-x/include`).

Programs using C code with embedded SQL have to be linked against the `libecpg` library, for example using the linker options `-L/usr/local/lightdb-x/lib -lecpg`.

The value of either of these directories that is appropriate for the installation can be found out using `lt_config`.

## Examples

If you have an embedded SQL C source file named `prog1.pgc`, you can create an executable program using the following sequence of commands:

```
ecpg prog1.pgc  
cc -I/usr/local/lightdb-x/include -c prog1.c  
cc -o prog1 prog1.o -L/usr/local/lightdb-x/lib -lecpg
```



---

# executor

executor — use to execute grouped sql file in parallel

## Synopsis

```
java -jar lt_lightdb_executor.jar [url] [username] [password] [filePath]
```

## Description

A batch of SQL divided into groups defined in text file. The SQL of the same group is executed sequentially in the same thread, and different groups are executed concurrently.

File format is `${group}`, `${sql}` pre line, use `' '` to separate group and sql, sql can not contain character `' "'`. Here is a simple example file:

```
group1, create table test(v int)
group1, insert into test(v) values(1)
group2, create table test2(v int)
group2, insert into test2(v) values(1)
```

## Options

executor accepts the following command-line arguments:

`url`

JDBC connection string for target database.

`username`

username for login.

`password`

password for login.

`filePath`

sql file to execute .

## Diagnostics

The parallel count is the same as the number of CPU cores on the machine where `lt_lightdb_executor.jar` running.

## Examples

```
$ java -jar lt_lightdb_executor.jar \  
  "jdbc:postgresql://localhost:5432/postgres" "lightdb" "123" t.sql
```

---

# lightdb\_service.py

lightdb\_service.py — start/stop/restart a LightDB service

## Synopsis

```
lightdb_service.py --command | -c start,stop,restart,status [ --filename  
| -F install_info ] [ --cn_only | -C ] [ --dn_only | -D ] [ --primary_only | -P ]  
[ --standby_only | -S ] [ --node | -n node_info ] --dry-run [ --force | -f ] [ --  
verbose | -v ] [ --quiet | -q ] [ --parallel | -B parallel_processes ] [ --log_dir  
| -l directory ] [ --ignore-keepalived | -i ] [ --help | -h ]
```

## Description

lightdb\_service.py is a utility for start/stop a LightDB service. It can full start or stop all component in a LightDB service installed by installer. It also has a simple status detection feature and can use some special mode to start or stop service.

The LightDB service must be installed by installer to use this application.

lightdb\_service.py must be executed under python3.

## Options

lightdb\_service.py accepts the following command-line arguments:

-h  
--help

show this help message and exit.

[-c] *start,stop,restart,status*  
[ --command ] *start,stop,restart,status*

start/stop/restart/status lightdb service.

[-F] *install\_info*  
[ --filename ] *install\_info*

Specifies a path to a json file containing installation information(default use uninstall/uninstallFile.json).

-C  
--cn\_only

Only start/stop/restart coordinator node.

-D  
--dn\_only

Only start/stop/restart data node.

-P  
--primary\_only

Only start/stop/restart primary node for primary restart.

-S  
--standby\_only

Only start/stop/restart standby node for standby restart.

-D  
--quiet  
Do not display progress messages.

-n *node\_info*  
--node *node\_info*  
Only start/stop/restart specified node, node\_info format: ip:port.

--dry-run  
Show what would happen for action, but don't execute it.

-f  
--force  
force stop, even if some nodes are in incorrect state, skip incorrect nodes.

-B *parallel\_processes*  
--parallel *parallel\_processes*  
Number of segment hosts to run in parallel. Default is 1.

-v  
--verbose  
Debug print

-q  
--quiet  
suppress status messages for stdout logging

-l *directory*  
--log\_dir *directory*  
Logfile directory, default is /tmp/ltAdminLogs.

--ignore-keepalived  
ignore keepalived, normally use for lightdb service without keepalived.

## Diagnostics

In case of difficulty, see log file for detail error message.

Following are error codes and normal reasons

**Table 272. Error Code Table**

Error Code	Reason
100	Start lightdb failed(please refer to lightdb log for details), not primary
101	Stop lightdb failed(please refer to lightdb log for details), not primary
102	Start primary lightdb failed(please refer to lightdb log for details)
103	Stop primary lightdb failed(please refer to lightdb log for details)
104	The node to operate is not in current lightdb service. used with '-n'

<b>Error Code</b>	<b>Reason</b>
105	Get lightdb role failed.
106	Cannot get lightdb process status, execute command that will check lightdb port failed. Usually, ssh encryption is not configured.
107	LightDB process is running, but can't connect to execute sql.
108	LightDB is stopped, but it should be running.
109	LightDB is running, but it should be stopped.
110	Cannot get Itcluster process status, because execute get command failed. Usually, ssh encryption is not configured or lightdb is stopped
111	Itclusterd is stopped, but it should be running.
112	Itclusterd is running, but it should be stopped.
113	All Itclusterd in cluster are unpaused. but should be paused
114	All Itclusterd in cluster are paused. but should be unpaused
115	All Itclusterd pause status in cluster are unknown.
116	Itclusterd pause status in cluster are inconsistent.
117	Itclusterd start failed. please refer to log for details.
118	Itclusterd stop failed. please refer to log for details.
119	Pause Itclusterd in cluster.
120	Unpause Itclusterd in cluster failed.
121	Cannot get keepalived process status, because execute get command failed.
122	keepalived is stopped, but should be running.
123	keepalived is running, but should be stopped.
124	keepalived start failed.
125	keepalived stop failed.
126	Use for execute command failed in Common scene, now only used for get standby.signal file num error.
127	standby.signal file's num is wrong when judge lightdb role.
128	Cannot get high available status, because execute command failed.
129	High available status is not right(right meaning all is running correctly).
130	install file about lightdb service's formart is error.
131	install file about lightdb service's content is error.

## Examples

To start all test:

```
$ lightdb_service.py -c start
```

To stop all:

```
$ lightdb_service.py -c stop
```

To restart all:

```
$ lightdb_service.py -c restart
```

To check status:

```
$ lightdb_service.py -c status
```

To start/stop/restart primary only(The active and standby states remain unchanged):

```
$ lightdb_service.py -c start/stop/restart --primary_only
```

To start/stop/restart standby only(The active and standby states remain unchanged):

```
$ lightdb_service.py -c start/stop/restart --standby_only
```

To start/stop/restart cn node only:

```
$ lightdb_service.py -c start/stop/restart --cn_only
```

To start/stop/restart dn node only:

```
$ lightdb_service.py -c start/stop/restart --dn_only
```

To start/stop/restart primary in dn node only:

```
$ lightdb_service.py -c start/stop/restart --dn_only --primary_only
```

To start/stop/restart specify node only(The active and standby states remain unchanged):

```
$ lightdb_service.py -c start/stop/restart -n 10.20.148.122:54333
```

To force stop:

```
$ lightdb_service.py -c stop -f
```

To dry run start command:

```
$ lightdb_service.py -c start --dry-run
```

---

# lt\_distributed\_probackup.py

lt\_distributed\_probackup.py — backup and restore a LightDB distributed cluster

## lt\_distributed\_probackup

lt\_distributed\_probackup.py is a utility to manage backup and recovery of LightDB Distributed database clusters. It is designed to perform periodic backups of the LightDB instance that enable you to restore the server in case of a failure. Python version need to be python3.

lt\_distributed\_probackup.py offers the following benefits like lt\_probackup that can help you implement different backup strategies and deal with large amounts of data:

- **Incremental backup:** page-level incremental backup allows you to save disk space, speed up backup and restore. With three different incremental modes, you can plan the backup strategy in accordance with your data flow.
- **Incremental restore:** page-level incremental restore allows you dramatically speed up restore by reusing valid unchanged pages in destination directory.
- **Merge:** using this feature allows you to implement "incrementally updated backups" strategy, eliminating the need to do periodical full backups.
- **Validation:** automatic data consistency checks and on-demand backup validation without actual data recovery
- **Verification:** on-demand verification of LightDB distributed instance with the `checkdb` command.
- **Retention:** managing WAL archive and backups in accordance with retention policy. You can configure retention policy based on recovery time or the number of backups to keep, as well as specify time to live (TTL) for a particular backup. Expired backups can be merged or deleted.
- **Parallelization:** running backup, restore, merge, delete, verification and validation processes on multiple parallel threads
- **Compression:** storing backup data in a compressed state to save disk space
- **Deduplication:** saving disk space by not copying unchanged non-data files, such as `_vm` or `_fsm`
- **Remote operations:** backing up LightDB distributed instance located on a remote system or restoring a backup remotely
- **Backup from standby:** avoid extra load on master by taking backups from a standby server
- **External directories:** backing up files and directories located outside of the LightDB `data directory` (LTDATA), such as scripts, configuration files, logs, or SQL dump files.
- **Backup Catalog:** get list of backups and corresponding meta information in plain text or JSON formats
- **Archive catalog:** getting the list of all WAL timelines and the corresponding meta information in plain text or JSON formats
- **Partial Restore:** restore only the specified databases or exclude the specified databases from restore.

To manage backup data, lt\_distributed\_probackup.py creates a backup catalog. This directory stores all backup files with additional meta information, as well as WAL archives required for point-in-time recovery. You can store backups for different instances in separate subdirectories of a single backup catalog.

Using `lt_distributed_probackup.py`, you can take full or incremental backups:

- Full backups contain all the data files required to restore the database cluster from scratch.
- Incremental backups only store the data that has changed since the previous backup. It allows to decrease the backup size and speed up backup operations. `lt_distributed_probackup.py` supports the following modes of incremental backups:
  - PAGE backup. In this mode, `lt_distributed_probackup.py` scans all WAL files in the archive from the moment the previous full or incremental backup was taken. Newly created backups contain only the pages that were mentioned in WAL records. This requires all the WAL files since the previous backup to be present in the WAL archive. If the size of these files is comparable to the total size of the database cluster files, speedup is smaller, but the backup still takes less space.
  - DELTA backup. In this mode, `lt_distributed_probackup.py` read all data files in LTDATA directory and only those pages, that where changed since previous backup, are copied. Continuous archiving is not necessary for it to operate. Also this mode could impose read-only I/O pressure equal to Full backup.
  - PTRACK backup. In this mode, LightDB tracks page changes on the fly. Continuous archiving is not necessary for it to operate. Each time a relation page is updated, this page is marked in a special PTRACK bitmap for this relation. As one page requires just one bit in the PTRACK fork, such bitmaps are quite small. Tracking implies some minor overhead on the database server operation, but speeds up incremental backups significantly.

Regardless of the chosen backup type, all backups taken with `lt_distributed_probackup.py` support the following strategies of WAL delivery:

- Autonomous backups streams via replication protocol all the WAL files required to restore the cluster to a consistent state at the time the backup was taken. Even if continuous archiving is not set up, the required WAL segments are included into the backup.
- Archive backups rely on continuous archiving.

`lt_distributed_probackup.py` will use `lt_probackup` to manage backup and recovery of LightDB Distributed database clusters. It has almost the same usage as `lt_probackup` and fully supports the functions supported by `lt_probackup`. The specific differences are as follows

## different from `lt_probackup`

`lt_distributed_probackup.py` use `connection` option to get datanode info from coordinator when `add-instance` and `backup`.

`lt_distributed_probackup.py` find matched datanode instance name in backup path by coordinator's instance name specified by `--instance`, when `restore`, `set-config`, `show-config`, `validate`, `checkdb`, `show`, `delete` and `del-instance`

To set different options for coordinator and datanode, some options can be set to a list, separated by semicolons. If it is not set to a list, than all node will set same option.

'`-i --backup-id`' can be a distributed backup id, you can see distributed backup id by `show` command. By specify it, you can operator dn's backup at the same time. This is supported from version 23.1 onwards. old backups status will all be 'ERROR' in `show` command without '`--detail`'.

## log options

- Log options is used to control `lt_distributed_probackup.py` logs, but not `lt_probackup` logs.
- Add option '`--lt-probackup-log-level`' for change `lt_probackup`'s console log level.

- By default, file logging is enabled. The log level is verbose and the log name is 'lt\_distributed\_probackup-%Y-%m-%d.log'. Default log directory is 'BACKUP\_PATH/log'. but when use backup command with '--with-init', 'BACKUP\_PATH' may not exist, log directory will be '/tmp/ltAdminLogs'.
- Not support '--error-log-filename', '--log-rotation-size' and '--log-rotation-age'. '--log-rotation-size' and '--log-rotation-age' is used for an individual log file, but by default it is not an individual log file.
- '--log-level-console' and '--log-rotation-age' is used for an individual log file, but by default it is not an individual log file.

## add-instance

- Add connection option for connect to coordinator node. if it is a primary, it will add-instance for all primary node, otherwise it will add-instance for all standby node.
- '--remote-host' will be ignored, because it will be same with '-h'.
- '--remote-path' can be a list.
- Add option '--no\_distribution' for execute like lt\_probackup.
- After execute add-instance command, it will output datanode's instance name generated. In datanode's archive\_comand, the '--instance' must be same with it, or you can get it by 'cn\_instance\_name\_dn\_id'(for example: 'cn\_dn\_1'), 'cn\_instance\_name' is then coordinator instance name specified by '--instacne', id is the node\_id in pg\_dist\_node.

## backup

- Use connection option to connect to coordinator node. if it is a primary, it will backup for all primary node, otherwise it will backup for all standby node.
- '--remote-host' will be ignored, because it will be same with '-h'.
- '-D pgdata-path' will be ignored, because it have been add to config in add-instance.
- Add option '--with-init', when set, backup will init and add-instance if it is not exist.
- Add option '--parallel-num' to execute lt\_probackup concurrently. default num is 1.

## restore

- By specify cn instance name, it will get all datanode instance name, and restore them.
- Not support '--db-include' and '--db-exclude' yet.
- '-D pgdata-path', '-i backup\_id', '--recovery-taget-xid', '--recovery-taget-lsn', '--recovery-taget-xid', '--recovery-taget-timeline', '--recovery-taget-name', '--restore\_command', '--primary\_conninfo', '--primary-slot-name', '--tablespace-mapping', '--remote-host' and '--remote-path' can be a list
- After restore, you may need to call canopy\_update\_node to change coordinator and datanode's metadata like host and port.
- Add option '--parallel-num' to execute lt\_probackup concurrently. default num is 1.
- Add option '--no\_distribution' for execute like lt\_probackup.

## show

- By specify cn instance name, it will get all datanode instance name, and execute command for them.



- show command support option '--no\_distribution' for execute like lt\_probackup.
- show command will show distributed backup status. It's status will not be ok if the backup status of a node is not ok.
- With '--detail', show command will show all node's backup info. This is the default behavior in LightDB version 22.4. In LightDB version 23.1 or later, you must specified '--detail' to show all node's backup info.

### set-config/show-config/checkdb/validate/delete/del-instance

- By specify cn instance name, it will get all datanode instance name, and execute command for them.
- set-config, delete and del-instance command support option '--no\_distribution' for execute like lt\_probackup.
- For checkdb, connection option must be set to coordinator if exist. It is recommended to use it by specifying -B and --instance.
- delete's option '-i' can be a list.
- validate's option '-i', '--recovery-taget-xid', '--recovery-taget-lsn', '--recovery-target-timeline' and '--recovery-target-name' can be a list.

### set-backup/merge

- Usage is same with lt\_probackup, but with more log output, you can directly use lt\_probackup.

## Example

### Preprocess

- ssh encryption Free

### Usage

```
backup server: 192.168.247.126; backup dir: /home/lightdb/backup coordinator info:
192.168.247.127:54332 coordinator data dir: /home/lightdb/data datanode1 info:
192.168.247.128:54332 datanode2 info: 192.168.247.129:54332 new cluster(cn;dn1;dn2):
192.168.247.130;192.168.247.131;192.168.247.132
```

1. init backup dir, dir path: /home/lightdb/backup

```
lt_distributed_probackup.py init -B /home/lightdb/backup
```

2. add instance, coordinator instance name: cn; coordinator instance ip,port: 192.168.247.128:54332; coordinator data dir: /home/lightdb/data.

```
lt_distributed_probackup.py add-instance -B /home/lightdb/backup
-D /home/lightdb/data --instance cn -h192.168.247.128 -p5432
```

3. Setting up Continuous WAL Archiving after add instance. datanode's instance is generated when execute add-instance command.

```
# cn
archive_mode=on
```

```
archive_command="/home/lightdb/lightdb-x/13.8-23.4/bin/  
lt_probackup archive-push -B /home/lightdb/backup --instance=cn  
--wal-file-name=%f --remote-host=192.168.247.126"  
# dn1  
archive_mode=on  
archive_command="/home/lightdb/lightdb-x/13.8-23.4/  
bin/lt_probackup archive-push -B /home/lightdb/backup  
--instance=cn_dn_1 --wal-file-name=%f --remote-  
host=192.168.247.126"
```

4. full backup distributed cluster

```
lt_distributed_probackup.py backup -B /home/lightdb/backup -D /  
home/lightdb/data --instance cn -h192.168.247.128 -p5432 -b full  
--parallel-num=1
```

5. restore LightDB distributed cluster

restore to original LightDB distributed cluster

```
lt_distributed_probackup.py restore -B /home/lightdb/backup --  
instance cn --parallel-num=1
```

restore to new LightDB distributed cluster

```
lt_distributed_probackup.py restore -B /home/lightdb/  
backup --instance cn --parallel-num=1 --remote-  
host='192.168.247.130;192.168.247.131;192.168.247.132'
```

6. checkdb, backup must be on local server

```
lt_distributed_probackup.py checkdb -B /home/lightdb/backup --  
instance cn  
lt_distributed_probackup.py checkdb -h10.19.70.50 -p54332
```

7. set config for instance

```
lt_distributed_probackup.py set-config -B /home/lightdb/backup  
--instance cn --archive-timeout=6min
```

8. show-config for instance

```
lt_distributed_probackup.py show-config -B /home/lightdb/backup  
--instance cn
```

9. validate backup

```
lt_distributed_probackup.py validate -B /home/lightdb/backup --  
instance cn
```

10. show backup

```
lt_distributed_probackup.py show -B /home/lightdb/backup --  
instance cn
```

11. delete backup

```
lt_distributed_probackup.py delete -B /home/lightdb/backup --  
instance cn --delete-expired --retention-redundancy=1
```

12. delete instance

```
lt_distributed_probackup.py del-instance -B /home/lightdb/backup  
--instance cn
```

13. merge, set-backup is same with lt\_probackup

```
lt_distributed_probackup.py merge -B /home/lightdb/backup --  
instance cn -i RMICH6 -j 2 --progress --no-validate --no-sync  
lt_distributed_probackup.py set-backup -B /home/lightdb/backup  
--instance cn_dn_2 -i RMI6YR --note='cn_dn_2'
```

## Limitations

lt\_distributed\_probackup.py currently has the following limitations:

- The server from which the backup was taken and the restored server must be compatible by the `block_size`(Reports the size of a disk block. It is determined by the value of `BLCKSZ` when building the server. The default value is 8192 bytes.) and `wal_block_size`(Reports the size of a WAL disk block. It is determined by the value of `XLOG_BLCKSZ` when building the server. The default value is 8192 bytes.) parameters and have the same major release number.
- If you do not have permission to create a directory, the directory is not actually created, although the init command is successfully executed.
- When running remote operations via ssh, remote and local `lt_probackup` versions must be the same.
- Even if you only need to back up the local LightDB Distributed database clusters, you also need to configure the local non-encryption for 127.0.0.1 and local ip
- The max parallel depend on '-j' and '--parallel-num' may limited by sshd config 'MaxStartups'. When 'MaxStartups' is small, execute `lt_distributed_probackup.py` with big parallel num may report error: 'ERROR: Agent error: kex\_exchange\_identification: read: Connection reset by peer'. If you want more concurrency, you should turn 'MaxStartups' up in `/etc/ssh/sshd_config`, and restart sshd service.

---

# lt\_distributed\_dump.py

lt\_distributed\_dump.py — extract a distributed LightDB database into an directory include script file or other archive file

## Synopsis

```
lt_distributed_dump.py [connection-option...] [option...]
```

## Description

lt\_distributed\_dump is a utility for backing up a distributed LightDB database. It makes consistent backups only if the database is not being used concurrently. lt\_distributed\_dump does not block other users accessing the database (readers or writers).

lt\_distributed\_dump use lt\_dump to dump database.

lt\_distributed\_dump only dumps a single distributed database.

Dumps can be output in script or archive file formats. The script format is not recommended, because for a distributed database, after a distributed table is created in coordinator, the name of the distributed sub-table in the plain-text files will be different from that of the sub-table in worker node.

Script dumps are plain-text files containing the SQL commands required to reconstruct the database to the state it was in at the time it was saved. To restore from such a script, feed it to ltsql. Script files can be used to reconstruct the database even on other machines and other architectures; with some modifications, even on other SQL database products.

The alternative archive file formats must be used with lt\_distributed\_restore.py to rebuild the database. They allow lt\_distributed\_restore.py to be selective about what is restored, or even to reorder the items prior to being restored. The archive file formats are designed to be portable across architectures.

When used with one of the archive file formats and combined with lt\_distributed\_restore.py, lt\_distributed\_dump.py provides a flexible archival and transfer mechanism. lt\_distributed\_dump.py can be used to backup an entire database, then lt\_distributed\_restore.py can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file formats are the “custom” format (-Fc) and the “directory” format (-Fd). They allow for selection and reordering of all archived items, support parallel restoration, and are compressed by default. The “directory” format is the only format that supports parallel dumps.

lt\_distributed\_dump.py support dump plorasql packages and procedures, like dump tables and so on.

While running lt\_distributed\_dump.py, one should examine the output for any warnings (printed on standard error), especially in light of the limitations listed below.

## Options

The following command-line options control the content and format of the output. Use '--folder' to specify a directory to store dump files. the directory must be not exist. Not support '--create', because for distributed database, restore muse have database exist.

-a  
--data-only

Dump only the worker node data and schema

This option is similar to specifying --section=data.

`-b`  
`--blobs`

Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified. The `-b` switch is therefore only useful to add large objects to dumps where a specific schema or table has been requested. Note that blobs are considered data and therefore will be included when `--data-only` is used, but not when `--schema-only` is.

`-B`  
`--no-blobs`

Exclude large objects in the dump.

When both `-b` and `-B` are given, the behavior is to output large objects, when data is being dumped, see the `-b` documentation.

`-K`  
`--recreate-schema`

Output commands to directly drop schema(use cascade mode) prior to outputting the commands for creating them, more faster then normal mode. (Unless `--if-exists` is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_distributed_restore.py`.

`-E encoding`  
`--encoding=encoding`

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `LTCLIENTENCODING` environment variable to the desired dump encoding.)

`-f dirname`  
`--folder=dirname`

Send output to the specified directory. The directory is created by `lt_distributed_dump.py` and must not exist before.

`-F format`  
`--format=format`

Selects the format of the output. *format* can be one of the following:

`p`  
`plain`

Output a plain-text SQL script file .

`c`  
`custom`

Output a custom-format archive suitable for input into `lt_restore`. Together with the directory output format, this is the most flexible output format in that it allows manual selection and reordering of archived items during restore. This format is also compressed by default.

`d`  
`directory`

Output a directory-format archive suitable for input into `lt_distributed_restore.py` (the default). This will create a directory with one file for each table and blob being dumped,

plus a so-called Table of Contents file describing the dumped objects in a machine-readable format that `lt_distributed_restore.py` can read. A directory format archive can be manipulated with standard Unix tools; for example, files in an uncompressed archive can be compressed with the `gzip` tool. This format is compressed by default and also supports parallel dumps.

t  
tar

Output a `tar`-format archive suitable for input into `lt_distributed_restore.py`. The `tar` format is compatible with the directory format: extracting a `tar`-format archive produces a valid directory-format archive. However, the `tar` format does not support compression. Also, when using `tar` format the relative order of table data items cannot be changed during restore.

-j *njobs*  
--jobs=*njobs*

Run the dump in parallel by dumping *njobs* tables simultaneously. This option may reduce the time needed to perform the dump but it also increases the load on the database server. You can only use this option with the directory output format because this is the only output format where multiple processes can write their data at the same time.

`lt_dump` will open *njobs* + 1 connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Requesting exclusive locks on database objects while running a parallel dump could cause the dump to fail. The reason is that the `lt_dump` master process requests shared locks on the objects that the worker processes are going to dump later in order to make sure that nobody deletes them and makes them go away while the dump is running. If another client then requests an exclusive lock on a table, that lock will not be granted but will be queued waiting for the shared lock of the master process to be released. Consequently any other access to the table will not be granted either and will queue after the exclusive lock request. This includes the worker process trying to dump the table. Without any precautions this would be a classic deadlock situation. To detect this conflict, the `lt_dump` worker process requests another shared lock using the `NOWAIT` option. If the worker process is not granted this shared lock, somebody else must have requested an exclusive lock in the meantime and there is no way to continue with the dump, so `lt_dump` has no choice but to abort the dump.

For a consistent backup, the database server needs to support synchronized snapshots, a feature that was introduced in LightDB 9.2 for primary servers and 10 for standbys. With this feature, database clients can ensure they see the same data set even though they use different connections. `lt_distributed_dump.py -j` uses multiple database connections; it connects to the database once with the master process and once again for each worker job. Without the synchronized snapshot feature, the different worker jobs wouldn't be guaranteed to see the same data in each connection, which could lead to an inconsistent backup.

-n *name*  
--schema=*name*

Dump only schemas matching *name*; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. see Examples below.

### Note

When `-n` is specified, `lt_distributed_dump.py` makes no attempt to dump any other database objects that the selected schema(s) might depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

**Note**

Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.

`-N name`  
`--exclude-schema=name`

Do not dump any schemas matching *name*. The pattern is interpreted according to the same rules as for `-n`. `-N` can be given more than once to exclude schemas matching any of several patterns.

When both `-n` and `-N` are given, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

`-O`  
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `lt_distributed_dump.py` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_distributed_restore.py`.

`-R`  
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`  
`--schema-only`

Dump only the object definitions (schema) in coordinator node, not data. worker node is not dumped.

This option is the inverse of `--data-only`. It is similar to specifying `--section=pre-data` `--section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

`-S username`  
`--superuser=username`

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

`-t name`  
`--table=name`

Dump only tables with names matching *name*. Multiple tables can be selected by writing multiple `-t` switches. see Examples below.

As well as tables, this option can be used to dump the definition of matching views, materialized views, foreign tables, and sequences. It will not dump the contents of views or materialized views.

The `-n` and `-N` switches have no effect when `-t` is used, because tables selected by `-t` will be dumped regardless of those switches, and non-table objects will not be dumped.

### Note

When `-t` is specified, `lt_distributed_dump.py` makes no attempt to dump any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

### Note

Writing `-t tab` would dump whichever one is visible in your default search path. you must write something like `-t sch.tab` to select a table in a particular schema.

`-T name`  
`--exclude-table=name`

Do not dump any tables matching `name`. `-T` can be given more than once to exclude tables matching any of several patterns.

When both `-t` and `-T` are given, the behavior is to dump just the tables that match at least one `-t` switch but no `-T` switches. If `-T` appears without `-t`, then tables matching `-T` are excluded from what is otherwise a normal dump.

`-v`  
`--verbose`

Specifies verbose mode. This will cause `lt_dump` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error. This also will cause `lt_distributed_dump.py` to output in debug log level.

`-V`  
`--version`

Print the `lt_distributed_dump.py` version and exit.

`-x`  
`--no-privileges`  
`--no-acl`

Prevent dumping of access privileges (grant/revoke commands).

`-Z 0..9`  
`--compress=0..9`

Specify the compression level to use. Zero means no compression. For the custom and directory archive formats, this specifies compression of individual table-data segments, and the default is to compress at a moderate level. For plain text output, setting a nonzero compression level causes the entire output file to be compressed, as though it had been fed through `gzip`; but the default is not to compress. The tar archive format currently does not support compression at all.

`--binary-upgrade`

Not support yet



--column-inserts  
--attribute-inserts

Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-LightDB databases. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

--disable-dollar-quoting

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

--disable-triggers

This option is relevant only when creating a data-only dump. It instructs `lt_distributed_dump.py` to include commands to temporarily disable triggers on the target tables while the data is restored. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data restore.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

--enable-row-security

This option is relevant only when dumping the contents of a table which has row security. By default, `lt_dump` called by `lt_distributed_dump.py` will set `row_security` to off, to ensure that all data is dumped from the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `lt_dump` called by `lt_distributed_dump.py` to set `row_security` to on instead, allowing the user to dump the parts of the contents of the table that they have access to.

Note that if you use this option currently, you probably also want the dump be in `INSERT` format, as the `COPY FROM` during restore does not support row security.

--exclude-table-data=*pattern*

Not support yet.

--extra-float-digits=*ndigits*

Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

--if-exists

Use conditional commands (i.e., add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

--include-foreign-data=*foreignserver*

Not support yet.

--lt-exclude-lightdb-objects

Exclude all built-in objects created by LightDB in the dump.

**Note**

For built-in tables or schemas created by LightDB, when both `-t` or `-n` are given, the behavior is to ignore the table or the schema, when data is being dumped, see the `-t` and `-n` documentation.

`--lt-dump-lightdb-tables`

Not support yet.

`--lt-disable-auto-analyze`

Do not automatic collect statistics when dump index. (see CREATE INDEX for more details).

`--inserts`

Dump data as INSERT commands (rather than COPY). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-LightDB databases. Any error during restoring will cause only rows that are part of the problematic INSERT to be lost, rather than the entire table contents. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

`--load-via-partition-root`

When dumping data for a table partition, make the COPY or INSERT statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when restoring data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type text and the two systems have different definitions of the collation used to sort the partitioning column.

It is best not to use parallelism when restoring from an archive made with this option, because `lt_restore` will not know exactly which partition(s) a given archive data item will load data into. This could result in inefficiency due to lock conflicts between parallel jobs, or perhaps even restore failures due to foreign key constraints being set up before all the relevant data is loaded.

`--lock-wait-timeout=timeout`

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead fail if unable to lock a table within the specified *timeout*. The timeout may be specified in any of the formats accepted by SET `statement_timeout`. (Allowed formats vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions.)

`--no-comments`

Do not dump comments.

`--no-publications`

Do not dump publications.

`--no-security-labels`

Do not dump security labels.

`--no-subscriptions`

Do not dump subscriptions.

`--no-sync`

By default, `lt_dump` called by `lt_distributed_dump.py` will wait for all files to be written safely to disk. This option causes `lt_dump` called by `lt_distributed_dump.py` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the dump corrupt. Generally, this option is useful for testing but should not be used when dumping data from production installation.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_distributed_restore.py`.

`--no-unlogged-table-data`

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data. Data in unlogged tables is always excluded when dumping from a standby server.

`--on-conflict-do-nothing`

Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts`, `--column-inserts` or `--rows-per-insert` is also specified.

`--quote-all-identifiers`

Force quoting of all identifiers. This option is recommended when dumping a database from a server whose LightDB major version is different from `lt_dump`'s called by `lt_distributed_dump.py`, or when the output is intended to be loaded into a server of a different major version. By default, `lt_dump` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

`--rows-per-insert=nrows`

Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

`--section=sectionname`

Only dump the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to dump all sections.

The data section contains actual table data, large-object contents, sequence values and data definition items in worker node. Post-data items include definitions of indexes, triggers, rules, and constraints other than validated check constraints in coordinator node. Pre-data items include all other data definition items in coordinator node.

`--serializable-deferrable`

Not support yet

`--snapshot=snapshotname`

Not support yet

--strict-names

Not support yet

--use-set-session-authorization

Output SQL-standard SET SESSION AUTHORIZATION commands instead of ALTER OWNER commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly. Also, a dump using SET SESSION AUTHORIZATION will certainly require superuser privileges to restore correctly, whereas ALTER OWNER requires lesser privileges.

--parallel-num=*number-of-lt\_dump*

Parallel execute *lt\_dump*.

--help

Show help about *lt\_distributed\_dump.py* command line arguments, and exit.

The following command-line options control the database connection parameters.

-d *dbname*

--dbname=*dbname*

Specifies the name of the database to connect to and dump. The *dbname* can't be a connection string.

If this is not specified, the environment variable LTDATABASE is used. If that is not set, the user name specified for the connection is used.

-h *host*

--host=*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the LTHOST environment variable, if set, else 'localhost'.

-p *port*

--port=*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the LTPORT environment variable, if set, or '5432'.

-U *username*

--username=*username*

User name to connect as. Defaults to the LTUSER environment variable, if set, or current user.

-w

--no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W

--password

Force *lt\_distributed\_dump.py* to prompt for a password before connecting to a database.

`--role=rolename`

Specifies a role name to be used to create the dump. This option causes `lt_dump` called by `lt_distributed_dump.py` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `lt_dump` called by `lt_distributed_dump.py`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

The following command-line options control the logging parameters.

`-l log-directory`

`--log-directory=log-directory`

Specifies the log directory path. default is `'/tmp/ltAdminLogs'`

`--log-level-console=log-level-console`

Specifies the console log level.

`--log-level-file=log-level-file`

Specifies the file log level.

`--log-filename=log-filename`

Specifies the log file name. Default is `'lt_distributed_dump-%Y-%m-%d.log'`.

## Environment

LTDATABASE

LTHOST

LTOPTIONS

LTPORT

LTUSER

Default connection parameters.

## Diagnostics

`lt_dump` called by `lt_distributed_dump.py` internally executes `SELECT` statements. If you have problems running `lt_dump`, make sure you are able to select information from the database using, for example, `ltsql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

The database activity of `lt_dump` is normally collected by the statistics collector. If this is undesirable, you can set parameter `track_counts` to `false` via `LTOPTIONS` or the `ALTER USER` command.

## Notes

If your database cluster has any local additions to the `template1` database, be careful to dump with `'--lt-exclude-lightdb-objects'`.

When a data-only dump is chosen and the option `--disable-triggers` is used, `lt_dump` emits commands to disable triggers on user tables before inserting the data, and then commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.

The dump file produced by `lt_distributed_dump.py` does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run `ANALYZE` after restoring from a dump file to ensure optimal performance; see Section 22.1.3 and Section 22.1.6 for more information.

Because `lt_distributed_dump.py` is used to transfer data to newer versions of LightDB, the output of `lt_distributed_dump.py` can be expected to load into LightDB server versions newer than `lt_dump`'s version. `lt_distributed_dump.py` can also dump from LightDB servers older than its own version. (Currently, servers back to version 8.0 are supported.) However, `lt_distributed_dump.py` cannot dump from LightDB servers newer than its own major version; it will refuse to even try, rather than risk making an invalid dump. Also, it is not guaranteed that `lt_distributed_dump.py`'s output can be loaded into a server of an older major version — not even if the dump was taken from a server of that version. Loading a dump file into an older server may require manual editing of the dump file to remove syntax not understood by the older server. Use of the `--quote-all-identifiers` option is recommended in cross-version cases, as it can prevent problems arising from varying reserved-word lists in different LightDB versions.

When dumping logical replication subscriptions, `lt_distributed_dump.py` will generate `CREATE SUBSCRIPTION` commands that use the `connect = false` option, so that restoring the subscription does not make remote connections for creating a replication slot or for initial table copy. That way, the dump can be restored without requiring network access to the remote servers. It is then up to the user to reactivate the subscriptions in a suitable way. If the involved hosts have changed, the connection information might have to be changed. It might also be appropriate to truncate the target tables before initiating a new full table copy.

## Examples

To dump a database into a custom-format archive file:

```
$ lt_distributed_dump.py -Fc --folder dumpdir -d mydb --lt-exclude-lightdb-objects
```

To dump a database into a directory-format archive:

```
$ lt_distributed_dump.py -Fd --folder dumpdir -d mydb --lt-exclude-lightdb-objects
```

To dump a database into a directory-format archive in parallel with 5 worker jobs:

```
$ lt_distributed_dump.py -Fd --folder dumpdir -d mydb -j 5 --lt-exclude-lightdb-objects
```

To reload an archive file into a (freshly created) database named `newdb`:

```
$ lt_distributed_restore.py -d newdb --folder dumpdir
```

To reload an archive file into the same database it was dumped from, discarding the current contents of that database:

```
$ lt_distributed_restore.py -d postgres --clean --create --folder dumpdir
```

To dump a single table named `mytab`:

```
$ lt_distributed_dump.py -t mytab -d mydb --folder dumpdir --lt-exclude-lightdb-objects
```

## See Also

`lt_dump`, `lt_restore`, `lt_distributed_restore.py`, `ltsql`

---

# lt\_distributed\_restore.py

lt\_distributed\_restore.py — restore a LightDB database from an archive file created by lt\_distributed\_dump.py

## Synopsis

```
lt_distributed_restore.py [connection-option...] [option...]
```

## Description

lt\_distributed\_restore.py is a utility for restoring a LightDB database from an archive created by lt\_distributed\_dump.py in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow lt\_distributed\_restore.py to be selective about what is restored, or even to reorder the items prior to being restored. The archive files are designed to be portable across architectures.

Obviously, lt\_distributed\_restore.py cannot restore information that is not present in the archive file. For instance, if the archive was made using the “dump data as INSERT commands” option, lt\_distributed\_restore.py will not be able to load the data using COPY statements.

## Options

lt\_distributed\_restore.py accepts the following command line arguments.

-f *dirname*

--folder=*dirname*

Specify dump file's dir for restore

-a

--data-only

Restore only the data, not the schema (data definitions). Table data, large objects, and sequence values are restored, if present in the archive.

This option is similar to specifying --section=data.

-c

--clean

Clean (drop) database objects before recreating them. (Unless --if-exists is used, this might generate some harmless error messages, if any objects were not present in the destination database.)

-K

--recreate-schema

Output commands to directly drop schema(use cascade mode) prior to outputting the commands for creating them, more faster then normal mode. (Unless --if-exists is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

-d *dbname*

--dbname=*dbname*

Connect to database *dbname* and restore directly into the database. The *dbname* can not be a connection string.

-e  
--exit-on-error

For `lt_restore` called by `lt_distributed_restore.py`, It will exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

-F *format*  
--format=*format*

Specify format of the archive. It is not necessary to specify the format, since `lt_restore` will determine the format automatically. If specified, it can be one of the following:

c  
custom

The archive is in the custom format of `lt_dump`.

d  
directory

The archive is a directory archive.

t  
tar

The archive is a tar archive.

-I *index*  
--index=*index*

Not support yet.

-j *number-of-jobs*  
--jobs=*number-of-jobs*

Run the most time-consuming steps of `lt_restore` — those that load data, create indexes, or create constraints — concurrently, using up to *number-of-jobs* concurrent sessions. This option can dramatically reduce the time to restore a large database to a server running on a multiprocessor machine. This option is ignored when emitting a script rather than connecting directly to a database server.

Each job is one process or one thread, depending on the operating system, and uses a separate connection to the server.

The optimal value for this option depends on the hardware setup of the server, of the client, and of the network. Factors include the number of CPU cores and the disk setup. A good place to start is the number of CPU cores on the server, but values larger than that can also lead to faster restore times in many cases. Of course, values that are too high will lead to decreased performance because of thrashing.

Only the custom and directory archive formats are supported with this option. The input must be a regular file or directory (not, for example, a pipe or standard input).

-l  
--list

Not support yet.

-L *list-file*  
--use-list=*list-file*

Not support yet.



`-n schema`  
`--schema=schema`

Restore only objects that are in the named schema. Multiple schemas may be specified with multiple `-n` switches. This can be combined with the `-t` option to restore just a specific table.

`-N schema`  
`--exclude-schema=schema`

Do not restore objects that are in the named schema. Multiple schemas to be excluded may be specified with multiple `-N` switches.

When both `-n` and `-N` are given for the same schema name, the `-N` switch wins and the schema is excluded.

`-O`  
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `lt_restore` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With `-O`, any user name can be used for the initial connection, and this user will own all the created objects.

`-P function-name(argtype [, ...])`  
`--function=function-name(argtype [, ...])`

Not support yet.

`-s`  
`--schema-only`

Restore only the schema (data definitions), not data, to the extent that schema entries are present in the archive.

This option is the inverse of `--data-only`. It is similar to specifying `--section=pre-data` `--section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

`-S username`  
`--superuser=username`

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used.

`-t table`  
`--table=table`

Restore definition and/or data of only the named table. For this purpose, “table” includes views, materialized views, sequences, and foreign tables. Multiple tables can be selected by writing multiple `-t` switches. This option can be combined with the `-n` option to specify table(s) in a particular schema.

### Note

When `-t` is specified, `lt_distributed_restore.py` makes no attempt to restore any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that a specific-table restore into a clean database will succeed.

**Note**

while `lt_distributed_dump.py`'s `-t` flag will also dump subsidiary objects (such as indexes) of the selected table(s), `lt_distributed_restore.py`'s `-t` flag does not include such subsidiary objects.

`-T trigger`  
`--trigger=trigger`

Not support yet

`-v`  
`--verbose`

Specifies verbose mode.

`-V`  
`--version`

Print the `lt_distributed_restore.py` version and exit.

`-x`  
`--no-privileges`  
`--no-acl`

Prevent restoration of access privileges (grant/revoke commands).

`-l`  
`--single-transaction`

Not supported yet.

`--disable-triggers`

This option is relevant only when performing a data-only restore. It instructs `lt_restore` to execute commands to temporarily disable triggers on the target tables while the data is restored. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data restore.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So you should also specify a superuser name with `-S` or, preferably, run `lt_distributed_restore.py` as a LightDB superuser.

`--enable-row-security`

This option is relevant only when restoring the contents of a table which has row security. By default, `lt_restore` will set `row_security` to off, to ensure that all data is restored in to the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `lt_restore` to set `row_security` to on instead, allowing the user to attempt to restore the contents of the table with row security enabled. This might still fail if the user does not have the right to insert the rows from the dump into the table.

Note that this option currently also requires the dump be in `INSERT` format, as `COPY FROM` does not support row security.

`--if-exists`

Use conditional commands (i.e., add an `IF EXISTS` clause) to drop database objects. This option is not valid unless `--clean` is also specified.

`--no-comments`

Do not output commands to restore comments, even if the archive contains them.

`--no-data-for-failed-tables`

Not supported yet.

`--no-publications`

Do not output commands to restore publications, even if the archive contains them.

`--no-security-labels`

Do not output commands to restore security labels, even if the archive contains them.

`--no-subscriptions`

Do not output commands to restore subscriptions, even if the archive contains them.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

`--section=sectionname`

Only restore the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to restore all sections.

The data section contains actual table data as well as large-object definitions. Post-data items consist of definitions of indexes, triggers, rules and constraints other than validated check constraints. Pre-data items consist of all other data definition items.

`--strict-names`

Not supported yet.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly.

`--table_exists_action`

Tells `lt_distributed_restore.py` what to do if the table it is trying to create already exists. `table_exists_action` has four options: `skip`, `append`, `truncate` or `replace`, the possible values have the following effects:

`skip`

`skip` leaves the table as is and moves on to the next object.

`append`

`append` loads rows from the source and leaves existing rows unchanged.

`truncate`

`truncate` deletes existing rows and then loads rows from the source.

replace

replace deletes existing rows and then loads rows from the source.

When you use `truncate` or `replace`, ensure that rows in the affected tables are not targets of any referential constraints. When you use `append` or `truncate`, ensure that rows from the source are compatible with the existing table before performing any action.

`--parallel-num=number-of-lt_restore`

Parallel execute `lt_restore`.

`--help`

Show help about `lt_distributed_restore.py` command line arguments, and exit.

`lt_distributed_restore.py` also accepts the following command line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else 'localhost'.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or '5432'.

`-U username`

`--username=username`

User name to connect as. Defaults to the `LTUSER` environment variable, if set, or current user.

`-w`

`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

`--password`

Force `lt_distributed_restore.py` to prompt for a password before connecting to a database.

`--role=rolename`

Specifies a role name to be used to perform the restore. This option causes `lt_restore` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `lt_restore`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows restores to be performed without violating the policy.

The following command-line options control the loggin parameters.

`-l log-directory`

`--log-directory=log-directory`

Specifies the log directory path. default is '/tmp/ltAdminLogs'

`--log-level-console=log-level-console`

Specifies the console log level.

`--log-level-file=log-level-file`

Specifies the file log level.

`--log-filename=log-filename`

Specifies the log file name. Default is 'lt\_distributed\_restore-%Y-%m-%d.log'.

## Environment

LTHOST  
LTOPTIONS  
LTPORT  
LTUSER

Default connection parameters

## Diagnostics

If you have problems running `lt_distributed_restore.py`, make sure you are able to select information from the database using, for example, `ltsql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

## Notes

If your installation has any local additions to the `template1` database, be careful to dump with '`--lt-exclude-lightdb-objects`'.

The limitations of `lt_distributed_restore.py` are detailed below.

- When restoring data to a pre-existing table and the option `--disable-triggers` is used, `lt_restore` called by `lt_distributed_restore.py` emits commands to disable triggers on user tables before inserting the data, then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.
- `lt_distributed_restore.py` cannot restore large objects selectively; for instance, only those for a specific table. If an archive contains large objects, then all large objects will be restored, or none of them if they are excluded via `-t`, or other options.

See also the `lt_distributed_dump.py` documentation for details on limitations of `lt_distributed_restore.py`.

Once restored, it is wise to run `ANALYZE` on each restored table so the optimizer has useful statistics; see Section 22.1.3 and Section 22.1.6 for more information.

## Examples

Assume we have dumped a database called `mydb` into a custom-format dump file:

```
$ lt_dump -Fc -d mydb -f dumpdir --lt-exclude-lightdb-objects
```

Note that we need dump with '`--lt-exclude-lightdb-objects`' to exclude extension.

To restore the dump into a new distributed database called `newdb` :

```
$ lt_restore -d newdb -f dumpdir
```

## See Also

lt\_dump, lt\_restore, lt\_distributed\_dump.py, ltsql

---

# ltdts\_recvlogical

`ltdts_recvlogical` — is forked from `lt_recvlogical`, so it has most all behavior that in `lt_recvlogical`, such as control LightDB logical decoding streams. After that, it use `wal2sql` plugin transform the change from LightDB to Oracle database, and future will support Redis, Kafka, LightDB-A and so on.

## Synopsis

```
ltdts_recvlogical [option...]
```

## Description

`ltdts_recvlogical` controls logical decoding replication slots and streams data from such replication slots.

### Note

In HA environment, make sure you are start `$LTHOME/bin/ltdts_logicalrepl_copier.sh`.

It creates a replication-mode connection, so it is subject to the same constraints as `lt_receivewal`, plus those for logical replication (see Chapter 45).

`ltdts_recvlogical` has no equivalent to the logical decoding SQL interface's `peek` and `get` modes. It sends replay confirmations for data lazily as it receives it and on clean exit. To examine pending data on a slot without consuming it, use `pg_logical_slot_peek_changes`.

## Options

At least one of the following options must be specified to select an action:

`--create-slot`

Create a new logical replication slot with the name specified by `--slot`, using the output plugin specified by `--plugin`, for the database specified by `--dbname`.

`--drop-slot`

Drop the replication slot with the name specified by `--slot`, then exit.

`--start`

Begin streaming changes from the logical replication slot specified by `--slot`, continuing until terminated by a signal. If the server side change stream ends with a server shutdown or disconnect, retry in a loop unless `--no-loop` is specified.

The stream format is determined by the output plugin specified when the slot was created.

The connection must be to the same database used to create the slot.

`--create-slot` and `--start` can be specified together. `--drop-slot` cannot be combined with another action.

The following command-line options control the location and format of the output and other replication behavior:

-E *lsn*  
 --endpos=*lsn*

In --start mode, automatically stop replication and exit with normal exit status 0 when receiving reaches the specified LSN. If specified when not in --start mode, an error is raised.

If there's a record with LSN exactly equal to *lsn*, the record will be output.

The --endpos option is not aware of transaction boundaries and may truncate output partway through a transaction. Any partially output transaction will not be consumed and will be replayed again when the slot is next read from. Individual messages are never truncated.

-f *filename*  
 --file=*filename*

Write received and decoded transaction data into this file. Use - for stdout.

-F *interval\_seconds*  
 --fsync-interval=*interval\_seconds*

Specifies how often ltdts\_recvlogical should issue `fsync()` calls to ensure the output file is safely flushed to disk.

The server will occasionally request the client to perform a flush and report the flush position to the server. This setting is in addition to that, to perform flushes more frequently.

Specifying an interval of 0 disables issuing `fsync()` calls altogether, while still reporting progress to the server. In this case, data could be lost in the event of a crash.

-I *lsn*  
 --startpos=*lsn*

In --start mode, start replication from the given LSN. For details on the effect of this, see the documentation in Chapter 45 and Section 49.4. Ignored in other modes.

--if-not-exists

Do not error out when --create-slot is specified and a slot with the specified name already exists.

-n  
 --no-loop

When the connection to the server is lost, do not retry in a loop, just exit.

-o *name*[=*value*]  
 --option=*name*[=*value*]

Pass the option *name* to the output plugin with, if specified, the option value *value*. Which options exist and their effects depends on the used output plugin.

-P *plugin*  
 --plugin=*plugin*

When creating a slot, use the specified logical decoding output plugin. See Chapter 45. This option has no effect if the slot already exists.

-s *interval\_seconds*  
 --status-interval=*interval\_seconds*

This option has the same effect as the option of the same name in `lt_receivewal`. See the description there.



*-S slot\_name*  
*--slot=slot\_name*

In *--start* mode, use the existing logical replication slot named *slot\_name*. In *--create-slot* mode, create the slot with this name. In *--drop-slot* mode, delete the slot with this name.

*-v*  
*--no-verbose*

Disable verbose mode.

The following command-line options control the database connection parameters.

*-d dbname*  
*--dbname=dbname*

The database to connect to. See the description of the actions for what this means in detail. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options. Defaults to the user name.

*-h hostname-or-ip*  
*--host=hostname-or-ip*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else a Unix domain socket connection is attempted.

*-p port*  
*--port=port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or a compiled-in default.

*-U user*  
*--username=user*

User name to connect as. Defaults to current operating system user name.

*-w*  
*--no-password*

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

*-W*  
*--password*

Force `ltdts_recvlogical` to prompt for a password before connecting to a database.

This option is never essential, since `ltdts_recvlogical` will automatically prompt for a password if the server demands password authentication. However, `ltdts_recvlogical` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

*-T target\_type*  
*--target=target\_type*

sync to where. `only-debug|oracle|lightdb|redis|kafka|es|mysql`. LightDB 22.2 only support `only-debug(not insert oracle, just to json parse)|oracle` target.

The following command-line options control the *Oracle* database connection parameters.

-t *tnsname*  
 --tnsname=*TNSNAME*

The Oracle tnsname to connect to.

-u *Oracle username*  
 --oracle-username=*NAME*

Specifies the username to connect to *Oracle*.

-k *Oracle password*  
 --oracle-password=*PASSWORD*

Specifies the password to connect to *Oracle*.

--ignore-duplicate

Ignore duplicate error when insert into *Oracle*.

--ignore-not-found

Ignore 0 effected rows when update or delete to *Oracle*.

-z *date format*  
 --date\_format=*DATE\_FORMAT*

nls\_date\_format, default is YYYY-MM-DD HH24:MI:SS.

-Z *date format*  
 --timestamp\_format=*TIMESTAMP\_FORMAT*

nls\_timestamp\_format, default is YYYY-MM-DD HH24:MI:SS.FF6.

The following additional options are available:

-V  
 --version

Print the ltdts\_recvlogical version and exit.

-?  
 --help

Show help about ltdts\_recvlogical command line arguments, and exit.

## Environment

This utility, like most other LightDB utilities, uses the environment variables supported by libpq (see Section 32.14).

The environment variable LT\_COLOR specifies whether to use color in diagnostic messages. Possible values are always, auto and never.

## Notes

ltdts\_recvlogical will preserve group permissions on the received WAL files if group permissions are enabled on the source cluster.

## See Also

lt\_receivewal

---

# ltdts\_ora

ltdts\_ora — Ltdts\_ora is used for synchronize data from Oracle to LightDB.

## Synopsis

```
java -jar ltdts_ora.jar [option...][ example:java -jar ltdts_ora.jar --server.port=7777 --
oh=192.168.1.1:1521/test --ou=XSTRM --op=dbz --oa=DBZXOUT --lh=192.168.1.2:7000/postgres
--lu=lightdb --lp=lightdb123 ]
```

## Description

ltdts\_ora is used for synchronize data from Oracle to LightDB. Befor you run the ltdts\_ora.jar, you should finish the prepare work as blow first.

```
# Open Oracle archive log and enable XStream.
sqlplus /nolog
CONNECT sys/password@host:port AS SYSDBA;

alter system set db_recovery_file_dest_size = 100G;
alter system set db_recovery_file_dest = '/opt/oracle/oradata/
recovery_area' scope=spfile;
alter system set enable_goldengate_replication=true;
shutdown immediate;
startup mount;
alter database archivelog;
alter database open;
-- select status from v$instance;
-- Should show "Database log mode: Archive Mode"
archive log list;

exit;

# Creating an XStream Administrator user
sqlplus sys/password@host:port/SID as sysdba

CREATE TABLESPACE xstream_adm_tbs DATAFILE '/opt/oracle/oradata/
orcl/xstream_adm_tbs.dbf' SIZE 25M REUSE AUTOEXTEND ON MAXSIZE
UNLIMITED;
CREATE USER xstrmadmin IDENTIFIED BY dbz DEFAULT TABLESPACE
xstream_adm_tbs QUOTA UNLIMITED ON xstream_adm_tbs;
GRANT CREATE SESSION TO xstrmadmin;
BEGIN
  DBMS_XSTREAM_AUTH.GRANT_ADMIN_PRIVILEGE(
    grantee          => 'xstrmadmin',
    privilege_type    => 'CAPTURE',
    grant_select_privileges => TRUE,
    container         => 'ALL'
  );
END;

# Creating the connector's XStream user

CREATE TABLESPACE xstream_tbs DATAFILE '/opt/oracle/oradata/orcl/
xstream_tbs.dbf' SIZE 25M REUSE AUTOEXTEND ON MAXSIZE UNLIMITED;
```

```
CREATE USER xstrm IDENTIFIED BY dbz DEFAULT TABLESPACE xstream_tbs
  QUOTA UNLIMITED ON xstream_tbs;
GRANT CREATE SESSION TO xstrm;
GRANT SELECT ON V_$DATABASE TO xstrm;
GRANT FLASHBACK ANY TABLE TO xstrm;
GRANT SELECT ANY TABLE TO xstrm;
GRANT LOCK ANY TABLE TO xstrm;
grant select_catalog_role to xstrm;
GRANT EXECUTE_CATALOG_ROLE TO xstrm;

# alter database add supplemental log data (all) columns;
alter database add supplemental log data (primary key, unique
  index) columns;

exit;

# Create an XStream Outbound Server
sqlplus xstrmadmin/password@host:port/SID

DECLARE
tables DBMS_UTILITY.UNCL_ARRAY;
schemas DBMS_UTILITY.UNCL_ARRAY;
BEGIN
  tables(1) := NULL;
  schemas(1) := 'XSTRM';
  DBMS_XSTREAM_ADM.CREATE_OUTBOUND(
    server_name => 'dbzxout',
    table_names => tables,
    schema_names => schemas
  );
END;
/

exit;

# Configure the XStream user account to connect to the XStream
  Outbound Server
sqlplus sys/password@host:port/SID as sysdba

BEGIN
  DBMS_XSTREAM_ADM.ALTER_OUTBOUND(
    server_name => 'dbzxout',
    connect_user => 'xstrm'
  );
END;
/

exit;
```

## Options

At least one of the following options must be specified to select an action:

--oh

Specifies the host of the Oracle,the port of the Oracle,and the database name of the Oracle. The format is like 192.168.1.1:1521/ORCL

--ou

Oracle user name to connect as

--op

Oracle user password

--oa

Oracle XStream out apply name

--m

Data synchronization format mode, options are {SQL,JSON},the default value is SQL.

--sd

Where do you want to synchronize data, options are {LT,FILE},the default value is LT. [tips:LT is short for LightDB]

--lh

Specifies the host of the LightDB,the port of the LightDB,and the database name of the LightDB. The format is like 192.168.1.1:5432/postgres

--lu

LightDB user name to connect as.

--lp

LightDB user password.

--bl

Blacklist table not to synchronize, if you have more then one, separate by ','.

## See Also

ltdts\_recvlogical

---

# ltdts\_mysql

ltdts\_mysql(Experiment) — ltdts\_mysql is used for synchronize data from MySQL|MariaDB to LightDB.

## Synopsis

```
java -jar ltdts_mysql.jar [option...]
```

example:

```
java -jar ltdts_mysql.jar --server.port=8888 --zk=127.0.0.1:2181
--kafka=127.0.0.1:9092 --db=database --lh=127.0.0.1:5432/test --
lu=lightdb --lp=lightdb123 --bl=table1,table2
```

## Description

ltdts\_mysql is used for synchronize data from MySQL|MariaDB to LightDB. Before you run the ltdts\_mysql.jar, you should finish the prepare work as blow first.

## Zookeeper

You can download it from this url:<https://dlcdn.apache.org/zookeeper/zookeeper-3.8.0/apache-zookeeper-3.8.0-bin.tar.gz>

```
# unpack the package
tar -zxvf apache-zookeeper-3.8.0-bin.tar.gz
# create a new directory to store zookeeper data
mkdir zk-data
cd conf/
# copy file
cp zoo_sample.cfg zoo.cfg
# edit file
vim zoo.cfg
dataDir=/data/lightdb/zm/apache-zookeeper-3.8.0-bin/zk-data

cd apache-zookeeper-3.8.0-bin/bin
# start zookeeper server
./zkServer.sh start
```

## Kafka

You can download kafka from this url:[https://downloads.apache.org/kafka/3.3.1/kafka\\_2.12-3.3.1.tgz](https://downloads.apache.org/kafka/3.3.1/kafka_2.12-3.3.1.tgz)

You can download Debezium for mysql from this url:<https://repol.maven.org/maven2/io/debezium/debezium-connector-mysql/1.9.7.Final/debezium-connector-mysql-1.9.7.Final-plugin.tar.gz>

```
# unpack the kafka package
tar -zxvf kafka_2.12-3.3.1.tgz
# unpack the debezium package
unzip debezium-debezium-connector-mysql-1.9.7.zip

# create a new directory to store kafka data
mkdir kafka-data

# create a new directory to store kafka plugin
mkdir kafka-plugin

# move the debezium directory to kafka-plugin
mv debezium-debezium-connector-mysql-1.9.7 kafka-plugin/

# then the kafka directory is like below
--kafka_2.12-3.3.1
  --config
  --bin
  --kafka-data
  --kafka-plugin
    --debezium-debezium-connector-mysql-1.9.7

# edit the kafka's server.properties
vim server.properties
# please change the value like this
log.dirs=/data/lightdb/zm/kafka_2.12-3.3.1/kafka-data
# please change the value like this,use your address
listeners=PLAINTEXT://Your IP:9092

# edit the kafka's connect-distributed.properties
vim connect-distributed.properties
# please change the value like this,use your address
bootstrap.servers=Your IP:9092
listeners=HTTP://Your IP:8083
# please change the value like this
plugin.path=/data/lightdb/zm/kafka_2.12-3.3.1/kafka-plugin

# start kafka
cd kafka_2.12-3.3.1/bin
./kafka-server-start.sh -daemon ../config/server.properties

# start kafka connect
./connect-distributed.sh -daemon ../config/connect-
distributed.properties
```

## Debezium

```
# you should check kafka connect is available first,use your IP
address
curl -H "Accept:application/json" IP:8083/

# list all the kafka connectors
```



```

curl -H "Accept:application/json" IP:8083/connectors

# deploying the MySQL connector
curl -i -X POST -H "Accept:application/json" -H "Content-Type:application/json" IP:8083/connectors/ -d '{
  "name": "test-connector",
  "config": {
    "connector.class":
"io.debezium.connector.mysql.MySqlConnector",
    "tasks.max": "1",
    "database.hostname": "mysql host,example:127.0.0.1",
    "database.port": "3306",
    "database.user": "mysql user",
    "database.password": "mysql password",
    "database.server.id": "184077",
    "database.server.name": "mysql database name,example:acm",
    "database.include.list": "mysql database name,example:acm",
    "database.history.kafka.bootstrap.servers": "your kafka IP
and port,example:127.0.0.1:9092",
    "database.history.kafka.topic": "schema-changes.acm",
    "include.schema.changes": "true",
    "decimal.handling.mode": "string",
    "include.schema.comments": "false"
  }
}'

# delete the MySQL connector
curl -v -X DELETE IP:8083/connectors/test-connector

# check the connector's work status
curl -i IP:8083/connectors/test-connector/status

# view the connector's config
curl -i IP:8083/connectors/test-connector/config

```

## Options

At least one of the following options must be specified to select an action:

--zk

Specifies the host of the Zookeeper and the port of the Zookeeper. The format is like 127.0.0.1:2181

--kafka

Specifies the host of the Kafka and the port of the Kafka. The format is like 127.0.0.1:9092

--db

The source database you want to synchronize. It can also be understood as kafka topic, because the kafka is been used.

--lh

Specifies the host of the LightDB, the port of the LightDB, and the database name of the LightDB. The format is like 192.168.1.1:5432/postgres

--lu

LightDB user name to connect as.

--lp

LightDB user password.

--bl

Blacklist table not to synchronize, if you have more than one, separate by ','.

## See Also

[ltdts\\_recvlogical](#)

---

# ltldr

ltldr — Compatible with ORACLE# loads data from external files into tables of an LightDB database#

## Synopsis

```
ltldr [connection-option...] [option...]
```

## ##

ltldr is a small and flexible tool that loads data from external files into tables of an LightDB database#

ltldr can specify the format of the data file. This includes the separator of field and field, row and row.

ltldr including txt and csv, and also fixed length of record.

ltldr supports writing logs to specified files.

## Options

The following command-line options control the content and format of the load.

*user*=

Specify the user who loads the table.

*dbname*=

Specify the dbname who loads the table.

*host*=

Specify the host who loads the table.

*port*=

Specify the port who loads the table.

*password*=

Specify the password who loads the table.

*control*=

Specifies the path to a control file that describes how to load data.

*log*=

Specifies the path to the log file where log information about the loading process is stored.

## ##

Connect to the database according to the control file LTLDR000003.ct1 loads data from external files into tables of an testdb database#

```
$ ltldr control=/home/lightdb/ltldrtest/LTLDR000003.ct1
host=127.0.0.1 port=5432 userid=lightdb password=111111
dbname=testdb
```

## Control file syntax

```
[ OPTIONS ( option [ , ... ] ) ]
LOAD DATA
[ CHARACTERSET charset ]
INFILE 'filename' [ "STR 'char'" ] [ "FIX count" ]
[ APPEND | INSERT | REPLACE ]
INTO TABLE tablename
[ WHEN condition ]
[ FIELDS [CSV] TERMINATED BY 'char' ]
[ [ OPTIONALLY ] ENCLOSED BY 'char' ]
[ TRAILING NULLCOLS ]
(
    column1 constant '321',
    column2 position(5:10),
    column3 position(12:14),
    ignore1 FILLER
    column4 FILLER
    [ ... ]
)
```

### OPTIONS

The supported options are skip and load. Skip indicates how many rows to skip, and load indicates how many rows to import at most.

### CHARACTERSET

For the character set of the data file, you need to ensure that the character set of the control file (obtaining the character set from the environment) and the data file are consistent.

### INFILE

Specify the path to the imported data file

### STR

Specify the line separator, the default is '\n', supports multi-byte and hexadecimal, optional

### FIX

Specify a fixed length of data to be processed as one row, optional;

### APPEND | INSERT | REPLACE

APPEND appends; INSERT inserts, can only be imported into an empty table; REPLACE replaces, clears the table before importing

### INTO TABLE

Specify the imported table name

### WHEN

Determine whether a certain row can be imported, supports equal and not equal operations, optional. Support column name or character range judgment;

CSV

Indicates using CSV format to parse data files, optional;

TERMINATED BY

Specify the column separator, the default is '\t', supports multi-byte and hexadecimal, optional

ENCLOSED BY

When CSV is specified, ENCLOSED BY represents the field bracket, only supports one byte, and is optional;

TRAILING NULLCOLS

When the number of data file columns is not enough, the remaining columns in the table are null and optional;

constant

Indicates that the field uses a fixed value and uses single quotes to quote constants, optional;

position

Indicates filling the field with a character range, optional;

FILLER

Indicates that the column value is skipped and no data is filled, optional;

---

# ltuldr

ltuldr — Compatible with ORACLE, obtaining all information of a table from the LightDB database.

## Synopsis

```
ltuldr [connection-option...] [option...]
```

## Description

ltuldr is a small and flexible tool that export LightDB data. It can directly export all data of a specified table, or use SQL statement to export specific data.

ltuldr can specify the format of the exported data. This includes the separator of field and field, row and row.

The file formats currently supported by ltuldr, including txt and csv, can also output data directly to standard devices.

ltuldr supports writing logs to specified files.

## Options

The following command-line options control the content and format of the output.

*user*=

Specify the user who exports the table.

*dbname*=

Specify the dbname who exports the table.

*host*=

Specify the host who exports the table.

*port*=

Specify the port who exports the table.

*password*=

Specify the password who exports the table.

*query*=

Specify the information to export the table. You can use the table name directly or use SQL statements.

Query and connection information are necessary for ltuldr. You can also use the following sql parameters to specify SQL statements.

*sql*=

Specify the file address of the SQL statement, which should be used together with the connection information.

If the SQL statement is very complex or long, it is difficult to specify it on the command line. At this time, you can write a SQL file containing complex SQL (note that there should be no semicolon or backslash at the end of the SQL statement), and then tell the user to read the complex SQL statement from the specified SQL file for data export.

The sql parameter and query parameter cannot be used together.

field=

Specify the separator between fields in the export file. The default value is ',';

The field separator is usually one character, but it can actually be multiple characters; In addition, visible, printable characters, strings, and invisible characters can be used as separators.

record=

Specify the separator between lines in the export file. The default value is '\n';

The record and file separators are named in the same way.

file=

Specify the name of the exported file. If the first character of the file surface is a plus sign (+), it means that added after the existing file. Otherwise, a new file will be generated. If there is already a file with the same name, the existing file will be overwritten. If not specified, the default is lowercase "uldrdata. txt". The storage path is the current directory where ltuldr is running.

There are several special format codes in the file option, which can be used to specify dynamic file names (with date information in the generated file names). Reasonable use of these format codes can meet some specific needs and reduce the workload of script writing. %Y#%y:four digit year representing the current time; %M#%m:the two digit month representing the current time; %D#%d:two digit day representing the current time; %W#%W:the number representing days in a week at the current time; %B#%b:500000 is a batch, which is also related to the option batch. If batch is 2, the count will be increased by one for every 1 million exported.

log=

Specify the file for the exported log. Other usage is the same as file paramter, except that %B and %b are not allowed by log files.

batch=

Specify the maximum saved batch of a file, 500000 is a batch. When writing files in batches, the file name must be dynamic, preferably with %B and %b added. Otherwise, the data in the original file will be overwritten.

## Examples

Connect to the database, query the pg\_class table and write the results to the default file uldrdata. txt:

```
$ ltuldr user=lightdb dbname=postgres host=127.0.0.1 port=5432
password=1 query=pg_class
```

Write the results to the specified file lightdb. txt:

```
$ ltuldr user=lightdb dbname=postgres host=127.0.0.1 port=5432
password=1 query=pg_class file=lightdb.txt
```

Write the log file to the dynamic file %Y\_%M\_%D.log:

```
$ ltuldr user=lightdb dbname=postgres host=127.0.0.1 port=5432
password=1 query=pg_class file=lightdb.txt log=%Y_%M_%D.log
```

All fields in the table are written to the file lightdb. txt:

```
$ ltuldr user=lightdb dbname=postgres host=127.0.0.1 port=5432
password=1 query=pg_class file=lightdb.txt log=%Y_%M_%D.log
head=yes
```

Get the data of two batches at a time and write it to the file lightdb. txt:

```
$ ltuldr user=lightdb dbname=postgres host=127.0.0.1 port=5432
password=1 query=pg_class file=lightdb.txt log=%Y_%M_%D.log
head=yes batch=2
```



---

# lt\_basebackup

lt\_basebackup — take a base backup of a LightDB cluster

## Synopsis

```
lt_basebackup [option...]
```

## Description

lt\_basebackup is used to take a base backup of a running LightDB database cluster. The backup is taken without affecting other clients of the database, and can be used both for point-in-time recovery (see Section 23.3) and as the starting point for a log-shipping or streaming-replication standby server (see Section 24.2).

lt\_basebackup makes an exact copy of the database cluster's files, while making sure the server is put into and out of backup mode automatically. Backups are always taken of the entire database cluster; it is not possible to back up individual databases or database objects. For selective backups, another tool such as lt\_dump must be used.

The backup is made over a regular LightDB connection that uses the replication protocol. The connection must be made with a user ID that has REPLICATION permissions (see Section 19.2) or is a superuser, and lt\_hba.conf must permit the replication connection. The server must also be configured with max\_wal\_senders set high enough to provide at least one walsender for the backup plus one for WAL streaming (if used).

There can be multiple lt\_basebackups running at the same time, but it is usually better from a performance point of view to take only one backup, and copy the result.

lt\_basebackup can make a base backup from not only a primary server but also a standby. To take a backup from a standby, set up the standby so that it can accept replication connections (that is, set max\_wal\_senders and hot\_standby, and configure its lt\_hba.conf appropriately). You will also need to enable full\_page\_writes on the primary.

Note that there are some limitations in taking a backup from a standby:

- The backup history file is not created in the database cluster backed up.
- lt\_basebackup cannot force the standby to switch to a new WAL file at the end of backup. When you are using -X none, if write activity on the primary is low, lt\_basebackup may need to wait a long time for the last WAL file required for the backup to be switched and archived. In this case, it may be useful to run pg\_switch\_wal on the primary in order to trigger an immediate WAL file switch.
- If the standby is promoted to be primary during backup, the backup fails.
- All WAL records required for the backup must contain sufficient full-page writes, which requires you to enable full\_page\_writes on the primary and not to use a tool like pg\_compresslog as archive\_command to remove full-page writes from WAL files.

Whenever lt\_basebackup is taking a base backup, the server's pg\_stat\_progress\_basebackup view will report the progress of the backup. See Section 25.4.5 for details.

## Options

The following command-line options control the location and format of the output:

`-D directory`  
`--pgdata=directory`

Sets the target directory to write the output to. `lt_basebackup` will create this directory (and any missing parent directories) if it does not exist. If it already exists, it must be empty.

When the backup is in tar format, the target directory may be specified as `-` (dash), causing the tar file to be written to `stdout`.

This option is required.

`-F format`  
`--format=format`

Selects the format for the output. *format* can be one of the following:

`p`  
`plain`

Write the output as plain files, with the same layout as the source server's data directory and tablespaces. When the cluster has no additional tablespaces, the whole database will be placed in the target directory. If the cluster contains additional tablespaces, the main data directory will be placed in the target directory, but all other tablespaces will be placed in the same absolute path as they have on the source server. (See `--tablespace-mapping` to change that.)

This is the default format.

`t`  
`tar`

Write the output as tar files in the target directory. The main data directory's contents will be written to a file named `base.tar`, and each other tablespace will be written to a separate tar file named after that tablespace's OID.

If the target directory is specified as `-` (dash), the tar contents will be written to standard output, suitable for piping to (for example) `gzip`. This is only allowed if the cluster has no additional tablespaces and WAL streaming is not used.

`-R`  
`--write-recovery-conf`

Creates a `standby.signal` file and appends connection settings to the `lightdb.auto.conf` file in the target directory (or within the base archive file when using tar format). This eases setting up a standby server using the results of the backup.

The `lightdb.auto.conf` file will record the connection settings and, if specified, the replication slot that `lt_basebackup` is using, so that streaming replication will use the same settings later on.

`-T olddir=newdir`  
`--tablespace-mapping=olddir=newdir`

Relocates the tablespace in directory *olddir* to *newdir* during the backup. To be effective, *olddir* must exactly match the path specification of the tablespace as it is defined on the source server. (But it is not an error if there is no tablespace in *olddir* on the source server.) Meanwhile *newdir* is a directory in the receiving host's filesystem. As with the main target directory, *newdir* need not exist already, but if it does exist it must be empty. Both *olddir* and *newdir* must be absolute paths. If either path needs to contain an equal sign (=), precede that with a backslash. This option can be specified multiple times for multiple tablespaces.

If a tablespace is relocated in this way, the symbolic links inside the main data directory are updated to point to the new location. So the new data directory is ready to be used for a new server instance with all tablespaces in the updated locations.

Currently, this option only works with plain output format; it is ignored if tar format is selected.

`--waldir=waldir`

Sets the directory to write WAL (write-ahead log) files to. By default WAL files will be placed in the `lt_wal` subdirectory of the target directory, but this option can be used to place them elsewhere. *waldir* must be an absolute path. As with the main target directory, *waldir* need not exist already, but if it does exist it must be empty. This option can only be specified when the backup is in plain format.

`-X method`

`--wal-method=method`

Includes the required WAL (write-ahead log) files in the backup. This will include all write-ahead logs generated during the backup. Unless the method `none` is specified, it is possible to start a postmaster in the target directory without the need to consult the log archive, thus making the output a completely standalone backup.

The following *methods* for collecting the write-ahead logs are supported:

`n`

`none`

Don't include write-ahead logs in the backup.

`f`

`fetch`

The write-ahead log files are collected at the end of the backup. Therefore, it is necessary for the source server's `wal_keep_size` parameter to be set high enough that the required log data is not removed before the end of the backup. If the required log data has been recycled before it's time to transfer it, the backup will fail and be unusable.

When tar format is used, the write-ahead log files will be included in the `base.tar` file.

`s`

`stream`

Stream write-ahead log data while the backup is being taken. This method will open a second connection to the server and start streaming the write-ahead log in parallel while running the backup. Therefore, it will require two replication connections not just one. As long as the client can keep up with the write-ahead log data, using this method requires no extra write-ahead logs to be saved on the source server.

When tar format is used, the write-ahead log files will be written to a separate file named `lt_wal.tar` (if the server is a version earlier than 10, the file will be named `pg_xlog.tar`).

This value is the default.

`-z`

`--gzip`

Enables gzip compression of tar file output, with the default compression level. Compression is only available when using the tar format, and the suffix `.gz` will automatically be added to all tar filenames.

`-Z level`  
`--compress=level`

Enables gzip compression of tar file output, and specifies the compression level (0 through 9, 0 being no compression and 9 being best compression). Compression is only available when using the tar format, and the suffix `.gz` will automatically be added to all tar filenames.

The following command-line options control the generation of the backup and the invocation of the program:

`-c fast/spread`  
`--checkpoint=fast/spread`

Sets checkpoint mode to fast (immediate) or spread (the default) (see Section 23.3.3).

`-C`  
`--create-slot`

Specifies that the replication slot named by the `--slot` option should be created before starting the backup. An error is raised if the slot already exists.

`-l label`  
`--label=label`

Sets the label for the backup. If none is specified, a default value of “`lt_basebackup base backup`” will be used.

`-n`  
`--no-clean`

By default, when `lt_basebackup` aborts with an error, it removes any directories it might have created before discovering that it cannot finish the job (for example, the target directory and write-ahead log directory). This option inhibits tidying-up and is thus useful for debugging.

Note that tablespace directories are not cleaned up either way.

`-N`  
`--no-sync`

By default, `lt_basebackup` will wait for all files to be written safely to disk. This option causes `lt_basebackup` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the base backup corrupt. Generally, this option is useful for testing but should not be used when creating a production installation.

`-P`  
`--progress`

Enables progress reporting. Turning this on will deliver an approximate progress report during the backup. Since the database may change during the backup, this is only an approximation and may not end at exactly 100%. In particular, when WAL log is included in the backup, the total amount of data cannot be estimated in advance, and in this case the estimated target size will increase once it passes the total estimate without WAL.

`-r rate`  
`--max-rate=rate`

Sets the maximum transfer rate at which data is collected from the source server. This can be useful to limit the impact of `lt_basebackup` on the server. Values are in kilobytes per second. Use a suffix of `M` to indicate megabytes per second. A suffix of `k` is also accepted, and has no effect. Valid values are between 32 kilobytes per second and 1024 megabytes per second.

This option always affects transfer of the data directory. Transfer of WAL files is only affected if the collection method is `fetch`.

`-S slotname`  
`--slot=slotname`

This option can only be used together with `-X stream`. It causes WAL streaming to use the specified replication slot. If the base backup is intended to be used as a streaming-replication standby using a replication slot, the standby should then use the same replication slot name as `primary_slot_name`. This ensures that the primary server does not remove any necessary WAL data in the time between the end of the base backup and the start of streaming replication on the new standby.

The specified replication slot has to exist unless the option `-C` is also used.

If this option is not specified and the server supports temporary replication slots (version 10 and later), then a temporary replication slot is automatically used for WAL streaming.

`-v`  
`--verbose`

Enables verbose mode. Will output some extra steps during startup and shutdown, as well as show the exact file name that is currently being processed if progress reporting is also enabled.

`--manifest-checksums=algorithm`

Specifies the checksum algorithm that should be applied to each file included in the backup manifest. Currently, the available algorithms are `NONE`, `CRC32C`, `SHA224`, `SHA256`, `SHA384`, and `SHA512`. The default is `CRC32C`.

If `NONE` is selected, the backup manifest will not contain any checksums. Otherwise, it will contain a checksum of each file in the backup using the specified algorithm. In addition, the manifest will always contain a `SHA256` checksum of its own contents. The `SHA` algorithms are significantly more CPU-intensive than `CRC32C`, so selecting one of them may increase the time required to complete the backup.

Using a `SHA` hash function provides a cryptographically secure digest of each file for users who wish to verify that the backup has not been tampered with, while the `CRC32C` algorithm provides a checksum that is much faster to calculate; it is good at catching errors due to accidental changes but is not resistant to malicious modifications. Note that, to be useful against an adversary who has access to the backup, the backup manifest would need to be stored securely elsewhere or otherwise verified not to have been modified since the backup was taken.

`It_verifybackup` can be used to check the integrity of a backup against the backup manifest.

`--manifest-force-encode`

Forces all filenames in the backup manifest to be hex-encoded. If this option is not specified, only non-UTF8 filenames are hex-encoded. This option is mostly intended to test that tools which read a backup manifest file properly handle this case.

`--no-estimate-size`

Prevents the server from estimating the total amount of backup data that will be streamed, resulting in the `backup_total` column in the `pg_stat_progress_basebackup` view always being `NULL`.

Without this option, the backup will start by enumerating the size of the entire database, and then go back and send the actual contents. This may make the backup take slightly longer, and in particular it will take longer before the first data is sent. This option is useful to avoid such estimation time if it's too long.

This option is not allowed when using `--progress`.

`--no-manifest`

Disables generation of a backup manifest. If this option is not specified, the server will generate and send a backup manifest which can be verified using `It_verifybackup`. The manifest is a list of every file present in the backup with the exception of any WAL files that may be included. It also stores the size, last modification time, and an optional checksum for each file.

`--no-slot`

Prevents the creation of a temporary replication slot for the backup.

By default, if log streaming is selected but no slot name is given with the `-S` option, then a temporary replication slot is created (if supported by the source server).

The main purpose of this option is to allow taking a base backup when the server has no free replication slots. Using a replication slot is almost always preferred, because it prevents needed WAL from being removed by the server during the backup.

`--no-verify-checksums`

Disables verification of checksums, if they are enabled on the server the base backup is taken from.

By default, checksums are verified and checksum failures will result in a non-zero exit status. However, the base backup will not be removed in such a case, as if the `--no-clean` option had been used. Checksum verification failures will also be reported in the `pg_stat_database` view.

The following command-line options control the connection to the source server:

`-d connstr`

`--dbname=connstr`

Specifies parameters used to connect to the server, as a connection string; these will override any conflicting command line options.

The option is called `--dbname` for consistency with other client applications, but because `It_basebackup` doesn't connect to any particular database in the cluster, any database name in the connection string will be ignored.

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for a Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or a compiled-in default.

`-s interval`

`--status-interval=interval`

Specifies the number of seconds between status packets sent back to the source server. Smaller values allow more accurate monitoring of backup progress from the server. A value of zero disables periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout-based disconnects. The default value is 10 seconds.

`-U username`  
`--username=username`

Specifies the user name to connect as.

`-w`  
`--no-password`

Prevents issuing a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Forces `lt_basebackup` to prompt for a password before connecting to the source server.

This option is never essential, since `lt_basebackup` will automatically prompt for a password if the server demands password authentication. However, `lt_basebackup` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Other options are also available:

`-V`  
`--version`

Prints the `lt_basebackup` version and exits.

`-?`  
`--help`

Shows help about `lt_basebackup` command line arguments, and exits.

## Environment

This utility, like most other LightDB utilities, uses the environment variables supported by `libpq` (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

At the beginning of the backup, a checkpoint needs to be performed on the source server. This can take some time (especially if the option `--checkpoint=fast` is not used), during which `lt_basebackup` will appear to be idle.

The backup will include all files in the data directory and tablespaces, including the configuration files and any additional files placed in the directory by third parties, except certain temporary files managed by LightDB. But only regular files and directories are copied, except that symbolic links used for tablespaces are preserved. Symbolic links pointing to certain directories known to LightDB are copied as empty directories. Other symbolic links and special device files are skipped. See Section 49.4 for the precise details.

In plain format, tablespaces will be backed up to the same path they have on the source server, unless the option `--tablespace-mapping` is used. Without this option, running a plain format base backup on the same host as the server will not work if tablespaces are in use, because the backup would have to be written to the same directory locations as the original tablespaces.

When tar format is used, it is the user's responsibility to unpack each tar file before starting a LightDB server that uses the data. If there are additional tablespaces, the tar files for them need to be unpacked in the correct locations. In this case the symbolic links for those tablespaces will be created by the server according to the contents of the `tablespace_map` file that is included in the `base.tar` file.

lt\_basebackup works with servers of the same or an older major version, down to 9.1. However, WAL streaming mode (`-X stream`) only works with server version 9.3 and later, and tar format (`--format=tar`) only works with server version 9.5 and later.

lt\_basebackup will preserve group permissions for data files if group permissions are enabled on the source cluster.

## Examples

To create a base backup of the server at `mydbserver` and store it in the local directory `/usr/local/lightdb-x/data`:

```
$ lt_basebackup -h mydbserver -D /usr/local/lightdb-x/data
```

To create a backup of the local server with one compressed tar file for each tablespace, and store it in the directory `backup`, showing a progress report while running:

```
$ lt_basebackup -D backup -Ft -z -P
```

To create a backup of a single-tablespace local database and compress this with bzip2:

```
$ lt_basebackup -D - -Ft -X fetch | bzip2 > backup.tar.bz2
```

(This command will fail if there are multiple tablespaces in the database.)

To create a backup of a local database where the tablespace in `/opt/ts` is relocated to `./backup/ts`:

```
$ lt_basebackup -D backup/data -T /opt/ts=$(pwd)/backup/ts
```

## See Also

lt\_dump



---

# lt\_config

lt\_config — retrieve information about the installed version of LightDB

## Synopsis

```
lt_config [option...]
```

## Description

The `lt_config` utility prints configuration parameters of the currently installed version of LightDB. It is intended, for example, to be used by software packages that want to interface to LightDB to facilitate finding the required header files and libraries.

## Options

To use `lt_config`, supply one or more of the following options:

`--bindir`

Print the location of user executables. Use this, for example, to find the `ltsql` program. This is normally also the location where the `lt_config` program resides.

`--docdir`

Print the location of documentation files.

`--htmldir`

Print the location of HTML documentation files.

`--includedir`

Print the location of C header files of the client interfaces.

`--pkgincludedir`

Print the location of other C header files.

`--includedir-server`

Print the location of C header files for server programming.

`--libdir`

Print the location of object code libraries.

`--pkglibdir`

Print the location of dynamically loadable modules, or where the server would search for them. (Other architecture-dependent data files might also be installed in this directory.)

`--localedir`

Print the location of locale support files. (This will be an empty string if locale support was not configured when LightDB was built.)

--mandir

Print the location of manual pages.

--sharedir

Print the location of architecture-independent support files.

--sysconfdir

Print the location of system-wide configuration files.

--pgxs

Print the location of extension makefiles.

--configure

Print the options that were given to the `configure` script when LightDB was configured for building. This can be used to reproduce the identical configuration, or to find out with what options a binary package was built. (Note however that binary packages often contain vendor-specific custom patches.) See also the examples below.

--cc

Print the value of the `CC` variable that was used for building LightDB. This shows the C compiler used.

--cppflags

Print the value of the `CPPFLAGS` variable that was used for building LightDB. This shows C compiler switches needed at preprocessing time (typically, `-I` switches).

--cflags

Print the value of the `CFLAGS` variable that was used for building LightDB. This shows C compiler switches.

--cflags\_sl

Print the value of the `CFLAGS_SL` variable that was used for building LightDB. This shows extra C compiler switches used for building shared libraries.

--ldflags

Print the value of the `LDFLAGS` variable that was used for building LightDB. This shows linker switches.

--ldflags\_ex

Print the value of the `LDFLAGS_EX` variable that was used for building LightDB. This shows linker switches used for building executables only.

--ldflags\_sl

Print the value of the `LDFLAGS_SL` variable that was used for building LightDB. This shows linker switches used for building shared libraries only.

--libs

Print the value of the `LIBS` variable that was used for building LightDB. This normally contains `-l` switches for external libraries linked into LightDB.

`--version`

Print the version of LightDB.

`-?`

`--help`

Show help about `lt_config` command line arguments, and exit.

If more than one option is given, the information is printed in that order, one item per line. If no options are given, all available information is printed, with labels.

## Notes

The options `--docdir`, `--pkgincludedir`, `--localedir`, `--mandir`, `--sharedir`, `--sysconfdir`, `--cc`, `--cppflags`, `--cflags`, `--cflags_sl`, `--ldflags`, `--ldflags_sl`, and `--libs` were added in LightDB 8.1. The option `--htmldir` was added in LightDB 8.4. The option `--ldflags_ex` was added in LightDB 9.0.

## Example

To reproduce the build configuration of the current LightDB installation, run the following command:

```
eval `./configure `lt_config --configure`
```

The output of `lt_config --configure` contains shell quotation marks so arguments with spaces are represented correctly. Therefore, using `eval` is required for proper results.

---

# lt\_dump

lt\_dump — extract a LightDB database into a script file or other archive file

## Synopsis

```
lt_dump [connection-option...] [option...] [dbname]
```

## Description

lt\_dump is a utility for backing up a LightDB database. It makes consistent backups even if the database is being used concurrently. lt\_dump does not block other users accessing the database (readers or writers).

lt\_dump only dumps a single database. To back up an entire cluster, or to back up global objects that are common to all databases in a cluster (such as roles and tablespaces), use lt\_dumpall.

Dumps can be output in script or archive file formats. Script dumps are plain-text files containing the SQL commands required to reconstruct the database to the state it was in at the time it was saved. To restore from such a script, feed it to ltsql. Script files can be used to reconstruct the database even on other machines and other architectures; with some modifications, even on other SQL database products.

The alternative archive file formats must be used with lt\_restore to rebuild the database. They allow lt\_restore to be selective about what is restored, or even to reorder the items prior to being restored. The archive file formats are designed to be portable across architectures.

When used with one of the archive file formats and combined with lt\_restore, lt\_dump provides a flexible archival and transfer mechanism. lt\_dump can be used to backup an entire database, then lt\_restore can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file formats are the “custom” format (-Fc) and the “directory” format (-Fd). They allow for selection and reordering of all archived items, support parallel restoration, and are compressed by default. The “directory” format is the only format that supports parallel dumps.

lt\_dump support dump plorasql packages and procedures, like dump tables and so on.

While running lt\_dump, one should examine the output for any warnings (printed on standard error), especially in light of the limitations listed below.

## Options

The following command-line options control the content and format of the output.

*dbname*

Specifies the name of the database to be dumped. If this is not specified, the environment variable LTDATABASE is used. If that is not set, the user name specified for the connection is used.

-a

--data-only

Dump only the data, not the schema (data definitions). Table data, large objects, and sequence values are dumped.

This option is similar to, but for historical reasons not identical to, specifying --section=data.

`-b`  
`--blobs`

Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified. The `-b` switch is therefore only useful to add large objects to dumps where a specific schema or table has been requested. Note that blobs are considered data and therefore will be included when `--data-only` is used, but not when `--schema-only` is.

`-B`  
`--no-blobs`

Exclude large objects in the dump.

When both `-b` and `-B` are given, the behavior is to output large objects, when data is being dumped, see the `-b` documentation.

`-c`  
`--clean`

Output commands to clean (drop) database objects prior to outputting the commands for creating them. (Unless `--if-exists` is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`-K`  
`--recreate-schema`

Output commands to directly drop schema(use cascade mode) prior to outputting the commands for creating them, more faster then normal mode. (Unless `--if-exists` is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`-C`  
`--create`

Begin the output with a command to create the database itself and reconnect to the created database. (With a script of this form, it doesn't matter which database in the destination installation you connect to before running the script.) If `--clean` is also specified, the script drops and recreates the target database before reconnecting to it.

With `--create`, the output also includes the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also dumped, unless `--no-acl` is specified.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

Lightdb 23.3 introduced a new database level GUC parameter `lightdb_ascii_zero_store_value`, the value is stored in table `lt_database_ext`, If we run `lt_dump` with `-C` (or run `lt_dumpall`), this option would be included in create database statement.

For more information about GUC `lightdb_ascii_zero_store_value`, See `lightdb_ascii_zero_store_value`

`-E encoding`  
`--encoding=encoding`

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `LTCLIENTENCODING` environment variable to the desired dump encoding.)

`-f file`  
`--file=file`

Send output to the specified file. This parameter can be omitted for file based output formats, in which case the standard output is used. It must be given for the directory output format however, where it specifies the target directory instead of a file. In this case the directory is created by `lt_dump` and must not exist before.

`-F format`  
`--format=format`

Selects the format of the output. *format* can be one of the following:

`p`  
`plain`

Output a plain-text SQL script file (the default).

`c`  
`custom`

Output a custom-format archive suitable for input into `lt_restore`. Together with the directory output format, this is the most flexible output format in that it allows manual selection and reordering of archived items during restore. This format is also compressed by default.

`d`  
`directory`

Output a directory-format archive suitable for input into `lt_restore`. This will create a directory with one file for each table and blob being dumped, plus a so-called Table of Contents file describing the dumped objects in a machine-readable format that `lt_restore` can read. A directory format archive can be manipulated with standard Unix tools; for example, files in an uncompressed archive can be compressed with the `gzip` tool. This format is compressed by default and also supports parallel dumps.

`t`  
`tar`

Output a `tar`-format archive suitable for input into `lt_restore`. The `tar` format is compatible with the directory format: extracting a `tar`-format archive produces a valid directory-format archive. However, the `tar` format does not support compression. Also, when using `tar` format the relative order of table data items cannot be changed during restore.

`-j njobs`  
`--jobs=njobs`

Run the dump in parallel by dumping *njobs* tables simultaneously. This option may reduce the time needed to perform the dump but it also increases the load on the database server. You can only use this option with the directory output format because this is the only output format where multiple processes can write their data at the same time.

`lt_dump` will open *njobs* + 1 connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Requesting exclusive locks on database objects while running a parallel dump could cause the dump to fail. The reason is that the `lt_dump` master process requests shared locks on the objects

that the worker processes are going to dump later in order to make sure that nobody deletes them and makes them go away while the dump is running. If another client then requests an exclusive lock on a table, that lock will not be granted but will be queued waiting for the shared lock of the master process to be released. Consequently any other access to the table will not be granted either and will queue after the exclusive lock request. This includes the worker process trying to dump the table. Without any precautions this would be a classic deadlock situation. To detect this conflict, the `lt_dump` worker process requests another shared lock using the `NOWAIT` option. If the worker process is not granted this shared lock, somebody else must have requested an exclusive lock in the meantime and there is no way to continue with the dump, so `lt_dump` has no choice but to abort the dump.

For a consistent backup, the database server needs to support synchronized snapshots, a feature that was introduced in LightDB 9.2 for primary servers and 10 for standbys. With this feature, database clients can ensure they see the same data set even though they use different connections. `lt_dump -j` uses multiple database connections; it connects to the database once with the master process and once again for each worker job. Without the synchronized snapshot feature, the different worker jobs wouldn't be guaranteed to see the same data in each connection, which could lead to an inconsistent backup.

If you want to run a parallel dump of a pre-9.2 server, you need to make sure that the database content doesn't change from between the time the master connects to the database until the last worker job has connected to the database. The easiest way to do this is to halt any data modifying processes (DDL and DML) accessing the database before starting the backup. You also need to specify the `--no-synchronized-snapshots` parameter when running `lt_dump -j` against a pre-9.2 LightDB server.

`-n pattern`  
`--schema=pattern`

Dump only schemas matching *pattern*; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `ltsql's \d` commands (see Patterns below), so multiple schemas can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see Examples below.

### Note

When `-n` is specified, `lt_dump` makes no attempt to dump any other database objects that the selected schema(s) might depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

### Note

Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.

`-N pattern`  
`--exclude-schema=pattern`

Do not dump any schemas matching *pattern*. The pattern is interpreted according to the same rules as for `-n`. `-N` can be given more than once to exclude schemas matching any of several patterns.

When both `-n` and `-N` are given, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

`-O`  
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `lt_dump` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`-R`  
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`  
`--schema-only`

Dump only the object definitions (schema), not data.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data` `--section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

To exclude table data for only a subset of tables in the database, see `--exclude-table-data`.

`-S username`  
`--superuser=username`

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

`-t pattern`  
`--table=pattern`

Dump only tables with names matching *pattern*. Multiple tables can be selected by writing multiple `-t` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `ltsql's \d` commands (see Patterns below), so multiple tables can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see Examples below.

As well as tables, this option can be used to dump the definition of matching views, materialized views, foreign tables, and sequences. It will not dump the contents of views or materialized views, and the contents of foreign tables will only be dumped if the corresponding foreign server is specified with `--include-foreign-data`.

The `-n` and `-N` switches have no effect when `-t` is used, because tables selected by `-t` will be dumped regardless of those switches, and non-table objects will not be dumped.

### Note

When `-t` is specified, `lt_dump` makes no attempt to dump any other database objects that the selected table(s) might depend upon. Therefore, there is no



guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

### Note

The behavior of the `-t` switch is not entirely upward compatible with pre-8.2 LightDB versions. Formerly, writing `-t tab` would dump all tables named `tab`, but now it just dumps whichever one is visible in your default search path. To get the old behavior you can write `-t '*.tab'`. Also, you must write something like `-t sch.tab` to select a table in a particular schema, rather than the old locution of `-n sch -t tab`.

`-T pattern`  
`--exclude-table=pattern`

Do not dump any tables matching *pattern*. The pattern is interpreted according to the same rules as for `-t`. `-T` can be given more than once to exclude tables matching any of several patterns.

When both `-t` and `-T` are given, the behavior is to dump just the tables that match at least one `-t` switch but no `-T` switches. If `-T` appears without `-t`, then tables matching `-T` are excluded from what is otherwise a normal dump.

`-v`  
`--verbose`

Specifies verbose mode. This will cause `lt_dump` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

`-V`  
`--version`

Print the `lt_dump` version and exit.

`-x`  
`--no-privileges`  
`--no-acl`

Prevent dumping of access privileges (grant/revoke commands).

`-Z 0..9`  
`--compress=0..9`

Specify the compression level to use. Zero means no compression. For the custom and directory archive formats, this specifies compression of individual table-data segments, and the default is to compress at a moderate level. For plain text output, setting a nonzero compression level causes the entire output file to be compressed, as though it had been fed through `gzip`; but the default is not to compress. The tar archive format currently does not support compression at all.

`--binary-upgrade`

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

`--column-inserts`  
`--attribute-inserts`

Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful

for making dumps that can be loaded into non-LightDB databases. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

`--disable-dollar-quoting`

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

`--disable-triggers`

This option is relevant only when creating a data-only dump. It instructs `lt_dump` to include commands to temporarily disable triggers on the target tables while the data is restored. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data restore.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`--enable-row-security`

This option is relevant only when dumping the contents of a table which has row security. By default, `lt_dump` will set `row_security` to off, to ensure that all data is dumped from the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `lt_dump` to set `row_security` to on instead, allowing the user to dump the parts of the contents of the table that they have access to.

Note that if you use this option currently, you probably also want the dump be in `INSERT` format, as the `COPY FROM` during restore does not support row security.

`--exclude-table-data=pattern`

Do not dump data for any tables matching *pattern*. The pattern is interpreted according to the same rules as for `-t`. `--exclude-table-data` can be given more than once to exclude tables matching any of several patterns. This option is useful when you need the definition of a particular table even though you do not need the data in it.

To exclude data for all tables in the database, see `--schema-only`.

`--extra-float-digits=ndigits`

Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

`--if-exists`

Use conditional commands (i.e., add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

`--include-foreign-data=foreignserver`

Dump the data for any foreign table with a foreign server matching *foreignserver* pattern. Multiple foreign servers can be selected by writing multiple `--include-foreign-data` switches. Also, the *foreignserver* parameter is interpreted as a pattern according to the same rules used by `ltsql's \d` commands (see Patterns below), so multiple foreign servers can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote

the pattern if needed to prevent the shell from expanding the wildcards; see Examples below. The only exception is that an empty pattern is disallowed.

### Note

When `--include-foreign-data` is specified, `lt_dump` does not check that the foreign table is writable. Therefore, there is no guarantee that the results of a foreign table dump can be successfully restored.

`--lt-target-version`

Specify the target lightdb version.

`--lt-exclude-lightdb-objects`

Exclude all built-in objects created by LightDB in the dump.

### Note

For built-in tables or schemas created by LightDB, when both `-t` or `-n` are given, the behavior is to ignore the table or the schema, when data is being dumped, see the `-t` and `-n` documentation.

`--lt-dump-lightdb-tables`

Dump only the data of built-in tables which specified in 'pg\_extension\_config\_dump' (in the extension's SQL scripts).

This tables will be truncate firstly when data is being restored.

### Note

When both `-s` or `--section` are given, the behavior is to ignore the table data, when data is being dumped.

For built-in tables created by LightDB, when `--exclude-table-data` are given, the behavior is to ignore the table data, when data is being dumped, see the `--exclude-table-data` documentation.

For built-in tables created by LightDB, when `-t` are given, dump only the data of tables with names matching *pattern*.

For built-in tables created by LightDB, when `-T` are given, exclude the tables with names matching *pattern*.

For built-in tables created by LightDB, when `-n` are given, dump only the data of tables under the schema with names matching *pattern*.

For built-in tables created by LightDB, when `-N` are given, exclude the tables under the schema with names matching *pattern*.

Options `--lt-exclude-lightdb-objects` and `--lt-dump-lightdb-tables` cannot be used together.

`--lt-escape-identifiers`

Force escaping single quotes in the table name. This option is necessary when a table has single quotes in its name. With this option, a single ' will be escaped as ' '.

`--lt-disable-auto-analyze`

Do not automatic collect statistics when dump index. (see CREATE INDEX for more details).

`--inserts`

Dump data as INSERT commands (rather than COPY). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-LightDB databases. Any error during restoring will cause only rows that are part of the problematic INSERT to be lost, rather than the entire table contents. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

`--load-via-partition-root`

When dumping data for a table partition, make the COPY or INSERT statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when restoring data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type text and the two systems have different definitions of the collation used to sort the partitioning column.

It is best not to use parallelism when restoring from an archive made with this option, because `lt_restore` will not know exactly which partition(s) a given archive data item will load data into. This could result in inefficiency due to lock conflicts between parallel jobs, or perhaps even restore failures due to foreign key constraints being set up before all the relevant data is loaded.

`--lock-wait-timeout=timeout`

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead fail if unable to lock a table within the specified *timeout*. The timeout may be specified in any of the formats accepted by SET `statement_timeout`. (Allowed formats vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions.)

`--no-comments`

Do not dump comments.

`--no-publications`

Do not dump publications.

`--no-security-labels`

Do not dump security labels.

`--no-subscriptions`

Do not dump subscriptions.

`--no-sync`

By default, `lt_dump` will wait for all files to be written safely to disk. This option causes `lt_dump` to return without waiting, which is faster, but means that a subsequent operating system

crash can leave the dump corrupt. Generally, this option is useful for testing but should not be used when dumping data from production installation.

`--no-synchronized-snapshots`

This option allows running `lt_dump -j` against a pre-9.2 server, see the documentation of the `-j` parameter for more details.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`--no-unlogged-table-data`

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data. Data in unlogged tables is always excluded when dumping from a standby server.

`--on-conflict-do-nothing`

Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts`, `--column-inserts` or `--rows-per-insert` is also specified.

`--quote-all-identifiers`

Force quoting of all identifiers. This option is recommended when dumping a database from a server whose LightDB major version is different from `lt_dump`'s, or when the output is intended to be loaded into a server of a different major version. By default, `lt_dump` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

`--rows-per-insert=nrows`

Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

`--section=sectionname`

Only dump the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to dump all sections.

The data section contains actual table data, large-object contents, and sequence values. Post-data items include definitions of indexes, triggers, rules, and constraints other than validated check constraints. Pre-data items include all other data definition items.

`--serializable-deferrable`

Use a `serializable` transaction for the dump, to ensure that the snapshot used is consistent with later database states; but do this by waiting for a point in the transaction stream at which no anomalies can be present, so that there isn't a risk of the dump failing or causing other transactions to roll back with a `serialization_failure`. See Chapter 13 for more information about transaction isolation and concurrency control.

This option is not beneficial for a dump which is intended only for disaster recovery. It could be useful for a dump used to load a copy of the database for reporting or other read-only load sharing while the original database continues to be updated. Without it the dump may reflect a state which is not consistent with any serial execution of the transactions eventually committed. For example, if batch processing techniques are used, a batch may show as closed in the dump without all of the items which are in the batch appearing.

This option will make no difference if there are no read-write transactions active when `lt_dump` is started. If read-write transactions are active, the start of the dump may be delayed for an indeterminate length of time. Once running, performance with or without the switch is the same.

`--snapshot=snapshotname`

Use the specified synchronized snapshot when making a dump of the database (see Table 9.89 for more details).

This option is useful when needing to synchronize the dump with a logical replication slot (see Chapter 45) or with a concurrent session.

In the case of a parallel dump, the snapshot name defined by this option is used rather than taking a new snapshot.

`--strict-names`

Require that each schema (`-n/--schema`) and table (`-t/--table`) qualifier match at least one schema/table in the database to be dumped. Note that if none of the schema/table qualifiers find matches, `lt_dump` will generate an error even without `--strict-names`.

This option has no effect on `-N/--exclude-schema`, `-T/--exclude-table`, or `--exclude-table-data`. An exclude pattern failing to match any objects is not considered an error.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly. Also, a dump using `SET SESSION AUTHORIZATION` will certainly require superuser privileges to restore correctly, whereas `ALTER OWNER` requires lesser privileges.

`-?`

`--help`

Show help about `lt_dump` command line arguments, and exit.

The following command-line options control the database connection parameters.

`-d dbname`

`--dbname=dbname`

Specifies the name of the database to connect to. This is equivalent to specifying *dbname* as the first non-option argument on the command line. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options.

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or a compiled-in default.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force `lt_dump` to prompt for a password before connecting to a database.

This option is never essential, since `lt_dump` will automatically prompt for a password if the server demands password authentication. However, `lt_dump` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=rolename`

Specifies a role name to be used to create the dump. This option causes `lt_dump` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `lt_dump`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

## Environment

`LTDATABASE`  
`LTHOST`  
`LTOPTIONS`  
`LTPORT`  
`LTUSER`

Default connection parameters.

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

## Diagnostics

`lt_dump` internally executes `SELECT` statements. If you have problems running `lt_dump`, make sure you are able to select information from the database using, for example, `ltsql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

The database activity of `lt_dump` is normally collected by the statistics collector. If this is undesirable, you can set parameter `track_counts` to `false` via `LTOPTIONS` or the `ALTER USER` command.

## Notes

If your database cluster has any local additions to the `template1` database, be careful to restore the output of `lt_dump` into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When a data-only dump is chosen and the option `--disable-triggers` is used, `lt_dump` emits commands to disable triggers on user tables before inserting the data, and then commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.

The dump file produced by `lt_dump` does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run `ANALYZE` after restoring from a dump file to ensure optimal performance; see Section 22.1.3 and Section 22.1.6 for more information.

Because `lt_dump` is used to transfer data to newer versions of LightDB, the output of `lt_dump` can be expected to load into LightDB server versions newer than `lt_dump`'s version. `lt_dump` can also dump from LightDB servers older than its own version. (Currently, servers back to version 8.0 are supported.) However, `lt_dump` cannot dump from LightDB servers newer than its own major version; it will refuse to even try, rather than risk making an invalid dump. Also, it is not guaranteed that `lt_dump`'s output can be loaded into a server of an older major version — not even if the dump was taken from a server of that version. Loading a dump file into an older server may require manual editing of the dump file to remove syntax not understood by the older server. Use of the `--quote-all-identifiers` option is recommended in cross-version cases, as it can prevent problems arising from varying reserved-word lists in different LightDB versions.

When dumping logical replication subscriptions, `lt_dump` will generate `CREATE SUBSCRIPTION` commands that use the `connect = false` option, so that restoring the subscription does not make remote connections for creating a replication slot or for initial table copy. That way, the dump can be restored without requiring network access to the remote servers. It is then up to the user to reactivate the subscriptions in a suitable way. If the involved hosts have changed, the connection information might have to be changed. It might also be appropriate to truncate the target tables before initiating a new full table copy.

## Examples

To dump a database called `mydb` into a SQL-script file:

```
$ lt_dump mydb > db.sql
```

To reload such a script into a (freshly created) database named `newdb`:

```
$ ltsql -d newdb -f db.sql
```

To dump a database into a custom-format archive file:

```
$ lt_dump -Fc mydb > db.dump
```

To dump a database into a directory-format archive:



```
$ lt_dump -Fd mydb -f dumpdir
```

To dump a database into a directory-format archive in parallel with 5 worker jobs:

```
$ lt_dump -Fd mydb -j 5 -f dumpdir
```

To reload an archive file into a (freshly created) database named newdb:

```
$ lt_restore -d newdb db.dump
```

To reload an archive file into the same database it was dumped from, discarding the current contents of that database:

```
$ lt_restore -d postgres --clean --create db.dump
```

To dump a single table named mytab:

```
$ lt_dump -t mytab mydb > db.sql
```

To dump all tables whose names start with emp in the detroit schema, except for the table named employee\_log:

```
$ lt_dump -t 'detroit.emp*' -T detroit.employee_log mydb > db.sql
```

To dump all schemas whose names start with east or west and end in gsm, excluding any schemas whose names contain the word test:

```
$ lt_dump -n 'east*gsm' -n 'west*gsm' -N '*test*' mydb > db.sql
```

The same, using regular expression notation to consolidate the switches:

```
$ lt_dump -n '(east|west)*gsm' -N '*test*' mydb > db.sql
```

To dump all database objects except for tables whose names begin with ts\_:

```
$ lt_dump -T 'ts_*' mydb > db.sql
```

To specify an upper-case or mixed-case name in -t and related switches, you need to double-quote the name; else it will be folded to lower case (see Patterns below). But double quotes are special to the shell, so in turn they must be quoted. Thus, to dump a single table with a mixed-case name, you need something like

```
$ lt_dump -t "\"MixedCaseName\"" mydb > mytab.sql
```

## See Also

lt\_dumpall, lt\_restore, ltsql

---

# lt\_dumpall

lt\_dumpall — extract a LightDB database cluster into a script file

## Synopsis

```
lt_dumpall [connection-option...] [option...]
```

## Description

lt\_dumpall is a utility for writing out (“dumping”) all LightDB databases of a cluster into one script file. The script file contains SQL commands that can be used as input to ltsql to restore the databases. It does this by calling lt\_dump for each database in the cluster. lt\_dumpall also dumps global objects that are common to all databases, that is, database roles and tablespaces. (lt\_dump does not save these objects.)

Since lt\_dumpall reads tables from all databases you will most likely have to connect as a database superuser in order to produce a complete dump. Also you will need superuser privileges to execute the saved script in order to be allowed to add roles and create databases.

The SQL script will be written to the standard output. Use the `-f/--file` option or shell operators to redirect it into a file.

lt\_dumpall needs to connect several times to the LightDB server (once per database). If you use password authentication it will ask for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 32.15 for more information.

## Options

The following command-line options control the content and format of the output.

`-a`  
`--data-only`

Dump only the data, not the schema (data definitions).

`-c`  
`--clean`

Include SQL commands to clean (drop) databases before recreating them. DROP commands for roles and tablespaces are added as well.

`-E encoding`  
`--encoding=encoding`

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `LTCLIENTENCODING` environment variable to the desired dump encoding.)

`-f filename`  
`--file=filename`

Send output to the specified file. If this is omitted, the standard output is used.

`-g`  
`--globals-only`

Dump only global objects (roles and tablespaces), no databases.

-O

--no-owner

Do not output commands to set ownership of objects to match the original database. By default, `lt_dumpall` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

-r

--roles-only

Dump only roles, no databases or tablespaces.

-s

--schema-only

Dump only the object definitions (schema), not data.

-S *username*

--superuser=*username*

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

-t

--tablespaces-only

Dump only tablespaces, no databases or roles.

-v

--verbose

Specifies verbose mode. This will cause `lt_dumpall` to output start/stop times to the dump file, and progress messages to standard error. It will also enable verbose output in `lt_dump`.

-V

--version

Print the `lt_dumpall` version and exit.

-x

--no-privileges

--no-acl

Prevent dumping of access privileges (grant/revoke commands).

--binary-upgrade

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

--column-inserts

--attribute-inserts

Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-LightDB databases.

--disable-dollar-quoting

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

**--disable-triggers**

This option is relevant only when creating a data-only dump. It instructs `lt_dumpall` to include commands to temporarily disable triggers on the target tables while the data is restored. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data restore.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

**--exclude-database=*pattern***

Do not dump databases whose name matches *pattern*. Multiple patterns can be excluded by writing multiple `--exclude-database` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `Itsql's \d` commands (see Patterns below), so multiple databases can also be excluded by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent shell wildcard expansion.

**--extra-float-digits=*ndigits***

Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

**--if-exists**

Use conditional commands (i.e., add an `IF EXISTS` clause) to drop databases and other objects. This option is not valid unless `--clean` is also specified.

**--inserts**

Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-LightDB databases. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safer, though even slower.

**--load-via-partition-root**

When dumping data for a table partition, make the `COPY` or `INSERT` statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when restoring data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type `text` and the two systems have different definitions of the collation used to sort the partitioning column.

**--lock-wait-timeout=*timeout***

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead, fail if unable to lock a table within the specified *timeout*. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. Allowed values vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions since 7.3. This option is ignored when dumping from a pre-7.3 server.

**--no-comments**

Do not dump comments.

**--no-publications**

Do not dump publications.

**--no-role-passwords**

Do not dump passwords for roles. When restored, roles will have a null password, and password authentication will always fail until the password is set. Since password values aren't needed when this option is specified, the role information is read from the catalog view `pg_roles` instead of `pg_authid`. Therefore, this option also helps if access to `pg_authid` is restricted by some security policy.

**--no-security-labels**

Do not dump security labels.

**--no-subscriptions**

Do not dump subscriptions.

**--no-sync**

By default, `lt_dumpall` will wait for all files to be written safely to disk. This option causes `lt_dumpall` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the dump corrupt. Generally, this option is useful for testing but should not be used when dumping data from production installation.

**--no-tablespaces**

Do not output commands to create tablespaces nor select tablespaces for objects. With this option, all objects will be created in whichever tablespace is the default during restore.

**--no-unlogged-table-data**

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data.

**--on-conflict-do-nothing**

Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts` or `--column-inserts` is also specified.

**--quote-all-identifiers**

Force quoting of all identifiers. This option is recommended when dumping a database from a server whose LightDB major version is different from `lt_dumpall`'s, or when the output is intended to be loaded into a server of a different major version. By default, `lt_dumpall` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

**--rows-per-insert=*nrows***

Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

**--use-set-session-authorization**

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, might not restore properly.

`--lt-target-version`

lt\_dumpall will pass this option to lt\_dump directly.

`--lt-exclude-lightdb-objects`

lt\_dumpall will pass this option to lt\_dump directly.

`--lt-dump-lightdb-tables`

lt\_dumpall will pass this option to lt\_dump directly.

`--lt-escape-identifiers`

lt\_dumpall will pass this option to lt\_dump directly.

`--lt-disable-auto-analyze`

Do not automatic collect statistics when dump index. (see CREATE INDEX for more details).

`-?`

`--help`

Show help about lt\_dumpall command line arguments, and exit.

The following command-line options control the database connection parameters.

`-d connstr`

`--dbname=connstr`

Specifies parameters used to connect to the server, as a connection string; these will override any conflicting command line options.

The option is called `--dbname` for consistency with other client applications, but because lt\_dumpall needs to connect to many databases, the database name in the connection string will be ignored. Use the `-l` option to specify the name of the database used for the initial connection, which will dump global objects and discover what other databases should be dumped.

`-h host`

`--host=host`

Specifies the host name of the machine on which the database server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the LTHOST environment variable, if set, else a Unix domain socket connection is attempted.

`-l dbname`

`--database=dbname`

Specifies the name of the database to connect to for dumping global objects and discovering what other databases should be dumped. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the LTPORT environment variable, if set, or a compiled-in default.

`-U username`

`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force `lt_dumpall` to prompt for a password before connecting to a database.

This option is never essential, since `lt_dumpall` will automatically prompt for a password if the server demands password authentication. However, `lt_dumpall` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Note that the password prompt will occur again for each database to be dumped. Usually, it's better to set up a `~/ .pgpass` file than to rely on manual password entry.

`--role=rolename`

Specifies a role name to be used to create the dump. This option causes `lt_dumpall` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `lt_dumpall`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

## Environment

`LTHOST`  
`LTOPTIONS`  
`LTPORT`  
`LTUSER`

Default connection parameters

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

## Notes

Since `lt_dumpall` calls `lt_dump` internally, some diagnostic messages will refer to `lt_dump`.

The `--clean` option can be useful even when your intention is to restore the dump script into a fresh cluster. Use of `--clean` authorizes the script to drop and re-create the built-in `postgres` and `template1` databases, ensuring that those databases will retain the same properties (for instance, locale and encoding) that they had in the source cluster. Without the option, those databases will retain their existing database-level properties, as well as any pre-existing contents.

Once restored, it is wise to run `ANALYZE` on each database so the optimizer has useful statistics. You can also run `vacuumdb -a -z` to analyze all databases.

The dump script should not be expected to run completely without errors. In particular, because the script will issue `CREATE ROLE` for every role existing in the source cluster, it is certain to get a

“role already exists” error for the bootstrap superuser, unless the destination cluster was initialized with a different bootstrap superuser name. This error is harmless and should be ignored. Use of the `--clean` option is likely to produce additional harmless error messages about non-existent objects, although you can minimize those by adding `--if-exists`.

`lt_dumpall` requires all needed tablespace directories to exist before the restore; otherwise, database creation will fail for databases in non-default locations.

## Examples

To dump all databases:

```
$ lt_dumpall > db.out
```

To restore database(s) from this file, you can use:

```
$ ltsql -f db.out postgres
```

It is not important to which database you connect here since the script file created by `lt_dumpall` will contain the appropriate commands to create and connect to the saved databases. An exception is that if you specified `--clean`, you must connect to the `postgres` database initially; the script will attempt to drop other databases immediately, and that will fail for the database you are connected to.

## See Also

Check `lt_dump` for details on possible error conditions.



---

# lt\_isready

lt\_isready — check the connection status of a LightDB server

## Synopsis

```
lt_isready [connection-option...] [option...]
```

## Description

lt\_isready is a utility for checking the connection status of a LightDB database server. The exit status specifies the result of the connection check.

## Options

-d *dbname*

--dbname=*dbname*

Specifies the name of the database to connect to. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options.

-h *hostname*

--host=*hostname*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

-p *port*

--port=*port*

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the LTPORT environment variable or, if not set, to the port specified at compile time, usually 5432.

-q

--quiet

Do not display status message. This is useful when scripting.

-t *seconds*

--timeout=*seconds*

The maximum number of seconds to wait when attempting connection before returning that the server is not responding. Setting to 0 disables. The default is 3 seconds.

-U *username*

--username=*username*

Connect to the database as the user *username* instead of the default.

-V

--version

Print the lt\_isready version and exit.

-?

--help

Show help about lt\_isready command line arguments, and exit.

## Exit Status

lt\_isready returns 0 to the shell if the server is accepting connections normally, 1 if the server is rejecting connections (for example during startup), 2 if there was no response to the connection attempt, and 3 if no attempt was made (for example due to invalid parameters).

## Environment

lt\_isready, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

The environment variable LT\_COLOR specifies whether to use color in diagnostic messages. Possible values are always, auto and never.

## Notes

It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

## Examples

Standard Usage:

```
$ lt_isready
/tmp:5432 - accepting connections
$ echo $?
0
```

Running with connection parameters to a LightDB cluster in startup:

```
$ lt_isready -h localhost -p 5433
localhost:5433 - rejecting connections
$ echo $?
1
```

Running with connection parameters to a non-responsive LightDB cluster:

```
$ lt_isready -h someremotehost
someremotehost:5432 - no response
$ echo $?
2
```

---

# lt\_probackup

lt\_probackup — manage backup and recovery of LightDB database clusters

## Synopsis

```
lt_probackup version

lt_probackup help [command]

lt_probackup init -B backup_dir

lt_probackup add-instance -B backup_dir -D data_dir --instance
instance_name

lt_probackup del-instance -B backup_dir --instance instance_name

lt_probackup set-config -B backup_dir --instance instance_name [option...]

lt_probackup set-backup -B backup_dir --instance instance_name -i
backup_id [option...]

lt_probackup show-config -B backup_dir --instance instance_name [--
format=format]

lt_probackup show -B backup_dir [option...]

lt_probackup backup -B backup_dir --instance instance_name -b
backup_mode [option...]

lt_probackup restore -B backup_dir --instance instance_name [option...]

lt_probackup checkdb -B backup_dir --instance instance_name -D data_dir
[option...]

lt_probackup validate -B backup_dir [option...]

lt_probackup merge -B backup_dir --instance instance_name -i backup_id
[option...]

lt_probackup delete -B backup_dir --instance instance_name { -i backup_id
|--delete-wal | --delete-expired | --merge-expired } [option...]

lt_probackup archive-push -B backup_dir --instance instance_name --wal-
file-name wal_file_name [option...]

lt_probackup archive-get -B backup_dir --instance instance_name --wal-
file-path wal_file_path --wal-file-name wal_file_name [option...]
```

## Description

lt\_probackup is a utility to manage backup and recovery of LightDB database clusters. It is designed to perform periodic backups of the LightDB instance that enable you to restore the server in case of a failure.

- Overview
- Installation and Setup
- Command-Line Reference

- Usage

## Overview

As compared to other backup solutions, `lt_probackup` offers the following benefits that can help you implement different backup strategies and deal with large amounts of data:

- Incremental backup: with three different incremental modes, you can plan the backup strategy in accordance with your data flow. Incremental backups allow you to save disk space and speed up backup as compared to taking full backups. It is also faster to restore the cluster by applying incremental backups than by replaying WAL files.
- Incremental restore: speed up restore from backup by reusing valid unchanged pages available in `LTDATA`.
- Validation: automatic data consistency checks and on-demand backup validation without actual data recovery.
- Verification: on-demand verification of LightDB instance with the `checkdb` command.
- Retention: managing WAL archive and backups in accordance with retention policy. You can configure retention policy based on recovery time or the number of backups to keep, as well as specify time to live (TTL) for a particular backup. Expired backups can be merged or deleted.
- Parallelization: running `backup`, `restore`, `merge`, `delete`, `validate`, and `checkdb` processes on multiple parallel threads.
- Compression: storing backup data in a compressed state to save disk space.
- Deduplication: saving disk space by excluding non-data files (such as `_vm` or `_fsm`) from incremental backups if these files have not changed since they were copied into one of the previous backups in this incremental chain.
- Remote operations: backing up LightDB instance located on a remote system or restoring a backup remotely.
- Backup from standby: avoiding extra load on master by taking backups from a standby server.
- External directories: backing up files and directories located outside of the LightDB data directory (`LTDATA`), such as scripts, configuration files, logs, or SQL dump files.
- Backup catalog: getting the list of backups and the corresponding meta information in plain text or JSON formats.
- Archive catalog: getting the list of all WAL timelines and the corresponding meta information in plain text or JSON formats.
- Partial restore: restoring only the specified databases.

To manage backup data, `lt_probackup` creates a *backup catalog*. This is a directory that stores all backup files with additional meta information, as well as WAL archives required for point-in-time recovery. You can store backups for different instances in separate subdirectories of a single backup catalog.

Using `lt_probackup`, you can take full or incremental backups:

- FULL backups contain all the data files required to restore the database cluster.
- Incremental backups operate at the page level, only storing the data that has changed since the previous backup. It allows you to save disk space and speed up the backup process as compared to taking full backups. It is also faster to restore the cluster by applying incremental backups than by replaying WAL files. `lt_probackup` supports the following modes of incremental backups:
  - DELTA backup. In this mode, `lt_probackup` reads all data files in the data directory and copies only those pages that have changed since the previous backup. This mode can impose read-only I/O pressure equal to a full backup.
  - PAGE backup. In this mode, `lt_probackup` scans all WAL files in the archive from the moment the previous full or incremental backup was taken. Newly created backups contain only the pages that were mentioned in WAL records. This requires all the WAL files since the previous backup to be present in the WAL archive. If the size of these files is comparable to the total size of the database cluster files, speedup is smaller, but the backup still takes less space. You have to configure WAL archiving as explained in [Setting up continuous WAL archiving to make PAGE backups](#).

- **PTRACK backup.** In this mode, LightDB tracks page changes on the fly. Continuous archiving is not necessary for it to operate. Each time a relation page is updated, this page is marked in a special PTRACK bitmap. Tracking implies some minor overhead on the database server operation, but speeds up incremental backups significantly.

lt\_probackup can take only physical online backups, and online backups require WAL for consistent recovery. So regardless of the chosen backup mode (FULL, PAGE or DELTA), any backup taken with lt\_probackup must use one of the following *WAL delivery modes*:

- **ARCHIVE.** Such backups rely on continuous archiving to ensure consistent recovery. This is the default WAL delivery mode.
- **STREAM.** Such backups include all the files required to restore the cluster to a consistent state at the time the backup was taken. Regardless of continuous archiving having been set up or not, the WAL segments required for consistent recovery are streamed via replication protocol during backup and included into the backup files. That's why such backups are called *autonomous*, or *standalone*.

## Limitations

lt\_probackup currently has the following limitations:

- The remote mode is not supported on Windows systems.
- On Unix systems, a backup can be made only by the same OS user that has started the LightDB server. For example, if LightDB server is started by user `lightdb`, the `backup` command must also be run by user `lightdb`. To satisfy this requirement when taking backups in the remote mode using SSH, you must set `--remote-user` option to `lightdb`.
- The LightDB server from which the backup was taken and the restored server must be compatible by the `block_size`<sup>1</sup> and `wal_block_size`<sup>2</sup> parameters and have the same major release number. Depending on cluster configuration, LightDB itself may apply additional restrictions, such as CPU architecture or `libc/libicu` versions.

## Installation and Setup

Once you have lt\_probackup installed, complete the following setup:

- Initialize the backup catalog.
- Add a new backup instance to the backup catalog.
- Configure the database cluster to enable lt\_probackup backups.
- Optionally, configure SSH for running lt\_probackup operations in the remote mode.

## Initializing the Backup Catalog

lt\_probackup stores all WAL and backup files in the corresponding subdirectories of the backup catalog.

To initialize the backup catalog, run the following command:

```
lt_probackup init -B backup_dir
```

where `backup_dir` is the path to the backup catalog. If the `backup_dir` already exists, it must be empty. Otherwise, lt\_probackup returns an error.

The user launching lt\_probackup must have full access to the `backup_dir` directory.

lt\_probackup creates the `backup_dir` backup catalog, with the following subdirectories:

- `wal/` — directory for WAL files.
- `backups/` — directory for backup files.

---

<sup>1</sup> [runtime-config-preset.html#GUC-BLOCK-SIZE](#)

<sup>2</sup> [runtime-config-preset.html#GUC-WAL-BLOCK-SIZE](#)

Once the backup catalog is initialized, you can add a new backup instance.

## Adding a New Backup Instance

lt\_probackup can store backups for multiple database clusters in a single backup catalog. To set up the required subdirectories, you must add a backup instance to the backup catalog for each database cluster you are going to back up.

To add a new backup instance, run the following command:

```
lt_probackup add-instance -B backup_dir -D data_dir --
instance instance_name [remote_options]
```

where:

- *data\_dir* is the data directory of the cluster you are going to back up. To set up and use lt\_probackup, write access to this directory is required.
- *instance\_name* is the name of the subdirectories that will store WAL and backup files for this cluster.
- *remote\_options* are optional parameters that need to be specified only if *data\_dir* is located on a remote system.

lt\_probackup creates the *instance\_name* subdirectories under the *backups/* and *wal/* directories of the backup catalog. The *backups/instance\_name* directory contains the *pg\_probackup.conf* configuration file that controls lt\_probackup settings for this backup instance. If you run this command with the *remote\_options*, the specified parameters will be added to *pg\_probackup.conf*.

For details on how to fine-tune lt\_probackup configuration, see the section called “Configuring lt\_probackup”.

The user launching lt\_probackup must have full access to *backup\_dir* directory and at least read-only access to *data\_dir* directory. If you specify the path to the backup catalog in the *BACKUP\_PATH* environment variable, you can omit the corresponding option when running lt\_probackup commands.

### Note

It is recommended to use the *allow-group-access*<sup>3</sup> feature, so that backup can be done by any OS user in the same group as the cluster owner. In this case, the user should have read permissions for the cluster directory.

## Configuring the Database Cluster

Although lt\_probackup can be used by a superuser, it is recommended to create a separate role with the minimum permissions required for the chosen backup strategy. In these configuration instructions, the *backup* role is used as an example.

To perform a backup, the following permissions for role *backup* are required only in the database **used for connection** to the LightDB server:

```
BEGIN;
CREATE ROLE backup WITH LOGIN;
GRANT USAGE ON SCHEMA pg_catalog TO backup;
```

---

<sup>3</sup> [app-initdb.html#APP-INITDB-ALLOW-GROUP-ACCESS](http://app-initdb.html#APP-INITDB-ALLOW-GROUP-ACCESS)

```

GRANT EXECUTE ON FUNCTION pg_catalog.current_setting(text) TO
backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_is_in_recovery() TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_start_backup(text, boolean,
boolean) TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_stop_backup(boolean,
boolean) TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_create_restore_point(text)
TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_switch_wal() TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_last_wal_replay_lsn() TO
backup;
GRANT EXECUTE ON FUNCTION pg_catalog.txid_current() TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.txid_current_snapshot() TO
backup;
GRANT EXECUTE ON FUNCTION
pg_catalog.txid_snapshot_xmax(txid_snapshot) TO backup;
GRANT EXECUTE ON FUNCTION pg_catalog.pg_control_checkpoint() TO
backup;
COMMIT;

```

In the `lt_hba.conf`<sup>4</sup> file, allow connection to the database cluster on behalf of the backup role.

Since `lt_probackup` needs to read cluster files directly, `lt_probackup` must be started by (or connected to, if used in the remote mode) the OS user that has read access to all files and directories inside the data directory (`LTDATA`) you are going to back up.

Depending on whether you plan to take standalone or archive backups, LightDB cluster configuration will differ, as specified in the sections below. To back up the database cluster from a standby server, run `lt_probackup` in the remote mode, or create PTRACK backups, additional setup is required.

For details, see the sections [Setting up STREAM Backups](#), [Setting up continuous WAL archiving](#), [Setting up Backup from Standby](#), [Configuring the Remote Mode](#), [Setting up Partial Restore](#), and [Setting up PTRACK Backups](#).

## Setting up STREAM Backups

To set up the cluster for STREAM backups, complete the following steps:

- Grant the `REPLICATION` privilege to the backup role:

```
ALTER ROLE backup WITH REPLICATION;
```

- In the `lt_hba.conf`<sup>5</sup> file, allow replication on behalf of the backup role.
- Make sure the parameter `max_wal_senders`<sup>6</sup> is set high enough to leave at least one session available for the backup process.
- Set the parameter `wal_level`<sup>7</sup> to be higher than `minimal`.

If you are planning to take PAGE backups in the STREAM mode or perform PITR with STREAM backups, you still have to configure WAL archiving, as explained in the section [Setting up continuous WAL archiving](#).

Once these steps are complete, you can start taking FULL, PAGE, DELTA, and PTRACK backups in the STREAM WAL mode.

<sup>4</sup> [auth-pg-hba-conf.html](#)

<sup>5</sup> [auth-pg-hba-conf.html](#)

<sup>6</sup> [runtime-config-replication.html#GUC-MAX-WAL-SENDERS](#)

<sup>7</sup> [runtime-config-wal.html#GUC-WAL-LEVEL](#)

**Note**

If you are planning to rely on `.pgpass`<sup>8</sup> for authentication when running backup in STREAM mode, then `.pgpass` must contain credentials for `replication` database, used to establish connection via replication protocol. Example: `pghost:5432:replication:backup_user:my_strong_password`

**Setting up Continuous WAL Archiving**

Making backups in PAGE backup mode, performing PITR, making backups with ARCHIVE WAL delivery mode and running incremental backup after timeline switch require continuous WAL archiving<sup>9</sup> to be enabled. To set up continuous archiving in the cluster, complete the following steps:

- Make sure the `wal_level`<sup>10</sup> parameter is higher than `minimal`.
- If you are configuring archiving on master, `archive_mode`<sup>11</sup> must be set to `on` or `always`. To perform archiving on standby, set this parameter to `always`.
- Set the `archive_command`<sup>12</sup> parameter, as follows:

```
archive_command = '"install_dir/lt_probackup" archive-push
-B "backup_dir" --instance instance_name --wal-file-name=%f
[remote_options]'
```

where `install_dir` is the installation directory of the `lt_probackup` version you are going to use, `backup_dir` and `instance_name` refer to the already initialized backup catalog instance for this database cluster, and `remote_options` only need to be specified to archive WAL on a remote host. For details about all possible `archive-push` parameters, see the section `archive-push`.

Once these steps are complete, you can start making backups in the ARCHIVE WAL mode, backups in the PAGE backup mode, as well as perform PITR.

You can view the current state of the WAL archive using the `show` command. For details, see the section called “Viewing WAL Archive Information”.

If you are planning to make PAGE backups and/or backups with ARCHIVE WAL mode from a standby server that generates a small amount of WAL traffic, without long waiting for WAL segment to fill up, consider setting the `archive_timeout`<sup>13</sup> LightDB parameter **on master**. The value of this parameter should be slightly lower than the `--archive-timeout` setting (5 minutes by default), so that there is enough time for the rotated segment to be streamed to standby and sent to WAL archive before the backup is aborted because of `--archive-timeout`.

**Note**

Instead of using the `archive-push` command provided by `lt_probackup`, you can use any other tool to set up continuous archiving as long as it delivers WAL segments into `backup_dir/wal/instance_name` directory. If compression is used, it should be `gzip`, and `.gz` suffix in filename is mandatory.

<sup>8</sup> libpq-pgpass.html

<sup>9</sup> continuous-archiving.html

<sup>10</sup> runtime-config-wal.html#GUC-WAL-LEVEL

<sup>11</sup> runtime-config-wal.html#GUC-ARCHIVE-MODE

<sup>12</sup> runtime-config-wal.html#GUC-ARCHIVE-COMMAND

<sup>13</sup> runtime-config-wal.html#GUC-ARCHIVE-TIMEOUT



**Note**

Instead of configuring continuous archiving by setting the `archive_mode` and `archive_command` parameters, you can opt for using the `pg_receivewal`<sup>14</sup> utility. In this case, `pg_receivewal -D directory` option should point to `backup_dir/wal/instance_name` directory. `It_probackup` supports WAL compression that can be done by `pg_receivewal`. “Zero Data Loss” archive strategy can be achieved only by using `pg_receivewal`.

**Setting up Backup from Standby**

For LightDB, `It_probackup` can take backups from a standby server. This requires the following additional setup:

- On the standby server, set the `hot_standby`<sup>15</sup> parameter to `on`.
- On the master server, set the `full_page_writes`<sup>16</sup> parameter to `on`.
- To perform standalone backups on standby, complete all steps in section **Setting up STREAM Backups**.
- To perform archive backups on standby, complete all steps in section **Setting up continuous WAL archiving**.

Once these steps are complete, you can start taking FULL, PAGE, DELTA, or PTRACK backups with appropriate WAL delivery mode: ARCHIVE or STREAM, from the standby server.

Backup from the standby server has the following limitations:

- If the standby is promoted to the master during backup, the backup fails.
- All WAL records required for the backup must contain sufficient full-page writes. This requires you to enable `full_page_writes` on the master, and not to use tools like `pg_compresslog` as `archive_command`<sup>17</sup> to remove full-page writes from WAL files.

**Setting up Cluster Verification**

Logical verification of a database cluster requires the following additional setup. Role backup is used as an example:

- Install the `amcheck`<sup>18</sup> **in every database** of the cluster:

```
CREATE EXTENSION amcheck;
```

- Grant the following permissions to the backup role **in every database** of the cluster:

```
GRANT SELECT ON TABLE pg_catalog.pg_am TO backup;
GRANT SELECT ON TABLE pg_catalog.pg_class TO backup;
GRANT SELECT ON TABLE pg_catalog.pg_database TO backup;
GRANT SELECT ON TABLE pg_catalog.pg_namespace TO backup;
GRANT SELECT ON TABLE pg_catalog.pg_extension TO backup;
GRANT EXECUTE ON FUNCTION bt_index_check(regclass) TO backup;
GRANT EXECUTE ON FUNCTION bt_index_check(regclass, bool) TO
backup;
```

<sup>14</sup> [app-pgreceivewal.html](#)

<sup>15</sup> [runtime-config-replication.html#GUC-HOT-STANDBY](#)

<sup>16</sup> [runtime-config-wal.html#GUC-FULL-PAGE-WRITES](#)

<sup>17</sup> [runtime-config-wal.html#GUC-ARCHIVE-COMMAND](#)

<sup>18</sup> [amcheck.html](#)

## Setting up Partial Restore

If you are planning to use partial restore, complete the following additional step:

- Grant the read-only access to `pg_catalog.pg_database` to the backup role only in the database **used for connection** to LightDB server:

```
GRANT SELECT ON TABLE pg_catalog.pg_database TO backup;
```

## Configuring the Remote Mode

lt\_probackup supports the remote mode that allows to perform backup, restore and WAL archiving operations remotely. In this mode, the backup catalog is stored on a local system, while LightDB instance to backup and/or to restore is located on a remote system. Currently the only supported remote protocol is SSH.

### Set up SSH

If you are going to use lt\_probackup in remote mode via SSH, complete the following steps:

- Install lt\_probackup on both systems: `backup_host` and `db_host`.
- For communication between the hosts set up the passwordless SSH connection between backup user on `backup_host` and `lightdb` user on `db_host`:

```
[backup@backup_host] ssh-copy-id lightdb@db_host
```

- If you are going to rely on continuous WAL archiving, set up passwordless SSH connection between `lightdb` user on `db_host` and backup user on `backup_host`:

```
[lightdb@db_host] ssh-copy-id backup@backup_host
```

where:

- `backup_host` is the system with *backup catalog*.
- `db_host` is the system with LightDB cluster.
- `backup` is the OS user on `backup_host` used to run lt\_probackup.
- `lightdb` is the OS user on `db_host` used to start the LightDB cluster. For LightDB a more secure approach can be used thanks to `allow-group-access`<sup>19</sup> feature.

lt\_probackup in the remote mode via SSH works as follows:

- Only the following commands can be launched in the remote mode: `add-instance`, `backup`, `restore`, `archive-push`, `archive-get`.
- Operating in remote mode requires lt\_probackup binary to be installed on both local and remote systems. The versions of local and remote binary must be the same.
- When started in the remote mode, the main lt\_probackup process on the local system connects to the remote system via SSH and launches one or more agent processes on the remote system, which are called *remote agents*. The number of remote agents is equal to the `-j/--threads` setting.
- The main lt\_probackup process uses remote agents to access remote files and transfer data between local and remote systems.
- Remote agents try to minimize the network traffic and the number of round-trips between hosts.
- The main process is usually started on `backup_host` and connects to `db_host`, but in case of `archive-push` and `archive-get` commands the main process is started on `db_host` and connects to `backup_host`.
- Once data transfer is complete, remote agents are terminated and SSH connections are closed.

---

<sup>19</sup> [app-initdb.html#APP-INITDB-ALLOW-GROUP-ACCESS](#)

- If an error condition is encountered by a remote agent, then all agents are terminated and error details are reported by the main `lt_probackup` process, which exits with an error.
- Compression is always done on `db_host`, while decompression is always done on `backup_host`.

### Note

You can impose additional restrictions<sup>20</sup> on SSH settings to protect the system in the event of account compromise.

## Setting up PTRACK Backups

The PTRACK backup mode can be used for LightDB. Links to PTRACK patches can be found here<sup>21</sup>.

### Note

PTRACK Will be used directly in feature.

If you are going to use PTRACK backups, complete the following additional steps. The role that will perform PTRACK backups (the `backup` role in the examples below) must have access to all the databases of the cluster.

For LightDB :

1. Create PTRACK extension:

```
CREATE EXTENSION ptrack;
```

2. To enable tracking page updates, set `ptrack.map_size` parameter to a positive integer and restart the server.

For optimal performance, it is recommended to set `ptrack.map_size` to  $N / 1024$ , where  $N$  is the size of the LightDB cluster, in MB. If you set this parameter to a lower value, PTRACK is more likely to map several blocks together, which leads to false-positive results when tracking changed blocks and increases the incremental backup size as unchanged blocks can also be copied into the incremental backup. Setting `ptrack.map_size` to a higher value does not affect PTRACK operation, but it is not recommended to set this parameter to a value higher than 1024.

### Note

If you change the `ptrack.map_size` parameter value, the previously created PTRACK map file is cleared, and tracking newly changed blocks starts from scratch. Thus, you have to retake a full backup before taking incremental PTRACK backups after changing `ptrack.map_size`.

## Usage

### Creating a Backup

To create a backup, run the following command:

<sup>20</sup> [https://man.openbsd.org/OpenBSD-current/man8/sshd.8#AUTHORIZED\\_KEYS\\_FILE\\_FORMAT](https://man.openbsd.org/OpenBSD-current/man8/sshd.8#AUTHORIZED_KEYS_FILE_FORMAT)

<sup>21</sup> [https://github.com/postgrespro/pg\\_probackup#ptrack-support](https://github.com/postgrespro/pg_probackup#ptrack-support)

```
lt_probackup backup -B backup_dir --instance instance_name -b backup_mode
```

Where *backup\_mode* can take one of the following values:

- FULL — creates a full backup that contains all the data files of the cluster to be restored.
- DELTA — reads all data files in the data directory and creates an incremental backup for pages that have changed since the previous backup.
- PAGE — creates an incremental backup based on the WAL files that have been generated since the previous full or incremental backup was taken. Only changed blocks are read from data files.
- PTRACK — creates an incremental backup tracking page changes on the fly.

When restoring a cluster from an incremental backup, `lt_probackup` relies on the parent full backup and all the incremental backups between them, which is called “the backup chain”. You must create at least one full backup before taking incremental ones.

## ARCHIVE Mode

ARCHIVE is the default WAL delivery mode.

For example, to make a FULL backup in ARCHIVE mode, run:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
```

ARCHIVE backups rely on continuous archiving to get WAL segments required to restore the cluster to a consistent state at the time the backup was taken.

When a backup is taken, `lt_probackup` ensures that WAL files containing WAL records between `Start LSN` and `Stop LSN` actually exist in `backup_dir/wal/instance_name` directory. `lt_probackup` also ensures that WAL records between `Start LSN` and `Stop LSN` can be parsed. This precaution eliminates the risk of silent WAL corruption.

## STREAM Mode

STREAM is the optional WAL delivery mode.

For example, to make a FULL backup in the STREAM mode, add the `--stream` flag to the command from the previous example:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL --stream --temp-slot
```

The optional `--temp-slot` flag ensures that the required segments remain available if the WAL is rotated before the backup is complete.

Unlike backups in ARCHIVE mode, STREAM backups include all the WAL segments required to restore the cluster to a consistent state at the time the backup was taken.

During backup `lt_probackup` streams WAL files containing WAL records between `Start LSN` and `Stop LSN` to `backup_dir/backups/instance_name/backup_id/database/lt_wal` directory. To eliminate the risk of silent WAL corruption, `lt_probackup` also checks that WAL records between `Start LSN` and `Stop LSN` can be parsed.

Even if you are using continuous archiving, STREAM backups can still be useful in the following cases:

- STREAM backups can be restored on the server that has no file access to WAL archive.
- STREAM backups enable you to restore the cluster state at the point in time for which WAL files in archive are no longer available.

- Backup in STREAM mode can be taken from a standby of a server that generates small amount of WAL traffic, without long waiting for WAL segment to fill up.

## Page Validation

If data checksums<sup>22</sup> are enabled in the database cluster, `lt_probackup` uses this information to check correctness of data files during backup. While reading each page, `lt_probackup` checks whether the calculated checksum coincides with the checksum stored in the page header. This guarantees that the LightDB instance and the backup itself have no corrupt pages. Note that `lt_probackup` reads database files directly from the filesystem, so under heavy write load during backup it can show false-positive checksum mismatches because of partial writes. If a page checksum mismatch occurs, the page is re-read and checksum comparison is repeated.

A page is considered corrupt if checksum comparison has failed more than 100 times. In this case, the backup is aborted.

Even if data checksums are not enabled, `lt_probackup` always performs sanity checks for page headers.

## External Directories

To back up a directory located outside of the data directory, use the optional `--external-dirs` parameter that specifies the path to this directory. If you would like to add more than one external directory, you can provide several paths separated by colons on Linux systems or semicolons on Windows systems.

For example, to include `/etc/dir1` and `/etc/dir2` directories into the full backup of your `instance_name` instance that will be stored under the `backup_dir` directory on Linux, run:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
--external-dirs=/etc/dir1:/etc/dir2
```

Similarly, to include `C:\dir1` and `C:\dir2` directories into the full backup on Windows, run:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
--external-dirs=C:\dir1;C:\dir2
```

`lt_probackup` recursively copies the contents of each external directory into a separate subdirectory in the backup catalog. Since external directories included into different backups do not have to be the same, when you are restoring the cluster from an incremental backup, only those directories that belong to this particular backup will be restored. Any external directories stored in the previous backups will be ignored.

To include the same directories into each backup of your instance, you can specify them in the `pg_probackup.conf` configuration file using the `set-config` command with the `--external-dirs` option.

## Performing Cluster Verification

To verify that LightDB database cluster is not corrupt, run the following command:

```
lt_probackup checkdb [-B backup_dir [--instance instance_name]] [-D data_dir] [connection_options]
```

This command performs physical verification of all data files located in the specified data directory by running page header sanity checks, as well as block-level checksum verification if checksums are enabled. If a corrupt page is detected, `checkdb` continues cluster verification until all pages in the cluster are validated.

---

<sup>22</sup> [runtime-config-preset.html#GUC-DATA-CHECKSUMS](#)

By default, similar page validation is performed automatically while a backup is taken by `lt_probackup`. The `checkdb` command enables you to perform such page validation on demand, without taking any backup copies, even if the cluster is not backed up using `lt_probackup` at all.

To perform cluster verification, `lt_probackup` needs to connect to the cluster to be verified. In general, it is enough to specify the backup instance of this cluster for `lt_probackup` to determine the required connection options. However, if `-B` and `--instance` options are omitted, you have to provide connection options and `data_dir` via environment variables or command-line options.

Physical verification cannot detect logical inconsistencies, missing or nullified blocks and entire files, or similar anomalies. Extensions `amcheck`<sup>23</sup> provide a partial solution to these problems.

If you would like, in addition to physical verification, to verify all indexes in all databases using these extensions, you can specify the `--amcheck` flag when running the `checkdb` command:

```
lt_probackup checkdb -D data_dir --amcheck [connection_options]
```

You can skip physical verification by specifying the `--skip-block-validation` flag. In this case, you can omit `backup_dir` and `data_dir` options, only connection options are mandatory:

```
lt_probackup checkdb --amcheck --skip-block-validation  
[connection_options]
```

Logical verification can be done more thoroughly with the `--heapallindexed` flag by checking that all heap tuples that should be indexed are actually indexed, but at the higher cost of CPU, memory, and I/O consumption.

## Validating a Backup

`lt_probackup` calculates checksums for each file in a backup during the backup process. The process of checking checksums of backup data files is called *the backup validation*. By default, validation is run immediately after the backup is taken and right before the restore, to detect possible backup corruption.

If you would like to skip backup validation, you can specify the `--no-validate` flag when running backup and restore commands.

To ensure that all the required backup files are present and can be used to restore the database cluster, you can run the `validate` command with the exact recovery target options you are going to use for recovery.

For example, to check that you can restore the database cluster from a backup copy up to transaction ID 4242, run this command:

```
lt_probackup validate -B backup_dir --instance instance_name --  
recovery-target-xid=4242
```

If validation completes successfully, `lt_probackup` displays the corresponding message. If validation fails, you will receive an error message with the exact time, transaction ID, and LSN up to which the recovery is possible.

If you specify `backup_id` via `-i/--backup-id` option, then only the backup copy with specified backup ID will be validated. If `backup_id` is specified with recovery target options, the `validate` command will check whether it is possible to restore the specified backup to the specified recovery target.

For example, to check that you can restore the database cluster from a backup copy with the PT8XFX backup ID up to the specified timestamp, run this command:

---

<sup>23</sup> [amcheck.html](#)

```
lt_probackup validate -B backup_dir --instance instance_name -i
PT8XFX --recovery-target-time="2017-05-18 14:18:11+03"
```

If you specify the *backup\_id* of an incremental backup, all its parents starting from FULL backup will be validated.

If you omit all the parameters, all backups are validated.

## Restoring a Cluster

To restore the database cluster from a backup, run the restore command with at least the following options:

```
lt_probackup restore -B backup_dir --instance instance_name -
i backup_id
```

where:

- *backup\_dir* is the backup catalog that stores all backup files and meta information.
- *instance\_name* is the backup instance for the cluster to be restored.
- *backup\_id* specifies the backup to restore the cluster from. If you omit this option, lt\_probackup uses the latest valid backup available for the specified instance. If you specify an incremental backup to restore, lt\_probackup automatically restores the underlying full backup and then sequentially applies all the necessary increments.

Once the restore command is complete, start the database service.

If you restore ARCHIVE backups, perform PITR, or specify the `--restore-as-replica` flag with the restore command to set up a standby server, lt\_probackup creates a recovery configuration file once all data files are copied into the target directory. This file includes the minimal settings required for recovery, except for the password in the `primary_conninfo`<sup>24</sup> parameter; you have to add the password manually or use the `--primary-conninfo` option, if required. For LightDB, lt\_probackup writes these settings into the `probackup_recovery.conf` file and then includes it into `lightdb.auto.conf`.

If you are restoring a STREAM backup, the restore is complete at once, with the cluster returned to a self-consistent state at the point when the backup was taken. For ARCHIVE backups, LightDB replays all available archived WAL segments, so the cluster is restored to the latest state possible within the current timeline. You can change this behavior by using the recovery target options with the restore command, as explained in the section called “Performing Point-in-Time (PITR) Recovery”.

If the cluster to restore contains tablespaces, lt\_probackup restores them to their original location by default. To restore tablespaces to a different location, use the `--tablespace-mapping/-T` option. Otherwise, restoring the cluster on the same host will fail if tablespaces are in use, because the backup would have to be written to the same directories.

When using the `--tablespace-mapping/-T` option, you must provide absolute paths to the old and new tablespace directories. If a path happens to contain an equals sign (=), escape it with a backslash. This option can be specified multiple times for multiple tablespaces. For example:

```
lt_probackup restore -B backup_dir --instance instance_name -
D data_dir -j 4 -i backup_id -T tablespace1_dir=tablespace1_newdir
-T tablespace2_dir=tablespace2_newdir
```

To restore the cluster on a remote host, follow the instructions in the section called “Using lt\_probackup in the Remote Mode”.

---

<sup>24</sup> runtime-config-replication.html#GUC-PRIMARY-CONNINFO

**Note**

By default, the restore command validates the specified backup before restoring the cluster. If you run regular backup validations and would like to save time when restoring the cluster, you can specify the `--no-validate` flag to skip validation and speed up the recovery.

**Incremental Restore**

The speed of restore from backup can be significantly improved by replacing only invalid and changed pages in already existing LightDB data directory using incremental restore options with the restore command.

To restore the database cluster from a backup in incremental mode, run the restore command with the following options:

```
lt_probackup restore -B backup_dir --instance instance_name -
D data_dir -I incremental_mode
```

Where *incremental\_mode* can take one of the following values:

- **CHECKSUM** — read all data files in the data directory, validate header and checksum in every page and replace only invalid pages and those with checksum and LSN not matching with corresponding page in backup. This is the simplest, the most fool-proof incremental mode. Recommended to use by default.
- **LSN** — read the *lt\_control* in the data directory to obtain redo LSN and redo TLI, which allows to determine a point in history(shiftpoint), where data directory state shifted from target backup chain history. If shiftpoint is not within reach of backup chain history, then restore is aborted. If shiftpoint is within reach of backup chain history, then read all data files in the data directory, validate header and checksum in every page and replace only invalid pages and those with LSN greater than shiftpoint. This mode offers a greater speed up compared to CHECKSUM, but rely on two conditions to be met. First, `data_checksums25` parameter must be enabled in data directory (to avoid corruption due to hint bits). This condition will be checked at the start of incremental restore and the operation will be aborted if checksums are disabled. Second, the *lt\_control* file must be synched with state of data directory. This condition cannot be checked at the start of restore, so it is a user responsibility to ensure that *lt\_control* contain valid information. Therefore it is not recommended to use LSN mode in any situation, where *lt\_control* cannot be trusted or has been tampered with: after `pg_resetxlog` execution, after restore from backup without recovery been run, etc.
- **NONE** — regular restore without any incremental optimizations.

Regardless of chosen incremental mode, `lt_probackup` will check, that postmaster in given destination directory is not running and `system-identifier` is the same as in the backup.

Suppose you want to return an old master as replica after switchover using incremental restore in LSN mode:

```
=====
Instance  Version  ID      Recovery Time      Mode  WAL Mode
  TLI      Time    Data    WAL  Zratio  Start LSN    Stop LSN
Status
=====
```

<sup>25</sup> [runtime-config-preset.html#GUC-DATA-CHECKSUMS](#)



```

node      12      QBRNBP  2020-06-11 17:40:58+03 DELTA  ARCHIVE
 16/15    40s    194MB  16MB    8.26  15/2C000028  15/2D000128
OK
node      12      QBRIDX  2020-06-11 15:51:42+03 PAGE   ARCHIVE
 15/15    11s    18MB   16MB    5.10  14/DC000028  14/DD0000B8
OK
node      12      QBRIAJ  2020-06-11 15:51:08+03 PAGE   ARCHIVE
 15/15    20s    141MB  96MB    6.22  14/D4BABFE0  14/DA9871D0
OK
node      12      QBRHT8  2020-06-11 15:45:56+03 FULL   ARCHIVE
 15/0     2m:11s 1371MB 416MB   10.93 14/9D000028  14/B782E9A0
OK

```

```

lt_probackup restore -B /backup --instance node -R -I lsn
INFO: Running incremental restore into nonempty directory: "/var/
lib/lightdb-x/12/data"
INFO: Destination directory redo point 15/2E000028 on tli 16 is
  within reach of backup QBRIDX with Stop LSN 14/DD0000B8 on tli 15
INFO: shift LSN: 14/DD0000B8
INFO: Restoring the database from backup at 2020-06-11 17:40:58+03
INFO: Extracting the content of destination directory for
  incremental restore
INFO: Destination directory content extracted, time elapsed: 1s
INFO: Removing redundant files in destination directory
INFO: Redundant files are removed, time elapsed: 1s
INFO: Start restoring backup files. LTDATA size: 15GB
INFO: Backup files are restored. Transferred bytes: 1693MB, time
  elapsed: 43s
INFO: Restore incremental ratio (less is better): 11% (1693MB/15GB)
INFO: Restore of backup QBRNBP completed.

```

### Note

Incremental restore is possible only for backups with `program_version` equal or greater than 2.4.0.

## Partial Restore

If you have enabled partial restore before taking backups, you can restore only some of the databases using partial restore options with the restore commands.

To restore the specified databases only, run the restore command with the following options:

```
lt_probackup restore -B backup_dir --instance instance_name --db-include=database_name
```

The `--db-include` option can be specified multiple times. For example, to restore only databases `db1` and `db2`, run the following command:

```
lt_probackup restore -B backup_dir --instance instance_name --db-include=db1 --db-include=db2
```

To exclude one or more databases from restore, use the `--db-exclude` option:

```
lt_probackup restore -B backup_dir --instance instance_name --db-exclude=database_name
```

The `--db-exclude` option can be specified multiple times. For example, to exclude the databases `db1` and `db2` from restore, run the following command:

```
lt_probackup restore -B backup_dir --instance instance_name --db-exclude=db1 --db-exclude=db2
```

Partial restore relies on lax behavior of LightDB recovery process toward truncated files. For recovery to work properly, files of excluded databases are restored as files of zero size. After the LightDB cluster is successfully started, you must drop the excluded databases using `DROP DATABASE` command.

To decouple a single cluster containing multiple databases into separate clusters with minimal downtime, you can do partial restore of the cluster as a standby using the `--restore-as-replica` option for specific databases.

### Note

The `template0` and `template1` databases are always restored.

## Performing Point-in-Time (PITR) Recovery

If you have enabled continuous WAL archiving before taking backups, you can restore the cluster to its state at an arbitrary point in time (recovery target) using recovery target options with the restore command.

You can use both `STREAM` and `ARCHIVE` backups for point in time recovery as long as the WAL archive is available at least starting from the time the backup was taken. If `-i/--backup-id` option is omitted, `lt_probackup` automatically chooses the backup that is the closest to the specified recovery target and starts the restore process, otherwise `lt_probackup` will try to restore the specified backup to the specified recovery target.

- To restore the cluster state at the exact time, specify the `--recovery-target-time` option, in the timestamp format. For example:

```
lt_probackup restore -B backup_dir --instance instance_name --recovery-target-time="2017-05-18 14:18:11+03"
```

- To restore the cluster state up to a specific transaction ID, use the `--recovery-target-xid` option:

```
lt_probackup restore -B backup_dir --instance instance_name --recovery-target-xid=687
```

- To restore the cluster state up to the specific LSN, use `--recovery-target-lsn` option:

```
lt_probackup restore -B backup_dir --instance instance_name --recovery-target-lsn=16/B374D848
```

- To restore the cluster state up to the specific named restore point, use `--recovery-target-name` option:

```
lt_probackup restore -B backup_dir --instance instance_name --
recovery-target-name="before_app_upgrade"
```

- To restore the backup to the latest state available in the WAL archive, use `--recovery-target` option with `latest` value:

```
lt_probackup restore -B backup_dir --instance instance_name --
recovery-target="latest"
```

- To restore the cluster to the earliest point of consistency, use `--recovery-target` option with the `immediate` value:

```
lt_probackup restore -B backup_dir --instance instance_name --
recovery-target='immediate'
```

## Using lt\_probackup in the Remote Mode

lt\_probackup supports the remote mode that allows to perform backup and restore operations remotely via SSH. In this mode, the backup catalog is stored on a local system, while LightDB instance to be backed up is located on a remote system. You must have lt\_probackup installed on both systems.

### Note

lt\_probackup relies on passwordless SSH connection for communication between the hosts.

The typical workflow is as follows:

- On your backup host, configure lt\_probackup as explained in the section Installation and Setup. For the `add-instance` and `set-config` commands, make sure to specify remote options that point to the database host with the LightDB instance.
- If you would like to take remote backups in PAGE mode, or rely on ARCHIVE WAL delivery mode, or use PITR, configure continuous WAL archiving from the database host to the backup host as explained in the section Setting up continuous WAL archiving. For the `archive-push` and `archive-get` commands, you must specify the remote options that point to the backup host with the backup catalog.
- Run backup or restore commands with remote options **on the backup host**. lt\_probackup connects to the remote system via SSH and creates a backup locally or restores the previously taken backup on the remote system, respectively.

For example, to create an archive full backup of a LightDB cluster located on a remote system with host address `192.168.0.2` on behalf of the `lightdb` user via SSH connection through port `2302`, run:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
--remote-user=lightdb --remote-host=192.168.0.2 --remote-port=2302
```

To restore the latest available backup on a remote system with host address `192.168.0.2` on behalf of the `lightdb` user via SSH connection through port `2302`, run:

```
lt_probackup restore -B backup_dir --instance instance_name --
remote-user=lightdb--remote-host=192.168.0.2 --remote-port=2302
```

Restoring an ARCHIVE backup or performing PITR in the remote mode require additional information: destination address, port and username for establishing an SSH connection **from** the host with database **to** the host with the backup catalog. This information will be used by the `restore_command` to copy WAL segments from the archive to the LightDB `lt_wal` directory.

To solve this problem, you can use Remote WAL Archive Options.

For example, to restore latest backup on remote system using remote mode through SSH connection to user `lightdb` on host with address `192.168.0.2` via port `2302` and user `backup` on backup catalog host with address `192.168.0.3` via port `2303`, run:

```
lt_probackup restore -B backup_dir --instance instance_name --
remote-user=lightdb--remote-host=192.168.0.2 --remote-port=2302 --
archive-host=192.168.0.3 --archive-port=2303 --archive-user=backup
```

Provided arguments will be used to construct the `restore_command`:

```
restore_command = '"install_dir/lt_probackup" archive-get -B
"backup_dir" --instance instance_name --wal-file-path=%p --wal-
file-name=%f --remote-host=192.168.0.3 --remote-port=2303 --remote-
user=backup'
```

Alternatively, you can use the `--restore-command` option to provide the entire `restore_command`:

```
lt_probackup restore -B backup_dir --instance instance_name --
remote-user=lightdb --remote-host=192.168.0.2 --remote-port=2302
--restore-command='"install_dir/lt_probackup" archive-get -B
"backup_dir" --instance instance_name --wal-file-path=%p --wal-
file-name=%f --remote-host=192.168.0.3 --remote-port=2303 --remote-
user=backup'
```

### Note

The remote mode is currently unavailable for Windows systems.

## Running lt\_probackup on Parallel Threads

backup, restore, merge, delete, checkdb and validate processes can be executed on several parallel threads. This can significantly speed up `lt_probackup` operation given enough resources (CPU cores, disk, and network bandwidth).

Parallel execution is controlled by the `-j/--threads` command-line option. For example, to create a backup using four parallel threads, run:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
-j 4
```

### Note

Parallel restore applies only to copying data from the backup catalog to the data directory of the cluster. When LightDB server is started, WAL records need to be replayed, and this cannot be done in parallel.

## Configuring lt\_probackup

Once the backup catalog is initialized and a new backup instance is added, you can use the `pg_probackup.conf` configuration file located in the `backup_dir/backups/instance_name` directory to fine-tune `lt_probackup` configuration.

For example, `backup` and `checkdb` commands use a regular LightDB connection. To avoid specifying connection options each time on the command line, you can set them in the `pg_probackup.conf` configuration file using the `set-config` command.

### Note

It is **not recommended** to edit `pg_probackup.conf` manually.

Initially, `pg_probackup.conf` contains the following settings:

- `LTDATA` — the path to the data directory of the cluster to back up.
- `system-identifier` — the unique identifier of the LightDB instance.

Additionally, you can define remote, retention, logging, and compression settings using the `set-config` command:

```
lt_probackup set-config -B backup_dir --instance instance_name
[--external-dirs=external_directory_path] [remote_options]
[connection_options] [retention_options] [logging_options]
```

To view the current settings, run the following command:

```
lt_probackup show-config -B backup_dir --instance instance_name
```

You can override the settings defined in `pg_probackup.conf` when running `lt_probackup` commands via the corresponding environment variables and/or command line options.

## Specifying Connection Settings

If you define connection settings in the `pg_probackup.conf` configuration file, you can omit connection options in all the subsequent `lt_probackup` commands. However, if the corresponding environment variables are set, they get higher priority. The options provided on the command line overwrite both environment variables and configuration file settings.

If nothing is given, the default values are taken. By default `lt_probackup` tries to use local connection via Unix domain socket (`localhost` on Windows) and tries to get the database name and the user name from the `LTUSER` environment variable or the current OS user name.

## Managing the Backup Catalog

With `lt_probackup`, you can manage backups from the command line:

- View backup information
- View WAL Archive Information
- Validate backups
- Merge backups
- Delete backups

## Viewing Backup Information

To view the list of existing backups for every instance, run the command:

```
lt_probackup show -B backup_dir
```

lt\_probackup displays the list of all the available backups. For example:

```
BACKUP INSTANCE 'node'
```

```
=====
Instance Version ID      Recovery time          Mode   WAL
Mode TLI  Time  Data  WAL  Zratio  Start LSN  Stop LSN
Status
=====
node      10      PYSUE8  2019-10-03 15:51:48+03  FULL  ARCHIVE
  1/0    16s  9047kB 16MB   4.31  0/12000028  0/12000160  OK
node      10      P7XDQV  2018-04-29 05:32:59+03  DELTA  STREAM
  1/1    11s   19MB 16MB   1.00  0/15000060  0/15000198  OK
node      10      P7XDJA  2018-04-29 05:28:36+03  PTRACK  STREAM
  1/1    21s   32MB 32MB   1.00  0/13000028  0/13000198  OK
node      10      P7XDHU  2018-04-29 05:27:59+03  PAGE   STREAM
  1/1    15s   33MB 16MB   1.00  0/11000028  0/110001D0  OK
node      10      P7XDHB  2018-04-29 05:27:15+03  FULL  STREAM
  1/0    11s   39MB 16MB   1.00  0/F000028   0/F000198   OK
=====
```

For each backup, the following information is provided:

- Instance — the instance name.
- Version — LightDB major version.
- ID — the backup identifier.
- Recovery time — the earliest moment for which you can restore the state of the database cluster.
- Mode — the method used to take this backup. Possible values: FULL, PAGE, DELTA, PTRACK.
- WAL Mode — WAL delivery mode. Possible values: STREAM and ARCHIVE.
- TLI — timeline identifiers of the current backup and its parent.
- Time — the time it took to perform the backup.
- Data — the size of the data files in this backup. This value does not include the size of WAL files. For STREAM backups, the total size of the backup can be calculated as Data + WAL.
- WAL — the uncompressed size of WAL files that need to be applied during recovery for the backup to reach a consistent state.
- Zratio — compression ratio calculated as “uncompressed-bytes” / “data-bytes”.
- Start LSN — WAL log sequence number corresponding to the start of the backup process. REDO point for LightDB recovery process to start from.
- Stop LSN — WAL log sequence number corresponding to the end of the backup process. Consistency point for LightDB recovery process.
- Status — backup status. Possible values:
  - OK — the backup is complete and valid.
  - DONE — the backup is complete, but was not validated.
  - RUNNING — the backup is in progress.
  - MERGING — the backup is being merged.
  - MERGED — the backup data files were successfully merged, but its metadata is in the process of being updated. Only full backups can have this status.
  - DELETING — the backup files are being deleted.

- CORRUPT — some of the backup files are corrupt.
- ERROR — the backup was aborted because of an unexpected error.
- ORPHAN — the backup is invalid because one of its parent backups is corrupt or missing.

You can restore the cluster from the backup only if the backup status is OK or DONE.

To get more detailed information about the backup, run the `show` command with the backup ID:

```
lt_probackup show -B backup_dir --instance instance_name -
i backup_id
```

The sample output is as follows:

```
#Configuration
backup-mode = FULL
stream = false
compress-alg = zlib
compress-level = 1
from-replica = false

#Compatibility
block-size = 8192
wal-block-size = 8192
checksum-version = 1
program-version = 2.1.3
server-version = 10

#Result backup info
timelineid = 1
start-lsn = 0/04000028
stop-lsn = 0/040000f8
start-time = '2017-05-16 12:57:29'
end-time = '2017-05-16 12:57:31'
recovery-xid = 597
recovery-time = '2017-05-16 12:57:31'
expire-time = '2020-05-16 12:57:31'
data-bytes = 22288792
wal-bytes = 16777216
uncompressed-bytes = 39961833
pgdata-bytes = 39859393
status = OK
parent-backup-id = 'PT8XFX'
primary_conninfo = 'user=backup passfile=/var/lib/lightdb-
x/.pgpass port=5432 sslmode=disable sslcompression=1
target_session_attrs=any'
```

Detailed output has additional attributes:

- `compress-alg` — compression algorithm used during backup. Possible values: `zlib`, `pglz`, `none`.
- `compress-level` — compression level used during backup.
- `from-replica` — was this backup taken on standby? Possible values: `1`, `0`.
- `block-size` — the `block_size`<sup>26</sup> setting of LightDB cluster at the backup start.
- `checksum-version` — are data block checksums<sup>27</sup> enabled in the backed up LightDB cluster? Possible values: `1`, `0`.

<sup>26</sup> [runtime-config-preset.html#GUC-BLOCK-SIZE](#)

<sup>27</sup> [runtime-config-preset.html#GUC-DATA-CHECKSUMS](#)

- `program-version` — full version of `lt_probackup` binary used to create the backup.
- `start-time` — the backup start time.
- `end-time` — the backup end time.
- `expire-time` — the point in time when a pinned backup can be removed in accordance with retention policy. This attribute is only available for pinned backups.
- `uncompressed-bytes` — the size of data files before adding page headers and applying compression. You can evaluate the effectiveness of compression by comparing `uncompressed-bytes` to `data-bytes` if compression is used.
- `pgdata-bytes` — the size of LightDB cluster data files at the time of backup. You can evaluate the effectiveness of an incremental backup by comparing `pgdata-bytes` to `uncompressed-bytes`.
- `recovery-xid` — transaction ID at the backup end time.
- `parent-backup-id` — ID of the parent backup. Available only for incremental backups.
- `primary_conninfo` — libpq connection parameters used to connect to the LightDB cluster to take this backup. The password is not included.
- `note` — text note attached to backup.
- `content-crc` — CRC32 checksum of `backup_content.control` file. It is used to detect corruption of backup meta-information.

You can also get the detailed information about the backup in the JSON format:

```
lt_probackup show -B backup_dir --instance instance_name --
format=json -i backup_id
```

The sample output is as follows:

```
[
  {
    "instance": "node",
    "backups": [
      {
        "id": "PT91HZ",
        "parent-backup-id": "PT8XFX",
        "backup-mode": "DELTA",
        "wal": "ARCHIVE",
        "compress-alg": "zlib",
        "compress-level": 1,
        "from-replica": false,
        "block-size": 8192,
        "xlog-block-size": 8192,
        "checksum-version": 1,
        "program-version": "2.1.3",
        "server-version": "10",
        "current-tli": 16,
        "parent-tli": 2,
        "start-lsn": "0/8000028",
        "stop-lsn": "0/8000160",
        "start-time": "2019-06-17 18:25:11+03",
        "end-time": "2019-06-17 18:25:16+03",
        "recovery-xid": 0,
        "recovery-time": "2019-06-17 18:25:15+03",
        "data-bytes": 106733,
        "wal-bytes": 16777216,
        "primary_conninfo": "user=backup passfile=/var/
lib/lightdb-x/.pgpass port=5432 sslmode=disable sslcompression=1
target_session_attrs=any",
        "status": "OK"
      }
    ]
  }
]
```



```

    }
  ]
}
]

```

## Viewing WAL Archive Information

To view the information about WAL archive for every instance, run the command:

```
lt_probackup show -B backup_dir [--instance instance_name] --
archive
```

lt\_probackup displays the list of all the available WAL files grouped by timelines. For example:

```
ARCHIVE INSTANCE 'node'
```

```

=====
  TLI  Parent TLI  Switchpoint  Min Segno          Max Segno
        N segments  Size      Zratio  N backups  Status
=====
  5    1      0/B000000  000000050000000000000000B
000000050000000000000000C  2      685kB   48.00   0
OK
  4    3      0/18000000  000000040000000000000018
00000004000000000000001A  3      648kB   77.00   0
OK
  3    2      0/15000000  000000030000000000000015
000000030000000000000017  3      648kB   77.00   0
OK
  2    1      0/B000108   00000002000000000000000B
000000020000000000000015  5      892kB   94.00   1
DEGRADED
  1    0      0/0         000000010000000000000001
00000001000000000000000A  10     8774kB  19.00   1
OK
=====

```

For each timeline, the following information is provided:

- **TLI** — timeline identifier.
- **Parent TLI** — identifier of the timeline from which this timeline branched off.
- **Switchpoint** — LSN of the moment when the timeline branched off from its parent timeline.
- **Min Segno** — the first WAL segment belonging to the timeline.
- **Max Segno** — the last WAL segment belonging to the timeline.
- **N segments** — number of WAL segments belonging to the timeline.
- **Size** — the size that files take on disk.
- **Zratio** — compression ratio calculated as  $N \text{ segments} * wal\_segment\_size * wal\_block\_size / Size$ .
- **N backups** — number of backups belonging to the timeline. To get the details about backups, use the JSON format.
- **Status** — status of the WAL archive for this timeline. Possible values:
  - **OK** — all WAL segments between **Min Segno** and **Max Segno** are present.
  - **DEGRADED** — some WAL segments between **Min Segno** and **Max Segno** are missing. To find out which files are lost, view this report in the JSON format.

To get more detailed information about the WAL archive in the JSON format, run the command:

```
lt_probackup show -B backup_dir [--instance instance_name] --
archive --format=json
```

The sample output is as follows:

```
[
  {
    "instance": "replica",
    "timelines": [
      {
        "tli": 5,
        "parent-tli": 1,
        "switchpoint": "0/B000000",
        "min-segno": "000000050000000000000000B",
        "max-segno": "000000050000000000000000C",
        "n-segments": 2,
        "size": 685320,
        "zratio": 48.00,
        "closest-backup-id": "PXS920",
        "status": "OK",
        "lost-segments": [],
        "backups": []
      },
      {
        "tli": 4,
        "parent-tli": 3,
        "switchpoint": "0/18000000",
        "min-segno": "00000004000000000000000018",
        "max-segno": "0000000400000000000000001A",
        "n-segments": 3,
        "size": 648625,
        "zratio": 77.00,
        "closest-backup-id": "PXS9CE",
        "status": "OK",
        "lost-segments": [],
        "backups": []
      },
      {
        "tli": 3,
        "parent-tli": 2,
        "switchpoint": "0/15000000",
        "min-segno": "00000003000000000000000015",
        "max-segno": "00000003000000000000000017",
        "n-segments": 3,
        "size": 648911,
        "zratio": 77.00,
        "closest-backup-id": "PXS9CE",
        "status": "OK",
        "lost-segments": [],
        "backups": []
      },
      {
        "tli": 2,
        "parent-tli": 1,
        "switchpoint": "0/B000108",
        "min-segno": "000000020000000000000000B",
        "max-segno": "00000002000000000000000015",
```

```

    "n-segments": 5,
    "size": 892173,
    "zratio": 94.00,
    "closest-backup-id": "PXS920",
    "status": "DEGRADED",
    "lost-segments": [
      {
        "begin-segno": "000000020000000000000000D",
        "end-segno": "000000020000000000000000E"
      },
      {
        "begin-segno": "00000002000000000000000010",
        "end-segno": "00000002000000000000000012"
      }
    ],
    "backups": [
      {
        "id": "PXS9CE",
        "backup-mode": "FULL",
        "wal": "ARCHIVE",
        "compress-alg": "none",
        "compress-level": 1,
        "from-replica": "false",
        "block-size": 8192,
        "xlog-block-size": 8192,
        "checksum-version": 1,
        "program-version": "2.1.5",
        "server-version": "10",
        "current-tli": 2,
        "parent-tli": 0,
        "start-lsn": "0/C000028",
        "stop-lsn": "0/C000160",
        "start-time": "2019-09-13 21:43:26+03",
        "end-time": "2019-09-13 21:43:30+03",
        "recovery-xid": 0,
        "recovery-time": "2019-09-13 21:43:29+03",
        "data-bytes": 104674852,
        "wal-bytes": 16777216,
        "primary_conninfo": "user=backup
passfile=/var/lib/lightdb-x/.pgpass port=5432 sslmode=disable
sslcompression=1 target_session_attrs=any",
        "status": "OK"
      }
    ]
  },
  {
    "tli": 1,
    "parent-tli": 0,
    "switchpoint": "0/0",
    "min-segno": "00000001000000000000000000001",
    "max-segno": "0000000100000000000000000000A",
    "n-segments": 10,
    "size": 8774805,
    "zratio": 19.00,
    "closest-backup-id": "",
    "status": "OK",
    "lost-segments": [],
    "backups": [

```

```

    {
      "id": "PXS92O",
      "backup-mode": "FULL",
      "wal": "ARCHIVE",
      "compress-alg": "none",
      "compress-level": 1,
      "from-replica": "true",
      "block-size": 8192,
      "xlog-block-size": 8192,
      "checksum-version": 1,
      "program-version": "2.1.5",
      "server-version": "10",
      "current-tli": 1,
      "parent-tli": 0,
      "start-lsn": "0/4000028",
      "stop-lsn": "0/6000028",
      "start-time": "2019-09-13 21:37:36+03",
      "end-time": "2019-09-13 21:38:45+03",
      "recovery-xid": 0,
      "recovery-time": "2019-09-13 21:37:30+03",
      "data-bytes": 25987319,
      "wal-bytes": 50331648,
      "primary_conninfo": "user=backup
passfile=/var/lib/lightdb-x/.pgpass port=5432 sslmode=disable
sslcompression=1 target_session_attrs=any",
      "status": "OK"
    }
  ]
}
},
{
  "instance": "master",
  "timelines": [
    {
      "tli": 1,
      "parent-tli": 0,
      "switchpoint": "0/0",
      "min-segno": "00000001000000000000000001",
      "max-segno": "0000000100000000000000000B",
      "n-segments": 11,
      "size": 8860892,
      "zratio": 20.00,
      "status": "OK",
      "lost-segments": [],
      "backups": [
        {
          "id": "PXS92H",
          "parent-backup-id": "PXS92C",
          "backup-mode": "PAGE",
          "wal": "ARCHIVE",
          "compress-alg": "none",
          "compress-level": 1,
          "from-replica": "false",
          "block-size": 8192,
          "xlog-block-size": 8192,
          "checksum-version": 1,
          "program-version": "2.1.5",

```

```
    "server-version": "10",
    "current-tli": 1,
    "parent-tli": 1,
    "start-lsn": "0/4000028",
    "stop-lsn": "0/50000B8",
    "start-time": "2019-09-13 21:37:29+03",
    "end-time": "2019-09-13 21:37:31+03",
    "recovery-xid": 0,
    "recovery-time": "2019-09-13 21:37:30+03",
    "data-bytes": 1328461,
    "wal-bytes": 33554432,
    "primary_conninfo": "user=backup
passfile=/var/lib/lightdb-x/.pgpass port=5432 sslmode=disable
sslcompression=1 target_session_attrs=any",
    "status": "OK"
  },
  {
    "id": "PXS92C",
    "backup-mode": "FULL",
    "wal": "ARCHIVE",
    "compress-alg": "none",
    "compress-level": 1,
    "from-replica": "false",
    "block-size": 8192,
    "xlog-block-size": 8192,
    "checksum-version": 1,
    "program-version": "2.1.5",
    "server-version": "10",
    "current-tli": 1,
    "parent-tli": 0,
    "start-lsn": "0/2000028",
    "stop-lsn": "0/2000160",
    "start-time": "2019-09-13 21:37:24+03",
    "end-time": "2019-09-13 21:37:29+03",
    "recovery-xid": 0,
    "recovery-time": "2019-09-13 21:37:28+03",
    "data-bytes": 24871902,
    "wal-bytes": 16777216,
    "primary_conninfo": "user=backup
passfile=/var/lib/lightdb-x/.pgpass port=5432 sslmode=disable
sslcompression=1 target_session_attrs=any",
    "status": "OK"
  }
]
}
]
}
```

Most fields are consistent with the plain format, with some exceptions:

- The size is in bytes.
- The `closest-backup-id` attribute contains the ID of the most recent valid backup that belongs to one of the previous timelines. You can use this backup to perform point-in-time recovery to this timeline. If such a backup does not exist, this string is empty.
- The `lost-segments` array provides with information about intervals of missing segments in DEGRADED timelines. In OK timelines, the `lost-segments` array is empty.

- The backups array lists all backups belonging to the timeline. If the timeline has no backups, this array is empty.

## Configuring Retention Policy

With `lt_probackup`, you can configure retention policy to remove redundant backups, clean up unneeded WAL files, as well as pin specific backups to ensure they are kept for the specified time, as explained in the sections below. All these actions can be combined together in any way.

### Removing Redundant Backups

By default, all backup copies created with `lt_probackup` are stored in the specified backup catalog. To save disk space, you can configure retention policy to remove redundant backup copies.

To configure retention policy, set one or more of the following variables in the `pg_probackup.conf` file via `set-config`:

```
--retention-redundancy=redundancy
```

Specifies **the number of full backup copies** to keep in the backup catalog.

```
--retention-window=window
```

Defines the earliest point in time for which `lt_probackup` can complete the recovery. This option is set in **the number of days** from the current moment. For example, if `retention-window=7`, `lt_probackup` must keep at least one backup copy that is older than seven days, with all the corresponding WAL files, and all the backups that follow.

If both `--retention-redundancy` and `--retention-window` options are set, both these conditions have to be taken into account when purging the backup catalog. For example, if you set `--retention-redundancy=2` and `--retention-window=7`, `lt_probackup` has to keep two full backup copies, as well as all the backups required to ensure recoverability for the last seven days:

```
lt_probackup set-config -B backup_dir --instance instance_name --  
retention-redundancy=2 --retention-window=7
```

To clean up the backup catalog in accordance with retention policy, you have to run the `delete` command with retention flags, as shown below, or use the `backup` command with these flags to process the outdated backup copies right when the new backup is created.

For example, to remove all backup copies that no longer satisfy the defined retention policy, run the following command with the `--delete-expired` flag:

```
lt_probackup delete -B backup_dir --instance instance_name --  
delete-expired
```

If you would like to also remove the WAL files that are no longer required for any of the backups, you should also specify the `--delete-wal` flag:

```
lt_probackup delete -B backup_dir --instance instance_name --  
delete-expired --delete-wal
```

You can also set or override the current retention policy by specifying `--retention-redundancy` and `--retention-window` options directly when running `delete` or `backup` commands:

```
lt_probackup delete -B backup_dir --instance instance_name --
delete-expired --retention-window=7 --retention-redundancy=2
```

Since incremental backups require that their parent full backup and all the preceding incremental backups are available, if any of such backups expire, they still cannot be removed while at least one incremental backup in this chain satisfies the retention policy. To avoid keeping expired backups that are still required to restore an active incremental one, you can merge them with this backup using the `--merge-expired` flag when running backup or delete commands.

Suppose you have backed up the `node` instance in the `backup_dir` directory, with the `--retention-window` option set to 7, and you have the following backups available on April 10, 2019:

```
BACKUP INSTANCE 'node'
```

```
=====
Instance  Version  ID      Recovery time          Mode  WAL
TLI  Time    Data    WAL  Zratio  Start LSN  Stop LSN  Status
=====
node      10      P7XDHR  2019-04-10 05:27:15+03  FULL  STREAM
1/0  11s    200MB  16MB    1.0  0/18000059  0/18000197  OK
node      10      P7XDQV  2019-04-08 05:32:59+03  PAGE  STREAM
1/0  11s    19MB   16MB    1.0  0/15000060  0/15000198  OK
node      10      P7XDJA  2019-04-03 05:28:36+03  DELTA  STREAM
1/0  21s    32MB   16MB    1.0  0/13000028  0/13000198  OK
-----retention
window-----
node      10      P7XDHU  2019-04-02 05:27:59+03  PAGE  STREAM
1/0  31s    33MB   16MB    1.0  0/11000028  0/110001D0  OK
node      10      P7XDHB  2019-04-01 05:27:15+03  FULL  STREAM
1/0  11s    200MB  16MB    1.0  0/F000028   0/F000198   OK
node      10      P7XDFT  2019-03-29 05:26:25+03  FULL  STREAM
1/0  11s    200MB  16MB    1.0  0/D000028   0/D000198   OK
```

Even though P7XDHB and P7XDHU backups are outside the retention window, they cannot be removed as it invalidates the succeeding incremental backups P7XDJA and P7XDQV that are still required, so, if you run the delete command with the `--delete-expired` flag, only the P7XDFT full backup will be removed.

With the `--merge-expired` option, the P7XDJA backup is merged with the underlying P7XDHU and P7XDHB backups and becomes a full one, so there is no need to keep these expired backups anymore:

```
lt_probackup delete -B backup_dir --instance node --delete-expired
--merge-expired
lt_probackup show -B backup_dir
```

```
BACKUP INSTANCE 'node'
```

```
=====
Instance  Version  ID      Recovery time          Mode  WAL
TLI  Time    Data    WAL  Zratio  Start LSN  Stop LSN  Status
=====
node      10      P7XDHR  2019-04-10 05:27:15+03  FULL  STREAM
1/0  11s    200MB  16MB    1.0  0/18000059  0/18000197  OK
node      10      P7XDQV  2019-04-08 05:32:59+03  PAGE  STREAM
1/0  11s    19MB   16MB    1.0  0/15000060  0/15000198  OK
```

---

```
node      10      P7XDJA  2019-04-03 05:28:36+03  FULL  STREAM
1/0    21s    32MB  16MB    1.0  0/13000028  0/13000198  OK
```

The Time field for the merged backup displays the time required for the merge.

## Pinning Backups

If you need to keep certain backups longer than the established retention policy allows, you can pin them for arbitrary time. For example:

```
lt_probackup set-backup -B backup_dir --instance instance_name -
i backup_id --ttl=30d
```

This command sets the expiration time of the specified backup to 30 days starting from the time indicated in its `recovery-time` attribute.

You can also explicitly set the expiration time for a backup using the `--expire-time` option. For example:

```
lt_probackup set-backup -B backup_dir --instance instance_name -
i backup_id --expire-time="2020-01-01 00:00:00+03"
```

Alternatively, you can use the `--ttl` and `--expire-time` options with the backup command to pin the newly created backup:

```
lt_probackup backup -B backup_dir --instance instance_name -b FULL
--ttl=30d
lt_probackup backup -B backup_dir --instance instance_name -b FULL
--expire-time="2020-01-01 00:00:00+03"
```

To check if the backup is pinned, run the show command:

```
lt_probackup show -B backup_dir --instance instance_name -
i backup_id
```

If the backup is pinned, it has the `expire-time` attribute that displays its expiration time:

```
...
recovery-time = '2017-05-16 12:57:31'
expire-time   = '2020-01-01 00:00:00+03'
data-bytes    = 22288792
...
```

You can unpin the backup by setting the `--ttl` option to zero:

```
lt_probackup set-backup -B backup_dir --instance instance_name -
i backup_id --ttl=0
```

### Note

A pinned incremental backup implicitly pins all its parent backups. If you unpin such a backup later, its implicitly pinned parents will also be automatically unpinned.



## Configuring WAL Archive Retention Policy

When continuous WAL archiving is enabled, archived WAL segments can take a lot of disk space. Even if you delete old backup copies from time to time, the `--delete-wal` flag can purge only those WAL segments that do not apply to any of the remaining backups in the backup catalog. However, if point-in-time recovery is critical only for the most recent backups, you can configure WAL archive retention policy to keep WAL archive of limited depth and win back some more disk space.

To configure WAL archive retention policy, you have to run the `set-config` command with the `--wal-depth` option that specifies the number of backups that can be used for PITR. This setting applies to all the timelines, so you should be able to perform PITR for the same number of backups on each timeline, if available. Pinned backups are not included into this count: if one of the latest backups is pinned, `lt_probackup` ensures that PITR is possible for one extra backup.

To remove WAL segments that do not satisfy the defined WAL archive retention policy, you simply have to run the `delete` or `backup` command with the `--delete-wal` flag. For archive backups, WAL segments between `Start LSN` and `Stop LSN` are always kept intact, so such backups remain valid regardless of the `--wal-depth` setting and can still be restored, if required.

You can also use the `--wal-depth` option with the `delete` and `backup` commands to override the previously defined WAL archive retention policy and purge old WAL segments on the fly.

Suppose you have backed up the `node` instance in the `backup_dir` directory and configured continuous WAL archiving:

```
lt_probackup show -B backup_dir --instance node
```

```
BACKUP INSTANCE 'node'
```

```
=====
Instance Version ID Recovery Time Mode WAL Mode
  TLI Time Data WAL Zratio Start LSN Stop LSN Status
=====
node 11 PZ9442 2019-10-12 10:43:21+03 DELTA STREAM
 1/0 10s 121kB 16MB 1.00 0/46000028 0/46000160 OK
node 11 PZ943L 2019-10-12 10:43:04+03 FULL STREAM
 1/0 10s 180MB 32MB 1.00 0/44000028 0/44000160 OK
node 11 PZ7YR5 2019-10-11 19:49:56+03 DELTA STREAM
 1/1 10s 112kB 32MB 1.00 0/41000028 0/41000160 OK
node 11 PZ7YMP 2019-10-11 19:47:16+03 DELTA STREAM
 1/1 10s 376kB 32MB 1.00 0/3E000028 0/3F0000B8 OK
node 11 PZ7YK2 2019-10-11 19:45:45+03 FULL STREAM
 1/0 11s 180MB 16MB 1.00 0/3C000028 0/3C000198 OK
node 11 PZ7YFO 2019-10-11 19:43:04+03 FULL STREAM
 1/0 10s 30MB 16MB 1.00 0/2000028 0/200ADD8 OK
```

You can check the state of the WAL archive by running the `show` command with the `--archive` flag:

```
lt_probackup show -B backup_dir --instance node --archive
```

```
ARCHIVE INSTANCE 'node'
```

```
=====
  TLI Parent TLI Switchpoint Min Segno Max Segno
      N segments Size Zratio N backups Status
=====
  1 0 0/0 00000001000000000000000000000001
00000001000000000000000000000047 71 36MB 31.00 6 OK
```

WAL purge without `--wal-depth` cannot achieve much, only one segment is removed:

```
lt_probackup delete -B backup_dir --instance node --delete-wal
```

```
ARCHIVE INSTANCE 'node'
```

```
=====
TLI  Parent TLI  Switchpoint  Min Segno          Max Segno
      N segments  Size  Zratio  N backups  Status
=====
1    0          0/0          0000000100000000000000002
0000000100000000000000047  70          34MB  32.00  6          OK
=====
```

If you would like, for example, to keep only those WAL segments that can be applied to the latest valid backup, set the `--wal-depth` option to 1:

```
lt_probackup delete -B backup_dir --instance node --delete-wal --
wal-depth=1
```

```
ARCHIVE INSTANCE 'node'
```

```
=====
TLI  Parent TLI  Switchpoint  Min Segno          Max Segno
      N segments  Size  Zratio  N backups  Status
=====
1    0          0/0          0000000100000000000000046
0000000100000000000000047  2          143kB  228.00  6          OK
=====
```

Alternatively, you can use the `--wal-depth` option with the backup command:

```
lt_probackup backup -B backup_dir --instance node -b DELTA --wal-
depth=1 --delete-wal
```

```
ARCHIVE INSTANCE 'node'
```

```
=====
TLI  Parent TLI  Switchpoint  Min Segno          Max Segno
      N segments  Size  Zratio  N backups  Status
=====
1    0          0/0          0000000100000000000000048
0000000100000000000000049  1          72kB  228.00  7          OK
=====
```

## Merging Backups

As you take more and more incremental backups, the total size of the backup catalog can substantially grow. To save disk space, you can merge incremental backups to their parent full backup by running the merge command, specifying the backup ID of the most recent incremental backup you would like to merge:

```
lt_probackup merge -B backup_dir --instance instance_name -
i backup_id
```

This command merges backups that belong to a common incremental backup chain. If you specify a full backup, it will be merged with its first incremental backup. If you specify an incremental backup, it will be merged to its parent full backup, together with all incremental backups between them. Once

the merge is complete, the full backup takes in all the merged data, and the incremental backups are removed as redundant. Thus, the merge operation is virtually equivalent to retaking a full backup and removing all the outdated backups, but it allows to save much time, especially for large data volumes, as well as I/O and network traffic if you are using `lt_probackup` in the remote mode.

Before the merge, `lt_probackup` validates all the affected backups to ensure that they are valid. You can check the current backup status by running the `show` command with the backup ID:

```
lt_probackup show -B backup_dir --instance instance_name -  
i backup_id
```

If the merge is still in progress, the backup status is displayed as `MERGING`. For full backups, it can also be shown as `MERGED` while the metadata is being updated at the final stage of the merge. The merge is idempotent, so you can restart the merge if it was interrupted.

## Deleting Backups

To delete a backup that is no longer required, run the following command:

```
lt_probackup delete -B backup_dir --instance instance_name -  
i backup_id
```

This command will delete the backup with the specified *backup\_id*, together with all the incremental backups that descend from *backup\_id*, if any. This way you can delete some recent incremental backups, retaining the underlying full backup and some of the incremental backups that follow it.

To delete obsolete WAL files that are not necessary to restore any of the remaining backups, use the `--delete-wal` flag:

```
lt_probackup delete -B backup_dir --instance instance_name --  
delete-wal
```

To delete backups that are expired according to the current retention policy, use the `--delete-expired` flag:

```
lt_probackup delete -B backup_dir --instance instance_name --  
delete-expired
```

Expired backups cannot be removed while at least one incremental backup that satisfies the retention policy is based on them. If you would like to minimize the number of backups still required to keep incremental backups valid, specify the `--merge-expired` flag when running this command:

```
lt_probackup delete -B backup_dir --instance instance_name --  
delete-expired --merge-expired
```

In this case, `lt_probackup` searches for the oldest incremental backup that satisfies the retention policy and merges this backup with the underlying full and incremental backups that have already expired, thus making it a full backup. Once the merge is complete, the remaining expired backups are deleted.

Before merging or deleting backups, you can run the `delete` command with the `--dry-run` flag, which displays the status of all the available backups according to the current retention policy, without performing any irreversible actions.

To delete all backups with specific status, use the `--status`:

```
lt_probackup delete -B backup_dir --instance instance_name --  
status=ERROR
```

Deleting backups by status ignores established retention policies.

## Command-Line Reference

### Commands

This section describes lt\_probackup commands. Optional parameters are enclosed in square brackets. For detailed parameter descriptions, see the section Options.

#### version

```
lt_probackup version
```

Prints lt\_probackup version.

#### help

```
lt_probackup help [command]
```

Displays the synopsis of lt\_probackup commands. If one of the lt\_probackup commands is specified, shows detailed information about the options that can be used with this command.

#### init

```
lt_probackup init -B backup_dir [--help]
```

Initializes the backup catalog in *backup\_dir* that will store backup copies, WAL archive, and meta information for the backed up database clusters. If the specified *backup\_dir* already exists, it must be empty. Otherwise, lt\_probackup displays a corresponding error message.

For details, see the section Initializing the Backup Catalog.

#### add-instance

```
lt_probackup add-instance -B backup_dir -D data_dir --  
instance instance_name [--help]
```

Initializes a new backup instance inside the backup catalog *backup\_dir* and generates the `pg_probackup.conf` configuration file that controls lt\_probackup settings for the cluster with the specified *data\_dir* data directory.

For details, see the section Adding a New Backup Instance.

#### del-instance

```
lt_probackup del-instance -B backup_dir --instance instance_name  
[--help]
```

Deletes all backups and WAL files associated with the specified instance.

## set-config

```
lt_probackup set-config -B backup_dir --instance instance_name
[--help] [--pgdata=pgdata_path]
[--retention-redundancy=redundancy][--retention-window=window][--
wal-depth=wal_depth]
[--compress-algorithm=compression_algorithm] [--compress-
level=compression_level]
[-d dbname] [-h host] [-p port] [-U username]
[--archive-timeout=timeout] [--external-
dirs=external_directory_path]
[--restore-command=cmdline]
[remote_options] [remote_wal_archive_options] [logging_options]
```

Adds the specified connection, compression, retention, logging, and external directory settings into the `pg_probackup.conf` configuration file, or modifies the previously defined values.

For all available settings, see the Options section.

It is **not recommended** to edit `pg_probackup.conf` manually.

## set-backup

```
lt_probackup set-backup -B backup_dir --instance instance_name -
i backup_id
{--ttl=ttd | --expire-time=time}
[--note=backup_note] [--help]
```

Sets the provided backup-specific settings into the `backup.control` configuration file, or modifies the previously defined values.

```
--note=backup_note
```

Sets the text note for backup copy. If *backup\_note* contain newline characters, then only substring before first newline character will be saved. Max size of text note is 1 KB. The 'none' value removes current note.

For all available pinning settings, see the section Pinning Options.

## show-config

```
lt_probackup show-config -B backup_dir --instance instance_name [--
format=plain|json]
```

Displays the contents of the `pg_probackup.conf` configuration file located in the `backup_dir/backups/instance_name` directory. You can specify the `--format=json` option to get the result in the JSON format. By default, configuration settings are shown as plain text.

To edit `pg_probackup.conf`, use the `set-config` command.

## show

```
lt_probackup show -B backup_dir
[--help] [--instance instance_name [-i backup_id | --archive]] [--
format=plain|json]
```

Shows the contents of the backup catalog. If *instance\_name* and *backup\_id* are specified, shows detailed information about this backup. If the `--archive` option is specified, shows the contents of WAL archive of the backup catalog.

By default, the contents of the backup catalog is shown as plain text. You can specify the `--format=json` option to get the result in the JSON format.

For details on usage, see the sections [Managing the Backup Catalog](#) and [Viewing WAL Archive Information](#).

## backup

```
lt_probackup backup -B backup_dir -b backup_mode --
instance instance_name
[--help] [-j num_threads] [--progress]
[-C] [--stream [-S slot_name] [--temp-slot]] [--backup-pg-log]
[--no-validate] [--skip-block-validation]
[-w --no-password] [-W --password]
[--archive-timeout=timeout] [--external-
dirs=external_directory_path]
[--no-sync] [--note=backup_note]
[connection_options] [compression_options] [remote_options]
[retention_options] [pinning_options] [logging_options]
```

Creates a backup copy of the LightDB instance.

`-b mode`

`--backup-mode=mode`

Specifies the backup mode to use. Possible values are:

- FULL — creates a full backup that contains all the data files of the cluster to be restored.
- DELTA — reads all data files in the data directory and creates an incremental backup for pages that have changed since the previous backup.
- PAGE — creates an incremental PAGE backup based on the WAL files that have changed since the previous full or incremental backup was taken.
- PTRACK — creates an incremental PTRACK backup tracking page changes on the fly.

`-C`

`--smooth-checkpoint`

Spreads out the checkpoint over a period of time. By default, `lt_probackup` tries to complete the checkpoint as soon as possible.

`--stream`

Makes a STREAM backup, which includes all the necessary WAL files by streaming them from the database server via replication protocol.

`--temp-slot`

Creates a temporary physical replication slot for streaming WAL from the backed up LightDB instance. It ensures that all the required WAL segments remain available if WAL is rotated while the backup is in progress. This flag can only be used together with the `--stream` flag. The default slot name is `lt_probackup_slot`, which can be changed using the `--slot/-S` option.

`-S slot_name`

`--slot=slot_name`

Specifies the replication slot for WAL streaming. This option can only be used together with the `--stream` flag.

`--backup-pg-log`

Includes the log directory into the backup. This directory usually contains log messages. By default, log directory is excluded.

`-E external_directory_path`

`--external-dirs=external_directory_path`

Includes the specified directory into the backup by recursively copying its contents into a separate subdirectory in the backup catalog. This option is useful to back up scripts, SQL dump files, and configuration files located outside of the data directory. If you would like to back up several external directories, separate their paths by a colon on Unix and a semicolon on Windows.

`--archive-timeout=wait_time`

Sets the timeout for WAL segment archiving and streaming, in seconds. By default, `lt_probackup` waits 300 seconds.

`--skip-block-validation`

Disables block-level checksum verification to speed up the backup process.

`--no-validate`

Skips automatic validation after the backup is taken. You can use this flag if you validate backups regularly and would like to save time when running backup operations.

`--no-sync`

Do not sync backed up files to disk. You can use this flag to speed up the backup process. Using this flag can result in data corruption in case of operating system or hardware crash. If you use this option, it is recommended to run the `validate` command once the backup is complete to detect possible issues.

`--note=backup_note`

Sets the text note for backup copy. If `backup_note` contain newline characters, then only substring before first newline character will be saved. Max size of text note is 1 KB. The `'none'` value removes current note.

Additionally, connection options, retention options, pinning options, remote mode options, compression options, logging options, and common options can be used.

For details on usage, see the section [Creating a Backup](#).

## restore

```
lt_probackup restore -B backup_dir --instance instance_name
[--help] [-D data_dir] [-i backup_id]
[-j num_threads] [--progress]
[-T OLDDIR=NEWDIR] [--external-mapping=OLDDIR=NEWDIR] [--skip-
external-dirs]
[-R | --restore-as-replica] [--no-validate] [--skip-block-
validation]
[--force] [--no-sync]
[--restore-command=cmdline]
[--primary-conninfo=primary_conninfo]
[-S | --primary-slot-name=slot_name]
[recovery_target_options] [logging_options] [remote_options]
```

[*partial\_restore\_options*] [*remote\_wal\_archive\_options*]

Restores the LightDB instance from a backup copy located in the *backup\_dir* backup catalog. If you specify a recovery target option, It\_probackup finds the closest backup and restores it to the specified recovery target. If neither the backup ID nor recovery target options are provided, It\_probackup uses the most recent backup to perform the recovery.

-R

--restore-as-replica

Creates a minimal recovery configuration file to facilitate setting up a standby server. If the replication connection requires a password, you must specify the password manually in the *primary\_conninfo*<sup>28</sup> parameter as it is not included. It\_probackup writes these settings into the *probackup\_recovery.conf* file in the data directory, and then includes them into the *lightdb.auto.conf* when the cluster is started.

--primary-conninfo=*primary\_conninfo*

Sets the *primary\_conninfo*<sup>29</sup> parameter to the specified value. This option will be ignored unless the -R flag is specified.

Example: --primary-conninfo="host=192.168.1.50 port=5432 user=foo password=foopass"

-S

--primary-slot-name=*slot\_name*

Sets the *primary\_slot\_name*<sup>30</sup> parameter to the specified value. This option will be ignored unless the -R flag is specified.

-T *OLDDIR=NEWDIR*

--tablespace-mapping=*OLDDIR=NEWDIR*

Relocates the tablespace from the *OLDDIR* to the *NEWDIR* directory at the time of recovery. Both *OLDDIR* and *NEWDIR* must be absolute paths. If the path contains the equals sign (=), escape it with a backslash. This option can be specified multiple times for multiple tablespaces.

--external-mapping=*OLDDIR=NEWDIR*

Relocates an external directory included into the backup from the *OLDDIR* to the *NEWDIR* directory at the time of recovery. Both *OLDDIR* and *NEWDIR* must be absolute paths. If the path contains the equals sign (=), escape it with a backslash. This option can be specified multiple times for multiple directories.

--skip-external-dirs

Skip external directories included into the backup with the --external-dirs option. The contents of these directories will not be restored.

--skip-block-validation

Disables block-level checksum verification to speed up validation. During automatic validation before the restore only file-level checksums will be verified.

--no-validate

Skips backup validation. You can use this flag if you validate backups regularly and would like to save time when running restore operations.

<sup>28</sup> runtime-config-replication.html#GUC-PRIMARY-CONNINFO

<sup>29</sup> runtime-config-replication.html#GUC-PRIMARY-CONNINFO

<sup>30</sup> runtime-config-replication.html#GUC-PRIMARY-SLOT-NAME



`--restore-command=cmdline`

Sets the `restore_command`<sup>31</sup> parameter to the specified command. For example: `--restore-command='cp /mnt/server/archivedir/%f "%p"'`

`--force`

Allows to ignore an invalid status of the backup. You can use this flag if you need to restore the LightDB cluster from a corrupt or an invalid backup. Use with caution. If `LTDATA` contains a non-empty directory with system ID different from that of the backup being restored, incremental restore with this flag overwrites the directory contents (while an error occurs without the flag). If tablespaces are remapped through the `--tablespace-mapping` option into non-empty directories, the contents of such directories will be deleted.

`--no-sync`

Do not sync restored files to disk. You can use this flag to speed up restore process. Using this flag can result in data corruption in case of operating system or hardware crash. If it happens, you have to run the restore command again.

Additionally, recovery target options, remote mode options, remote WAL archive options, logging options, partial restore options, and common options can be used.

For details on usage, see the section Restoring a Cluster.

## checkdb

```
lt_probackup checkdb
[-B backup_dir] [--instance instance_name] [-D data_dir]
[--help] [-j num_threads] [--progress]
[--skip-block-validation] [--amcheck] [--heapallindexed]
[connection_options] [logging_options]
```

Verifies the LightDB database cluster correctness by detecting physical and logical corruption.

`--amcheck`

Performs logical verification of indexes for the specified LightDB instance if no corruption was found while checking data files. You must have the `amcheck` extension or the `amcheck_next` extension installed in the database to check its indexes. For databases without `amcheck`, index verification will be skipped.

`--skip-block-validation`

Skip validation of data files. You can use this flag only together with the `--amcheck` flag, so that only logical verification of indexes is performed.

`--heapallindexed`

Checks that all heap tuples that should be indexed are actually indexed. You can use this flag only together with the `--amcheck` flag.

This check is only possible if you are using the `amcheck` extension of version 2.0 or higher, or the `amcheck_next` extension of any version.

Additionally, connection options and logging options can be used.

For details on usage, see the section Verifying a Cluster.

<sup>31</sup> [archive-recovery-settings.html#RESTORE-COMMAND](#)

## validate

```
lt_probackup validate -B backup_dir
[--help] [--instance instance_name] [-i backup_id]
[-j num_threads] [--progress]
[--skip-block-validation]
[recovery_target_options] [logging_options]
```

Verifies that all the files required to restore the cluster are present and are not corrupt. If *instance\_name* is not specified, lt\_probackup validates all backups available in the backup catalog. If you specify the *instance\_name* without any additional options, lt\_probackup validates all the backups available for this backup instance. If you specify the *instance\_name* with a recovery target option and/or a *backup\_id*, lt\_probackup checks whether it is possible to restore the cluster using these options.

For details, see the section [Validating a Backup](#).

## merge

```
lt_probackup merge -B backup_dir --instance instance_name -
i backup_id
[--help] [-j num_threads] [--progress] [--no-validate] [--no-sync]
[logging_options]
```

Merges backups that belong to a common incremental backup chain. If you specify a full backup, it will be merged with its first incremental backup. If you specify an incremental backup, it will be merged to its parent full backup, together with all incremental backups between them. Once the merge is complete, the full backup takes in all the merged data, and the incremental backups are removed as redundant.

--no-validate

Skips automatic validation before and after merge.

--no-sync

Do not sync merged files to disk. You can use this flag to speed up the merge process. Using this flag can result in data corruption in case of operating system or hardware crash.

For details, see the section [Merging Backups](#).

## delete

```
lt_probackup delete -B backup_dir --instance instance_name
[--help] [-j num_threads] [--progress]
[--retention-redundancy=redundancy][--retention-window=window][--
wal-depth=wal_depth] [--delete-wal]
{-i backup_id | --delete-expired [--merge-expired] | --merge-
expired | --status=backup_status}
[--dry-run] [--no-validate] [--no-sync] [logging_options]
```

Deletes backup with specified *backup\_id* or launches the retention purge of backups and archived WAL that do not satisfy the current retention policies.

--no-validate

Skips automatic validation before and after retention merge.

`--no-sync`

Do not sync merged files to disk. You can use this flag to speed up the retention merge process. Using this flag can result in data corruption in case of operating system or hardware crash.

For details, see the sections [Deleting Backups](#), [Retention Options](#) and [Configuring Retention Policy](#).

## archive-push

```
lt_probackup archive-push -B backup_dir --instance instance_name
--wal-file-name=wal_file_name [--wal-file-path=wal_file_path]
[--help] [--no-sync] [--compress] [--no-ready-rename] [--overwrite]
[-j num_threads] [--batch-size=batch_size]
[--archive-timeout=timeout]
[--compress-algorithm=compression_algorithm]
[--compress-level=compression_level]
[remote_options] [logging_options]
```

Copies WAL files into the corresponding subdirectory of the backup catalog and validates the backup instance by *instance\_name* and *system-identifier*. If parameters of the backup instance and the cluster do not match, this command fails with the following error message: `Refuse to push WAL segment segment_name into archive. Instance parameters mismatch.`

If the files to be copied already exists in the backup catalog, `lt_probackup` computes and compares their checksums. If the checksums match, `archive-push` skips the corresponding file and returns a successful execution code. Otherwise, `archive-push` fails with an error. If you would like to replace WAL files in the case of checksum mismatch, run the `archive-push` command with the `--overwrite` flag.

Each file is copied to a temporary file with the `.part` suffix. If the temporary file already exists, `lt_probackup` will wait `archive_timeout` seconds before discarding it. After the copy is done, atomic rename is performed. This algorithm ensures that a failed `archive-push` will not stall continuous archiving and that concurrent archiving from multiple sources into a single WAL archive has no risk of archive corruption.

To speed up archiving, you can specify the `--batch-size` option to copy WAL segments in batches of the specified size. If `--batch-size` option is used, then you can also specify the `-j` option to copy the batch of WAL segments on multiple threads.

WAL segments copied to the archive are synced to disk unless the `--no-sync` flag is used.

You can use `archive-push` in the `archive_command`<sup>32</sup> LightDB parameter to set up continuous WAL archiving.

For details, see sections [Archiving Options](#) and [Compression Options](#).

## archive-get

```
lt_probackup archive-get -B backup_dir --instance instance_name --
wal-file-path=wal_file_path --wal-file-name=wal_file_name
[-j num_threads] [--batch-size=batch_size]
[--prefetch-dir=prefetch_dir_path] [--no-validate-wal]
[--help] [remote_options] [logging_options]
```

Copies WAL files from the corresponding subdirectory of the backup catalog to the cluster's write-ahead log location. This command is automatically set by `lt_probackup` as part of the

<sup>32</sup> [runtime-config-wal.html#GUC-ARCHIVE-COMMAND](#)

`restore_command` when restoring backups using a WAL archive. You do not need to set it manually.

To speed up recovery, you can specify the `--batch-size` option to copy WAL segments in batches of the specified size. If `--batch-size` option is used, then you can also specify the `-j` option to copy the batch of WAL segments on multiple threads.

For details, see section Archiving Options.

## Options

This section describes command-line options for `lt_probackup` commands. If the option value can be derived from an environment variable, this variable is specified below the command-line option, in the uppercase. Some values can be taken from the `pg_probackup.conf` configuration file located in the backup catalog.

For details, see the section called “Configuring `lt_probackup`”.

If an option is specified using more than one method, command-line input has the highest priority, while the `pg_probackup.conf` settings have the lowest priority.

## Common Options

The list of general options.

`-B directory`  
`--backup-path=directory`  
BACKUP\_PATH

Specifies the absolute path to the backup catalog. Backup catalog is a directory where all backup files and meta information are stored. Since this option is required for most of the `lt_probackup` commands, you are recommended to specify it once in the `BACKUP_PATH` environment variable. In this case, you do not need to use this option each time on the command line.

`-D directory`  
`--pgdata=directory`  
LTDATA

Specifies the absolute path to the data directory of the database cluster. This option is mandatory only for the `add-instance` command. Other commands can take its value from the `LTDATA` environment variable, or from the `pg_probackup.conf` configuration file.

`-i backup_id`  
`--backup-id=backup_id`

Specifies the unique identifier of the backup.

`-j num_threads`  
`--threads=num_threads`

Sets the number of parallel threads for backup, restore, merge, validate, checkdb, and `archive-push` processes.

`--progress`

Shows the progress of operations.

`--help`

Shows detailed information about the options that can be used with this command.

## Recovery Target Options

If continuous WAL archiving is configured, you can use one of these options together with `restore` or `validate` commands to specify the moment up to which the database cluster must be restored or validated.

`--recovery-target=immediate|latest`

Defines when to stop the recovery:

- The `immediate` value stops the recovery after reaching the consistent state of the specified backup, or the latest available backup if the `-i/--backup-id` option is omitted. This is the default behavior for `STREAM` backups.
- The `latest` value continues the recovery until all WAL segments available in the archive are applied. This is the default behavior for `ARCHIVE` backups.

`--recovery-target-timeline=time line`

Specifies a particular timeline to be used for recovery. By default, the timeline of the specified backup is used.

`--recovery-target-lsn=lsn`

Specifies the LSN of the write-ahead log location up to which recovery will proceed. Can be used only when restoring a database cluster of major version 10 or higher.

`--recovery-target-name=recovery_target_name`

Specifies a named savepoint up to which to restore the cluster.

`--recovery-target-time=time`

Specifies the timestamp up to which recovery will proceed. If the time zone offset is not specified, the local time zone is used.

Example: `--recovery-target-time="2020-01-01 00:00:00+03"`

`--recovery-target-xid=xid`

Specifies the transaction ID up to which recovery will proceed.

`--recovery-target-inclusive=boolean`

Specifies whether to stop just after the specified recovery target (`true`), or just before the recovery target (`false`). This option can only be used together with `--recovery-target-name`, `--recovery-target-time`, `--recovery-target-lsn` or `--recovery-target-xid` options. The default depends on the `recovery_target_inclusive`<sup>33</sup> parameter.

`--recovery-target-action=pause|promote|shutdown`

Specifies the action<sup>34</sup> the server should take when the recovery target is reached.

Default: `pause`

## Retention Options

You can use these options together with `backup` and `delete` commands.

For details on configuring retention policy, see the section [Configuring Retention Policy](#).

<sup>33</sup> `runtime-config-wal#GUC-RECOVERY-TARGET-INCLUSIVE`

<sup>34</sup> `recovery-target-settings.html#RECOVERY-TARGET-ACTION`

`--retention-redundancy=redundancy`

Specifies the number of full backup copies to keep in the data directory. Must be a non-negative integer. The zero value disables this setting.

Default: 0

`--retention-window=window`

Number of days of recoverability. Must be a non-negative integer. The zero value disables this setting.

Default: 0

`--wal-depth=wal_depth`

Number of latest valid backups on every timeline that must retain the ability to perform PITR. Must be a non-negative integer. The zero value disables this setting.

Default: 0

`--delete-wal`

Deletes WAL files that are no longer required to restore the cluster from any of the existing backups.

`--delete-expired`

Deletes backups that do not conform to the retention policy defined in the `pg_probackup.conf` configuration file.

`--merge-expired`

Merges the oldest incremental backup that satisfies the requirements of retention policy with its parent backups that have already expired.

`--dry-run`

Displays the current status of all the available backups, without deleting or merging expired backups, if any.

## Pinning Options

You can use these options together with `backup` and `set-backup` commands.

For details on backup pinning, see the section [Backup Pinning](#).

`--ttl=ttl`

Specifies the amount of time the backup should be pinned. Must be a non-negative integer. The zero value unpins the already pinned backup. Supported units: ms, s, min, h, d (s by default).

Example: `--ttl=30d`

`--expire-time=time`

Specifies the timestamp up to which the backup will stay pinned. Must be an ISO-8601 compliant timestamp. If the time zone offset is not specified, the local time zone is used.

Example: `--expire-time="2020-01-01 00:00:00+03"`

## Logging Options

You can use these options with any command.

`--log-level-console=log_level`

Controls which message levels are sent to the console log. Valid values are `verbose`, `log`, `info`, `warning`, `error` and `off`. Each level includes all the levels that follow it. The later the level, the fewer messages are sent. The `off` level disables console logging.

Default: `info`

**Note**

All console log messages are going to `stderr`, so the output of `show` and `show-config` commands does not mingle with log messages.

`--log-level-file=log_level`

Controls which message levels are sent to a log file. Valid values are `verbose`, `log`, `info`, `warning`, `error`, and `off`. Each level includes all the levels that follow it. The later the level, the fewer messages are sent. The `off` level disables file logging.

Default: `off`

`--log-filename=log_filename`

Defines the filenames of the created log files. The filenames are treated as a `strftime` pattern, so you can use %-escapes to specify time-varying filenames.

Default: `pg_probackup.log`

For example, if you specify the `lt_probackup-%u.log` pattern, `lt_probackup` generates a separate log file for each day of the week, with `%u` replaced by the corresponding decimal number: `lt_probackup-1.log` for Monday, `lt_probackup-2.log` for Tuesday, and so on.

This option takes effect if file logging is enabled by the `--log-level-file` option.

`--error-log-filename=error_log_filename`

Defines the filenames of log files for error messages only. The filenames are treated as a `strftime` pattern, so you can use %-escapes to specify time-varying filenames.

Default: `none`

For example, if you specify the `error-lt_probackup-%u.log` pattern, `lt_probackup` generates a separate log file for each day of the week, with `%u` replaced by the corresponding decimal number: `error-lt_probackup-1.log` for Monday, `error-lt_probackup-2.log` for Tuesday, and so on.

This option is useful for troubleshooting and monitoring.

`--log-directory=log_directory`

Defines the directory in which log files will be created. You must specify the absolute path. This directory is created lazily, when the first log message is written.

Default: `$BACKUP_PATH/log/`

`--log-rotation-size=log_rotation_size`

Maximum size of an individual log file. If this value is reached, the log file is rotated once a `lt_probackup` command is launched, except `help` and `version` commands. The zero value disables size-based rotation. Supported units: `kB`, `MB`, `GB`, `TB` (`kB` by default).

Default: 0

`--log-rotation-age=log_rotation_age`

Maximum lifetime of an individual log file. If this value is reached, the log file is rotated once a `lt_probackup` command is launched, except `help` and `version` commands. The time of the last log file creation is stored in `$BACKUP_PATH/log/log_rotation`. The zero value disables time-based rotation. Supported units: ms, s, min, h, d (min by default).

Default: 0

## Connection Options

You can use these options together with `backup` and `checkdb` commands.

All `libpq` environment variables<sup>35</sup> are supported.

`-d dbname`  
`--pgdatabase=dbname`  
LTDATABASE

Specifies the name of the database to connect to. The connection is used only for managing backup process, so you can connect to any existing database. If this option is not provided on the command line, `LTDATABASE` environment variable, or the `pg_probackup.conf` configuration file, `lt_probackup` tries to take this value from the `LTUSER` environment variable, or from the current user name if `LTUSER` variable is not set.

`-h host`  
`--pghost=host`  
LTHOST

Specifies the host name of the system on which the server is running. If the value begins with a slash, it is used as a directory for the Unix domain socket.

Default: localhost

`-p port`  
`--pgport=port`  
LTPORT

Specifies the TCP port or the local Unix domain socket file extension on which the server is listening for connections.

Default: 5432

`-U username`  
`--pguser=username`  
LTUSER

User name to connect as.

`-w`  
`--no-password`

Disables a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass`<sup>36</sup> file or `PGPASSWORD` environment variable, the connection attempt will fail. This flag can be useful in batch jobs and scripts where no user is present to enter a password.

---

<sup>35</sup> `libpq-envars.html`

<sup>36</sup> `libpq-pgpass.html`



`-W`  
`--password`

Forces a password prompt. (Deprecated)

## Compression Options

You can use these options together with `backup` and `archive-push` commands.

`--compress-algorithm=compression_algorithm`

Defines the algorithm to use for compressing data files. Possible values are `zlib`, `pglz`, and `none`. If set to `zlib` or `pglz`, this option enables compression. By default, compression is disabled. For the `archive-push` command, the `pglz` compression algorithm is not supported.

Default: `none`

`--compress-level=compression_level`

Defines compression level (0 through 9, 0 being no compression and 9 being best compression). This option can be used together with the `--compress-algorithm` option.

Default: `1`

`--compress`

Alias for `--compress-algorithm=zlib` and `--compress-level=1`.

## Archiving Options

These options can be used with the `archive-push` command in the `archive_command`<sup>37</sup> setting and the `archive-get` command in the `restore_command`<sup>38</sup> setting.

Additionally, remote mode options and logging options can be used.

`--wal-file-path=wal_file_path`

Provides the path to the WAL file in `archive_command` and `restore_command`. Use the `%p` variable as the value for this option for correct processing.

`--wal-file-name=wal_file_name`

Provides the name of the WAL file in `archive_command` and `restore_command`. Use the `%f` variable as the value for this option for correct processing.

`--overwrite`

Overwrites archived WAL file. Use this flag together with the `archive-push` command if the specified subdirectory of the backup catalog already contains this WAL file and it needs to be replaced with its newer copy. Otherwise, `archive-push` reports that a WAL segment already exists, and aborts the operation. If the file to replace has not changed, `archive-push` skips this file regardless of the `--overwrite` flag.

`--batch-size=batch_size`

Sets the maximum number of files that can be copied into the archive by a single `archive-push` process, or from the archive by a single `archive-get` process.

---

<sup>37</sup> [runtime-config-wal.html#GUC-ARCHIVE-COMMAND](#)

<sup>38</sup> [archive-recovery-settings.html#RESTORE-COMMAND](#)

`--archive-timeout=wait_time`

Sets the timeout for considering existing `.part` files to be stale. By default, `lt_probackup` waits 300 seconds. This option can be used only with `archive-push` command.

`--no-ready-rename`

Do not rename status files in the `archive_status` directory. This option should be used only if `archive_command` contains multiple commands. This option can be used only with `archive-push` command.

`--no-sync`

Do not sync copied WAL files to disk. You can use this flag to speed up archiving process. Using this flag can result in WAL archive corruption in case of operating system or hardware crash. This option can be used only with `archive-push` command.

`--prefetch-dir=path`

Directory used to store prefetched WAL segments if `--batch-size` option is used. Directory must be located on the same filesystem and on the same mountpoint the `LTDATA/lt_wal` is located. By default files are stored in `LTDATA/lt_wal/pbk_prefetch` directory. This option can be used only with `archive-get` command.

`--no-validate-wal`

Do not validate prefetched WAL file before using it. Use this option if you want to increase the speed of recovery. This option can be used only with `archive-get` command.

## Remote Mode Options

This section describes the options related to running `lt_probackup` operations remotely via SSH. These options can be used with `add-instance`, `set-config`, `backup`, `restore`, `archive-push`, and `archive-get` commands.

For details on configuring and using the remote mode, see the section called “Configuring the Remote Mode” and the section called “Using `lt_probackup` in the Remote Mode”.

`--remote-proto=proto`

Specifies the protocol to use for remote operations. Currently only the SSH protocol is supported. Possible values are:

- `ssh` enables the remote mode via SSH. This is the default value.
- `none` explicitly disables the remote mode.

You can omit this option if the `--remote-host` option is specified.

`--remote-host=destination`

Specifies the remote host IP address or hostname to connect to.

`--remote-port=port`

Specifies the remote host port to connect to.

Default: 22

`--remote-user=username`

Specifies remote host user for SSH connection. If you omit this option, the current user initiating the SSH connection is used.

`--remote-path=path`

Specifies `lt_probackup` installation directory on the remote system.

`--ssh-options=ssh_options`

Provides a string of SSH command-line options. For example, the following options can be used to set `keep-alive` for SSH connections opened by `lt_probackup`: `--ssh-options="-o ServerAliveCountMax=5 -o ServerAliveInterval=60"`. For the full list of possible options, see `ssh_config` manual page<sup>39</sup>.

## Remote WAL Archive Options

This section describes the options used to provide the arguments for remote mode options in `archive-get` used in the `restore_command`<sup>40</sup> command when restoring ARCHIVE backups or performing PITR.

`--archive-host=destination`

Provides the argument for the `--remote-host` option in the `archive-get` command.

`--archive-port=port`

Provides the argument for the `--remote-port` option in the `archive-get` command.

Default: 22

`--archive-user=username`

Provides the argument for the `--remote-user` option in the `archive-get` command. If you omit this option, the user that has started the LightDB cluster is used.

Default: LightDB user

## Incremental Restore Options

This section describes the options for incremental cluster restore. These options can be used with the `restore` command.

`-I incremental_mode`

`--incremental-mode=incremental_mode`

Specifies the incremental mode to be used. Possible values are:

- `CHECKSUM` — replace only pages with mismatched checksum and LSN.
- `LSN` — replace only pages with LSN greater than point of divergence.
- `NONE` — regular restore.

## Partial Restore Options

This section describes the options for partial cluster restore. These options can be used with the `restore` command.

`--db-exclude=dbname`

Specifies the name of the database to exclude from restore. All other databases in the cluster will be restored as usual, including `template0` and `template1`. This option can be specified multiple times for multiple databases.

---

<sup>39</sup> [https://man.openbsd.org/ssh\\_config.5](https://man.openbsd.org/ssh_config.5)

<sup>40</sup> [archive-recovery-settings.html#RESTORE-COMMAND](https://man.openbsd.org/restore-command.html#RESTORE-COMMAND)

`--db-include=dbname`

Specifies the name of the database to restore from a backup. All other databases in the cluster will not be restored, with the exception of `template0` and `template1`. This option can be specified multiple times for multiple databases.

## Replica Options

This section describes the options related to taking a backup from standby.

### Note

Starting from `lt_probackup 2.0.24`, backups can be taken from standby without connecting to the master server, so these options are no longer required. In lower versions, `lt_probackup` had to connect to the master to determine recovery time — the earliest moment for which you can restore a consistent state of the database cluster.

`--master-db=dbname`

Deprecated. Specifies the name of the database on the master server to connect to. The connection is used only for managing the backup process, so you can connect to any existing database. Can be set in the `pg_probackup.conf` using the `set-config` command.

Default: `postgres`, the default LightDB database

`--master-host=host`

Deprecated. Specifies the host name of the system on which the master server is running.

`--master-port=port`

Deprecated. Specifies the TCP port or the local Unix domain socket file extension on which the master server is listening for connections.

Default: `5432`, the LightDB default port

`--master-user=username`

Deprecated. User name to connect as.

Default: `lightdb`, the LightDB default user name

`--replica-timeout=timeout`

Deprecated. Wait time for WAL segment streaming via replication, in seconds. By default, `lt_probackup` waits 300 seconds. You can also define this parameter in the `pg_probackup.conf` configuration file using the `set-config` command.

Default: `300 sec`

## How-To

All examples below assume the remote mode of operations via SSH. If you are planning to run backup and restore operation locally, skip the “Setup passwordless SSH connection” step and omit all `--remote-*` options.

Examples are based on Centos 7.9, LightDB 22.3, and `lt_probackup 2.4.15`.

- `backup` — LightDB role used for connection to LightDB cluster.
- `backupdb` — database used for connection to LightDB cluster.

- backup\_host — host with backup catalog.
- backupman — user on backup\_host running all lt\_probackup operations.
- /mnt/backups — directory on backup\_host where backup catalog is stored.
- lightdb\_host — host with LightDB cluster.
- lightdb — user on lightdb\_host that has started the LightDB cluster.
- /var/lib/postgresql/11/main — LightDB data directory on lightdb\_host.

## Minimal Setup

This scenario illustrates setting up standalone FULL and DELTA backups.

### 1. Set up passwordless SSH connection from backup\_host to lightdb\_host:

```
[backupman@backup_host] ssh-copy-id lightdb@lightdb_host
```

### 2. Configure your LightDB cluster.

For security purposes, it is recommended to use a separate database for backup operations.

```
lightdb@postgres=#  
CREATE DATABASE backupdb;
```

Connect to the backupdb database, create the probackup role, and grant the following permissions to this role:

```
backupdb=#  
BEGIN;  
CREATE ROLE backup WITH LOGIN REPLICATION;  
GRANT USAGE ON SCHEMA pg_catalog TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.current_setting(text) TO  
  backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_is_in_recovery() TO  
  backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_start_backup(text,  
  boolean, boolean) TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_stop_backup(boolean,  
  boolean) TO backup;  
GRANT EXECUTE ON FUNCTION  
  pg_catalog.pg_create_restore_point(text) TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_switch_wal() TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_last_wal_replay_lsn()  
  TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.txid_current() TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.txid_current_snapshot() TO  
  backup;  
GRANT EXECUTE ON FUNCTION  
  pg_catalog.txid_snapshot_xmax(txid_snapshot) TO backup;  
GRANT EXECUTE ON FUNCTION pg_catalog.pg_control_checkpoint() TO  
  backup;  
COMMIT;
```

### 3. Initialize the backup catalog:

```
[backupman@backup_host]$ lt_probackup init -B /mnt/backups  
INFO: Backup catalog '/mnt/backups' successfully initied
```

**4. Add instance node to the backup catalog:**

```
[backupman@backup_host]$ lt_probackup add-instance -B /mnt/
backups --instance node --remote-host=lightdb_host --remote-
user=lightdb -D /var/lib/postgresql/11/main
INFO: Instance 'node' successfully inited
```

**5. Take a FULL backup:**

```
[backupman@backup_host] lt_probackup backup -B /mnt/backups --
instance node -b FULL --stream --remote-host=lightdb_host --
remote-user=lightdb -U backup -d backupdb
INFO: Backup start, lt_probackup version: 2.4.15, instance:
node, backup ID: PZ7YK2, backup mode: FULL, wal mode: STREAM,
remote: true, compress-algorithm: none, compress-level: 1
INFO: Start transferring data files
INFO: Data files are transferred
INFO: wait for pg_stop_backup()
INFO: pg_stop backup() successfully executed
INFO: Validating backup PZ7YK2
INFO: Backup PZ7YK2 data files are valid
INFO: Backup PZ7YK2 resident size: 196MB
INFO: Backup PZ7YK2 completed
```

**6. Let's take a look at the backup catalog:**

```
[backupman@backup_host] lt_probackup show -B /mnt/backups --
instance node
```

```
BACKUP INSTANCE 'node'
```

```
=====
Instance Version ID      Recovery Time          Mode WAL
Mode TLI  Time  Data  WAL  Zratio Start LSN  Stop LSN
Status
=====
node      13      PZ7YK2  2019-10-11 19:45:45+03  FULL
STREAM   1/0    11s  180MB  16MB   1.00  0/3C000028
0/3C000198  OK
```

**7. Take an incremental backup in the DELTA mode:**

```
[backupman@backup_host] lt_probackup backup -B /mnt/backups --
instance node -b delta --stream --remote-host=lightdb_host --
remote-user=lightdb -U backup -d backupdb
INFO: Backup start, lt_probackup version: 2.4.15, instance:
node, backup ID: PZ7YMP, backup mode: DELTA, wal mode: STREAM,
remote: true, compress-algorithm: none, compress-level: 1
INFO: Parent backup: PZ7YK2
INFO: Start transferring data files
INFO: Data files are transferred
INFO: wait for pg_stop_backup()
INFO: pg_stop backup() successfully executed
INFO: Validating backup PZ7YMP
INFO: Backup PZ7YMP data files are valid
INFO: Backup PZ7YMP resident size: 32MB
```

```
INFO: Backup PZ7YMP completed
```

8. **Let's add some parameters to lt\_probackup configuration file, so that you can omit them from the command line:**

```
[backupman@backup_host] lt_probackup set-config -B /mnt/backups --instance node --remote-host=lightdb_host --remote-user=lightdb -U backup -d backupdb
```

9. **Take another incremental backup in the DELTA mode, omitting some of the previous parameters:**

```
[backupman@backup_host] lt_probackup backup -B /mnt/backups --instance node -b delta --stream
INFO: Backup start, lt_probackup version: 2.4.15, instance: node, backup ID: PZ7YR5, backup mode: DELTA, wal mode: STREAM, remote: true, compress-algorithm: none, compress-level: 1
INFO: Parent backup: PZ7YMP
INFO: Start transferring data files
INFO: Data files are transferred
INFO: wait for pg_stop_backup()
INFO: pg_stop_backup() successfully executed
INFO: Validating backup PZ7YR5
INFO: Backup PZ7YR5 data files are valid
INFO: Backup PZ7YR5 resident size: 32MB
INFO: Backup PZ7YR5 completed
```

10. **Let's take a look at the instance configuration:**

```
[backupman@backup_host] lt_probackup show-config -B /mnt/backups --instance node
```

```
# Backup instance information
pgdata = /var/lib/postgresql/11/main
system-identifier = 6746586934060931492
xlog-seg-size = 16777216
# Connection parameters
pgdatabase = backupdb
pghost = lightdb_host
pguser = backup
# Replica parameters
replica-timeout = 5min
# Archive parameters
archive-timeout = 5min
# Logging parameters
log-level-console = INFO
log-level-file = OFF
log-filename = lt_probackup.log
log-rotation-size = 0
log-rotation-age = 0
# Retention parameters
retention-redundancy = 0
retention-window = 0
wal-depth = 0
# Compression parameters
compress-algorithm = none
```

```
compress-level = 1
# Remote access parameters
remote-proto = ssh
remote-host = lightdb_host
```

Note that we are getting the default values for other options that were not overwritten by the `set-config` command.

#### 11. Let's take a look at the backup catalog:

```
[backupman@backup_host] lt_probackup show -B /mnt/backups --
instance node
```

```
=====
Instance Version ID      Recovery Time           Mode  WAL
Mode TLI  Time  Data  WAL  Zratio  Start LSN  Stop LSN
Status
=====
node      11      PZ7YR5  2019-10-11 19:49:56+03  DELTA
  STREAM  1/1    10s   112kB  32MB    1.00  0/41000028
0/41000160 OK
node      11      PZ7YMP  2019-10-11 19:47:16+03  DELTA
  STREAM  1/1    10s   376kB  32MB    1.00  0/3E000028
0/3F0000B8 OK
node      11      PZ7YK2  2019-10-11 19:45:45+03  FULL
  STREAM  1/0    11s   180MB  16MB    1.00  0/3C000028
0/3C000198 OK
```



---

# lt\_receivewal

lt\_receivewal — stream write-ahead logs from a LightDB server

## Synopsis

```
lt_receivewal [option...]
```

## Description

lt\_receivewal is used to stream the write-ahead log from a running LightDB cluster. The write-ahead log is streamed using the streaming replication protocol, and is written to a local directory of files. This directory can be used as the archive location for doing a restore using point-in-time recovery (see Section 23.3).

lt\_receivewal streams the write-ahead log in real time as it's being generated on the server, and does not wait for segments to complete like archive\_command does. For this reason, it is not necessary to set archive\_timeout when using lt\_receivewal.

Unlike the WAL receiver of a LightDB standby server, lt\_receivewal by default flushes WAL data only when a WAL file is closed. The option `--synchronous` must be specified to flush WAL data in real time. Since lt\_receivewal does not apply WAL, you should not allow it to become a synchronous standby when `synchronous_commit` equals `remote_apply`. If it does, it will appear to be a standby that never catches up, and will cause transaction commits to block. To avoid this, you should either configure an appropriate value for `synchronous_standby_names`, or specify `application_name` for lt\_receivewal that does not match it, or change the value of `synchronous_commit` to something other than `remote_apply`.

The write-ahead log is streamed over a regular LightDB connection and uses the replication protocol. The connection must be made with a user having `REPLICATION` permissions (see Section 19.2) or a superuser, and `lt_hba.conf` must permit the replication connection. The server must also be configured with `max_wal_senders` set high enough to leave at least one session available for the stream.

The starting point of the write-ahead log streaming is calculated when lt\_receivewal starts:

1. First, scan the directory where the WAL segment files are written and find the newest completed segment file, using as the starting point the beginning of the next WAL segment file.
2. If a starting point cannot be calculated with the previous method, the latest WAL flush location is used as reported by the server from an `IDENTIFY_SYSTEM` command.

If the connection is lost, or if it cannot be initially established, with a non-fatal error, lt\_receivewal will retry the connection indefinitely, and reestablish streaming as soon as possible. To avoid this behavior, use the `-n` parameter.

In the absence of fatal errors, lt\_receivewal will run until terminated by the `SIGINT` signal (**Control+C**).

## Options

```
-D directory  
--directory=directory
```

Directory to write the output to.

This parameter is required.

`-E lsn`

`--endpos=lsn`

Automatically stop replication and exit with normal exit status 0 when receiving reaches the specified LSN.

If there is a record with LSN exactly equal to *lsn*, the record will be processed.

`--if-not-exists`

Do not error out when `--create-slot` is specified and a slot with the specified name already exists.

`-n`

`--no-loop`

Don't loop on connection errors. Instead, exit right away with an error.

`--no-sync`

This option causes `lt_receivewal` to not force WAL data to be flushed to disk. This is faster, but means that a subsequent operating system crash can leave the WAL segments corrupt. Generally, this option is useful for testing but should not be used when doing WAL archiving on a production deployment.

This option is incompatible with `--synchronous`.

`-s interval`

`--status-interval=interval`

Specifies the number of seconds between status packets sent back to the server. This allows for easier monitoring of the progress from server. A value of zero disables the periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout disconnect. The default value is 10 seconds.

`-S slotname`

`--slot=slotname`

Require `lt_receivewal` to use an existing replication slot (see Section 24.2.6). When this option is used, `lt_receivewal` will report a flush position to the server, indicating when each segment has been synchronized to disk so that the server can remove that segment if it is not otherwise needed.

When the replication client of `lt_receivewal` is configured on the server as a synchronous standby, then using a replication slot will report the flush position to the server, but only when a WAL file is closed. Therefore, that configuration will cause transactions on the primary to wait for a long time and effectively not work satisfactorily. The option `--synchronous` (see below) must be specified in addition to make this work correctly.

`--synchronous`

Flush the WAL data to disk immediately after it has been received. Also send a status packet back to the server immediately after flushing, regardless of `--status-interval`.

This option should be specified if the replication client of `lt_receivewal` is configured on the server as a synchronous standby, to ensure that timely feedback is sent to the server.

`-v`

`--verbose`

Enables verbose mode.

`-Z level`  
`--compress=level`

Enables gzip compression of write-ahead logs, and specifies the compression level (0 through 9, 0 being no compression and 9 being best compression). The suffix `.gz` will automatically be added to all filenames.

The following command-line options control the database connection parameters.

`-d connstr`  
`--dbname=connstr`

Specifies parameters used to connect to the server, as a connection string; these will override any conflicting command line options.

The option is called `--dbname` for consistency with other client applications, but because `lt_receivewal` doesn't connect to any particular database in the cluster, database name in the connection string will be ignored.

`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or a compiled-in default.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force `lt_receivewal` to prompt for a password before connecting to a database.

This option is never essential, since `lt_receivewal` will automatically prompt for a password if the server demands password authentication. However, `lt_receivewal` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`lt_receivewal` can perform one of the two following actions in order to control physical replication slots:

`--create-slot`

Create a new physical replication slot with the name specified in `--slot`, then exit.

`--drop-slot`

Drop the replication slot with the name specified in `--slot`, then exit.

Other options are also available:

`-V`

`--version`

Print the `lt_receivewal` version and exit.

`-?`

`--help`

Show help about `lt_receivewal` command line arguments, and exit.

## Exit Status

`lt_receivewal` will exit with status 0 when terminated by the SIGINT signal. (That is the normal way to end it. Hence it is not an error.) For fatal errors or other signals, the exit status will be nonzero.

## Environment

This utility, like most other LightDB utilities, uses the environment variables supported by libpq (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

When using `lt_receivewal` instead of `archive_command` as the main WAL backup method, it is strongly recommended to use replication slots. Otherwise, the server is free to recycle or remove write-ahead log files before they are backed up, because it does not have any information, either from `archive_command` or the replication slots, about how far the WAL stream has been archived. Note, however, that a replication slot will fill up the server's disk space if the receiver does not keep up with fetching the WAL data.

`lt_receivewal` will preserve group permissions on the received WAL files if group permissions are enabled on the source cluster.

## Examples

To stream the write-ahead log from the server at `mydbserver` and store it in the local directory `/usr/local/lightdb-x/archive`:

```
$ lt_receivewal -h mydbserver -D /usr/local/lightdb-x/archive
```

## See Also

`lt_basebackup`

---

# lt\_recvlogical

lt\_recvlogical — control LightDB logical decoding streams

## Synopsis

```
lt_recvlogical [option...]
```

## Description

lt\_recvlogical controls logical decoding replication slots and streams data from such replication slots.

It creates a replication-mode connection, so it is subject to the same constraints as lt\_receivewal, plus those for logical replication (see Chapter 45).

lt\_recvlogical has no equivalent to the logical decoding SQL interface's peek and get modes. It sends replay confirmations for data lazily as it receives it and on clean exit. To examine pending data on a slot without consuming it, use pg\_logical\_slot\_peek\_changes.

## Options

At least one of the following options must be specified to select an action:

`--create-slot`

Create a new logical replication slot with the name specified by `--slot`, using the output plugin specified by `--plugin`, for the database specified by `--dbname`.

`--drop-slot`

Drop the replication slot with the name specified by `--slot`, then exit.

`--start`

Begin streaming changes from the logical replication slot specified by `--slot`, continuing until terminated by a signal. If the server side change stream ends with a server shutdown or disconnect, retry in a loop unless `--no-loop` is specified.

The stream format is determined by the output plugin specified when the slot was created.

The connection must be to the same database used to create the slot.

`--create-slot` and `--start` can be specified together. `--drop-slot` cannot be combined with another action.

The following command-line options control the location and format of the output and other replication behavior:

`-E lsn`

`--endpos=lsn`

In `--start` mode, automatically stop replication and exit with normal exit status 0 when receiving reaches the specified LSN. If specified when not in `--start` mode, an error is raised.

If there's a record with LSN exactly equal to `lsn`, the record will be output.

The `--endpos` option is not aware of transaction boundaries and may truncate output partway through a transaction. Any partially output transaction will not be consumed and will be replayed again when the slot is next read from. Individual messages are never truncated.

`-f filename`  
`--file=filename`

Write received and decoded transaction data into this file. Use `-` for stdout.

`-F interval_seconds`  
`--fsync-interval=interval_seconds`

Specifies how often `lt_recvlogical` should issue `fsync()` calls to ensure the output file is safely flushed to disk.

The server will occasionally request the client to perform a flush and report the flush position to the server. This setting is in addition to that, to perform flushes more frequently.

Specifying an interval of 0 disables issuing `fsync()` calls altogether, while still reporting progress to the server. In this case, data could be lost in the event of a crash.

`-I lsn`  
`--startpos=lsn`

In `--start` mode, start replication from the given LSN. For details on the effect of this, see the documentation in Chapter 45 and Section 49.4. Ignored in other modes.

`--if-not-exists`

Do not error out when `--create-slot` is specified and a slot with the specified name already exists.

`-n`  
`--no-loop`

When the connection to the server is lost, do not retry in a loop, just exit.

`-o name[=value]`  
`--option=name[=value]`

Pass the option `name` to the output plugin with, if specified, the option value `value`. Which options exist and their effects depends on the used output plugin.

`-P plugin`  
`--plugin=plugin`

When creating a slot, use the specified logical decoding output plugin. See Chapter 45. This option has no effect if the slot already exists.

`-s interval_seconds`  
`--status-interval=interval_seconds`

This option has the same effect as the option of the same name in `lt_receivewal`. See the description there.

`-S slot_name`  
`--slot=slot_name`

In `--start` mode, use the existing logical replication slot named `slot_name`. In `--create-slot` mode, create the slot with this name. In `--drop-slot` mode, delete the slot with this name.

-v  
--verbose

Enables verbose mode.

The following command-line options control the database connection parameters.

-d *dbname*  
--dbname=*dbname*

The database to connect to. See the description of the actions for what this means in detail. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options. Defaults to the user name.

-h *hostname-or-ip*  
--host=*hostname-or-ip*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the *LTHOST* environment variable, if set, else a Unix domain socket connection is attempted.

-p *port*  
--port=*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the *LTPORT* environment variable, if set, or a compiled-in default.

-U *user*  
--username=*user*

User name to connect as. Defaults to current operating system user name.

-w  
--no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a *.pgpass* file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W  
--password

Force *lt\_recvlogical* to prompt for a password before connecting to a database.

This option is never essential, since *lt\_recvlogical* will automatically prompt for a password if the server demands password authentication. However, *lt\_recvlogical* will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing *-W* to avoid the extra connection attempt.

The following additional options are available:

-V  
--version

Print the *lt\_recvlogical* version and exit.

-?  
--help

Show help about *lt\_recvlogical* command line arguments, and exit.

## Environment

This utility, like most other LightDB utilities, uses the environment variables supported by libpq (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

`lt_recvlogical` will preserve group permissions on the received WAL files if group permissions are enabled on the source cluster.

## Examples

See Section 45.1 for an example.

## See Also

`lt_receivewal`



---

# lt\_restore

lt\_restore — restore a LightDB database from an archive file created by lt\_dump

## Synopsis

```
lt_restore [connection-option...] [option...] [filename]
```

## Description

lt\_restore is a utility for restoring a LightDB database from an archive created by lt\_dump in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow lt\_restore to be selective about what is restored, or even to reorder the items prior to being restored. The archive files are designed to be portable across architectures.

lt\_restore can operate in two modes. If a database name is specified, lt\_restore connects to that database and restores archive contents directly into the database. Otherwise, a script containing the SQL commands necessary to rebuild the database is created and written to a file or standard output. This script output is equivalent to the plain text output format of lt\_dump. Some of the options controlling the output are therefore analogous to lt\_dump options.

Obviously, lt\_restore cannot restore information that is not present in the archive file. For instance, if the archive was made using the “dump data as INSERT commands” option, lt\_restore will not be able to load the data using COPY statements.

## Options

lt\_restore accepts the following command line arguments.

*filename*

Specifies the location of the archive file (or directory, for a directory-format archive) to be restored. If not specified, the standard input is used.

-a

--data-only

Restore only the data, not the schema (data definitions). Table data, large objects, and sequence values are restored, if present in the archive.

This option is similar to, but for historical reasons not identical to, specifying --section=data.

-c

--clean

Clean (drop) database objects before recreating them. (Unless --if-exists is used, this might generate some harmless error messages, if any objects were not present in the destination database.)

-K

--recreate-schema

Output commands to directly drop schema(use cascade mode) prior to outputting the commands for creating them, more faster then normal mode. (Unless --if-exists is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is ignored when emitting an archive (non-text) output file. For the archive formats, you can specify the option when you call `lt_restore`.

`-C`  
`--create`

Create the database before restoring into it. If `--clean` is also specified, drop and recreate the target database before connecting to it.

With `--create`, `lt_restore` also restores the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also restored, unless `--no-acl` is specified.

When this option is used, the database named with `-d` is used only to issue the initial `DROP DATABASE` and `CREATE DATABASE` commands. All data is restored into the database name that appears in the archive.

`-d dbname`  
`--dbname=dbname`

Connect to database `dbname` and restore directly into the database. The `dbname` can be a connection string. If so, connection string parameters will override any conflicting command line options.

`-e`  
`--exit-on-error`

Exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

`-f filename`  
`--file=filename`

Specify output file for generated script, or for the listing when used with `-l`. Use `-` for stdout.

`-F format`  
`--format=format`

Specify format of the archive. It is not necessary to specify the format, since `lt_restore` will determine the format automatically. If specified, it can be one of the following:

`c`  
custom

The archive is in the custom format of `lt_dump`.

`d`  
directory

The archive is a directory archive.

`t`  
tar

The archive is a tar archive.

`-I index`  
`--index=index`

Restore definition of named index only. Multiple indexes may be specified with multiple `-I` switches.

---

`-j number-of-jobs`  
`--jobs=number-of-jobs`

Run the most time-consuming steps of `It_restore` — those that load data, create indexes, or create constraints — concurrently, using up to *number-of-jobs* concurrent sessions. This option can dramatically reduce the time to restore a large database to a server running on a multiprocessor machine. This option is ignored when emitting a script rather than connecting directly to a database server.

Each job is one process or one thread, depending on the operating system, and uses a separate connection to the server.

The optimal value for this option depends on the hardware setup of the server, of the client, and of the network. Factors include the number of CPU cores and the disk setup. A good place to start is the number of CPU cores on the server, but values larger than that can also lead to faster restore times in many cases. Of course, values that are too high will lead to decreased performance because of thrashing.

Only the custom and directory archive formats are supported with this option. The input must be a regular file or directory (not, for example, a pipe or standard input). Also, multiple jobs cannot be used together with the option `--single-transaction`.

`-l`  
`--list`

List the table of contents of the archive. The output of this operation can be used as input to the `-L` option. Note that if filtering switches such as `-n` or `-t` are used with `-l`, they will restrict the items listed.

`-L list-file`  
`--use-list=list-file`

Restore only those archive elements that are listed in *list-file*, and restore them in the order they appear in the file. Note that if filtering switches such as `-n` or `-t` are used with `-L`, they will further restrict the items restored.

*list-file* is normally created by editing the output of a previous `-l` operation. Lines can be moved or removed, and can also be commented out by placing a semicolon (`:`) at the start of the line. See below for examples.

`-n schema`  
`--schema=schema`

Restore only objects that are in the named schema. Multiple schemas may be specified with multiple `-n` switches. This can be combined with the `-t` option to restore just a specific table.

`-N schema`  
`--exclude-schema=schema`

Do not restore objects that are in the named schema. Multiple schemas to be excluded may be specified with multiple `-N` switches.

When both `-n` and `-N` are given for the same schema name, the `-N` switch wins and the schema is excluded.

`-O`  
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `It_restore` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set

ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With `-O`, any user name can be used for the initial connection, and this user will own all the created objects.

```
-P function-name(argtype [, ...])
--function=function-name(argtype [, ...])
```

Restore the named function only. Be careful to spell the function name and arguments exactly as they appear in the dump file's table of contents. Multiple functions may be specified with multiple `-P` switches.

```
-R
--no-reconnect
```

This option is obsolete but still accepted for backwards compatibility.

```
-s
--schema-only
```

Restore only the schema (data definitions), not data, to the extent that schema entries are present in the archive.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data` `--section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

```
-S username
--superuser=username
```

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used.

```
-t table
--table=table
```

Restore definition and/or data of only the named table. For this purpose, “table” includes views, materialized views, sequences, and foreign tables. Multiple tables can be selected by writing multiple `-t` switches. This option can be combined with the `-n` option to specify table(s) in a particular schema.

### Note

When `-t` is specified, `lt_restore` makes no attempt to restore any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that a specific-table restore into a clean database will succeed.

### Note

This flag does not behave identically to the `-t` flag of `lt_dump`. There is not currently any provision for wild-card matching in `lt_restore`, nor can you include a schema name within its `-t`. And, while `lt_dump`'s `-t` flag will also dump subsidiary objects (such as indexes) of the selected table(s), `lt_restore`'s `-t` flag does not include such subsidiary objects.

**Note**

In versions prior to LightDB 9.6, this flag matched only tables, not any other type of relation.

`-T trigger`  
`--trigger=trigger`

Restore named trigger only. Multiple triggers may be specified with multiple `-T` switches.

`-v`  
`--verbose`

Specifies verbose mode.

`-V`  
`--version`

Print the `lt_restore` version and exit.

`-x`  
`--no-privileges`  
`--no-acl`

Prevent restoration of access privileges (grant/revoke commands).

`-l`  
`--single-transaction`

Execute the restore as a single transaction (that is, wrap the emitted commands in `BEGIN/COMMIT`). This ensures that either all the commands complete successfully, or no changes are applied. This option implies `--exit-on-error`.

`--disable-triggers`

This option is relevant only when performing a data-only restore. It instructs `lt_restore` to execute commands to temporarily disable triggers on the target tables while the data is restored. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data restore.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So you should also specify a superuser name with `-S` or, preferably, run `lt_restore` as a LightDB superuser.

`--enable-row-security`

This option is relevant only when restoring the contents of a table which has row security. By default, `lt_restore` will set `row_security` to off, to ensure that all data is restored in to the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `lt_restore` to set `row_security` to on instead, allowing the user to attempt to restore the contents of the table with row security enabled. This might still fail if the user does not have the right to insert the rows from the dump into the table.

Note that this option currently also requires the dump be in `INSERT` format, as `COPY FROM` does not support row security.

`--if-exists`

Use conditional commands (i.e., add an `IF EXISTS` clause) to drop database objects. This option is not valid unless `--clean` is also specified.

---

`--no-comments`

Do not output commands to restore comments, even if the archive contains them.

`--no-data-for-failed-tables`

By default, table data is restored even if the creation command for the table failed (e.g., because it already exists). With this option, data for such a table is skipped. This behavior is useful if the target database already contains the desired table contents. For example, auxiliary tables for LightDB extensions such as PostGIS might already be loaded in the target database; specifying this option prevents duplicate or obsolete data from being loaded into them.

This option is effective only when restoring directly into a database, not when producing SQL script output.

`--no-publications`

Do not output commands to restore publications, even if the archive contains them.

`--no-security-labels`

Do not output commands to restore security labels, even if the archive contains them.

`--no-subscriptions`

Do not output commands to restore subscriptions, even if the archive contains them.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

`--ignore-restore-error`

lt\_restore returns 0 when successfully restored. It will return 1 when an error is encountered while sending SQL commands to the database. With this option, the exit code of lt\_restore will always be 0.

`--section=sectionname`

Only restore the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to restore all sections.

The data section contains actual table data as well as large-object definitions. Post-data items consist of definitions of indexes, triggers, rules and constraints other than validated check constraints. Pre-data items consist of all other data definition items.

`--strict-names`

Require that each schema (`-n/--schema`) and table (`-t/--table`) qualifier match at least one schema/table in the backup file.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly.

`--table_exists_action`

Tells lt\_restore what to do if the table it is trying to create already exists. `table_exists_action` has four options: `skip`, `append`, `truncate` or `replace`, the possible values have the following effects:

skip

skip leaves the table as is and moves on to the next object.

append

append loads rows from the source and leaves existing rows unchanged.

truncate

truncate deletes existing rows and then loads rows from the source.

replace

replace drops the existing table, and then creates and loads it from the source.

When you use `truncate` or `replace`, ensure that rows in the affected tables are not targets of any referential constraints. When you use `append` or `truncate`, ensure that rows from the source are compatible with the existing table before performing any action.

-?

--help

Show help about `lt_restore` command line arguments, and exit.

`lt_restore` also accepts the following command line arguments for connection parameters:

-h *host*

--host=*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `LTHOST` environment variable, if set, else a Unix domain socket connection is attempted.

-p *port*

--port=*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `LTPORT` environment variable, if set, or a compiled-in default.

-U *username*

--username=*username*

User name to connect as.

-w

--no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W

--password

Force `lt_restore` to prompt for a password before connecting to a database.

This option is never essential, since `lt_restore` will automatically prompt for a password if the server demands password authentication. However, `lt_restore` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=rolename`

Specifies a role name to be used to perform the restore. This option causes `lt_restore` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `lt_restore`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows restores to be performed without violating the policy.

## Environment

LTHOST  
LTOPTIONS  
LTPORT  
LTUSER

Default connection parameters

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14). However, it does not read `LTDATABASE` when a database name is not supplied.

## Diagnostics

When a direct database connection is specified using the `-d` option, `lt_restore` internally executes SQL statements. If you have problems running `lt_restore`, make sure you are able to select information from the database using, for example, `ltsql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

## Notes

If your installation has any local additions to the `template1` database, be careful to load the output of `lt_restore` into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

The limitations of `lt_restore` are detailed below.

- When restoring data to a pre-existing table and the option `--disable-triggers` is used, `lt_restore` emits commands to disable triggers on user tables before inserting the data, then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.
- `lt_restore` cannot restore large objects selectively; for instance, only those for a specific table. If an archive contains large objects, then all large objects will be restored, or none of them if they are excluded via `-L`, `-t`, or other options.

See also the `lt_dump` documentation for details on limitations of `lt_dump`.

Once restored, it is wise to run `ANALYZE` on each restored table so the optimizer has useful statistics; see Section 22.1.3 and Section 22.1.6 for more information.



## Examples

Assume we have dumped a database called `mydb` into a custom-format dump file:

```
$ lt_dump -Fc mydb > db.dump
```

To drop the database and recreate it from the dump:

```
$ dropdb mydb
$ lt_restore -C -d postgres db.dump
```

The database named in the `-d` switch can be any database existing in the cluster; `lt_restore` only uses it to issue the `CREATE DATABASE` command for `mydb`. With `-C`, data is always restored into the database name that appears in the dump file.

To restore the dump into a new database called `newdb`:

```
$ createdb -T template0 newdb
$ lt_restore -d newdb db.dump
```

Notice we don't use `-C`, and instead connect directly to the database to be restored into. Also note that we clone the new database from `template0` not `template1`, to ensure it is initially empty.

To reorder database items, it is first necessary to dump the table of contents of the archive:

```
$ lt_restore -l db.dump > db.list
```

The listing file consists of a header and one line for each item, e.g.:

```
;
; Archive created at Mon Sep 14 13:55:39 2009
;   dbname: DBDEMOS
;   TOC Entries: 81
;   Compression: 9
;   Dump Version: 1.10-0
;   Format: CUSTOM
;   Integer: 4 bytes
;   Offset: 8 bytes
;   Dumped from database version: 8.3.5
;   Dumped by lt_dump version: 8.3.8
;
;
; Selected TOC Entries:
;
3; 2615 2200 SCHEMA - public pasha
1861; 0 0 COMMENT - SCHEMA public pasha
1862; 0 0 ACL - public pasha
317; 1247 17715 TYPE public composite pasha
319; 1247 25899 DOMAIN public domain0 pasha
```

Semicolons start a comment, and the numbers at the start of lines refer to the internal archive ID assigned to each item.

Lines in the file can be commented out, deleted, and reordered. For example:

```
10; 145433 TABLE map_resolutions postgres
;2; 145344 TABLE species postgres
;4; 145359 TABLE nt_header postgres
6; 145402 TABLE species_records postgres
;8; 145416 TABLE ss_old postgres
```

could be used as input to lt\_restore and would only restore items 10 and 6, in that order:

```
$ lt_restore -L db.list db.dump
```

## See Also

lt\_dump, lt\_dumpall, ltsql

---

# lt\_verifybackup

lt\_verifybackup — verify the integrity of a base backup of a LightDB cluster

## Synopsis

```
lt_verifybackup [option...]
```

## Description

lt\_verifybackup is used to check the integrity of a database cluster backup taken using lt\_basebackup against a backup\_manifest generated by the server at the time of the backup. The backup must be stored in the "plain" format; a "tar" format backup can be checked after extracting it.

It is important to note that the validation which is performed by lt\_verifybackup does not and cannot include every check which will be performed by a running server when attempting to make use of the backup. Even if you use this tool, you should still perform test restores and verify that the resulting databases work as expected and that they appear to contain the correct data. However, lt\_verifybackup can detect many problems that commonly occur due to storage problems or user error.

Backup verification proceeds in four stages. First, lt\_verifybackup reads the backup\_manifest file. If that file does not exist, cannot be read, is malformed, or fails verification against its own internal checksum, lt\_verifybackup will terminate with a fatal error.

Second, lt\_verifybackup will attempt to verify that the data files currently stored on disk are exactly the same as the data files which the server intended to send, with some exceptions that are described below. Extra and missing files will be detected, with a few exceptions. This step will ignore the presence or absence of, or any modifications to, lightdb.auto.conf, standby.signal, and recovery.signal, because it is expected that these files may have been created or modified as part of the process of taking the backup. It also won't complain about a backup\_manifest file in the target directory or about anything inside lt\_wal, even though these files won't be listed in the backup manifest. Only files are checked; the presence or absence of directories is not verified, except indirectly: if a directory is missing, any files it should have contained will necessarily also be missing.

Next, lt\_verifybackup will checksum all the files, compare the checksums against the values in the manifest, and emit errors for any files for which the computed checksum does not match the checksum stored in the manifest. This step is not performed for any files which produced errors in the previous step, since they are already known to have problems. Files which were ignored in the previous step are also ignored in this step.

Finally, lt\_verifybackup will use the manifest to verify that the write-ahead log records which will be needed to recover the backup are present and that they can be read and parsed. The backup\_manifest contains information about which write-ahead log records will be needed, and lt\_verifybackup will use that information to invoke lt\_waldump to parse those write-ahead log records. The --quiet flag will be used, so that lt\_waldump will only report errors, without producing any other output. While this level of verification is sufficient to detect obvious problems such as a missing file or one whose internal checksums do not match, they aren't extensive enough to detect every possible problem that might occur when attempting to recover. For instance, a server bug that produces write-ahead log records that have the correct checksums but specify nonsensical actions can't be detected by this method.

Note that if extra WAL files which are not required to recover the backup are present, they will not be checked by this tool, although a separate invocation of lt\_waldump could be used for that purpose. Also note that WAL verification is version-specific: you must use the version of

lt\_verifybackup, and thus of lt\_waldump, which pertains to the backup being checked. In contrast, the data file integrity checks should work with any version of the server that generates a backup\_manifest file.

## Options

lt\_verifybackup accepts the following command-line arguments:

-e  
--exit-on-error

Exit as soon as a problem with the backup is detected. If this option is not specified, lt\_verifybackup will continue checking the backup even after a problem has been detected, and will report all problems detected as errors.

-i *path*  
--ignore=*path*

Ignore the specified file or directory, which should be expressed as a relative path name, when comparing the list of data files actually present in the backup to those listed in the backup\_manifest file. If a directory is specified, this option affects the entire subtree rooted at that location. Complaints about extra files, missing files, file size differences, or checksum mismatches will be suppressed if the relative path name matches the specified path name. This option can be specified multiple times.

-m *path*  
--manifest-path=*path*

Use the manifest file at the specified path, rather than one located in the root of the backup directory.

-n  
--no-parse-wal

Don't attempt to parse write-ahead log data that will be needed to recover from this backup.

-q  
--quiet

Don't print anything when a backup is successfully verified.

-s  
--skip-checksums

Do not verify data file checksums. The presence or absence of files and the sizes of those files will still be checked. This is much faster, because the files themselves do not need to be read.

-w *path*  
--wal-directory=*path*

Try to parse WAL files stored in the specified directory, rather than in lt\_wal. This may be useful if the backup is stored in a separate location from the WAL archive.

Other options are also available:

-V  
--version

Print the lt\_verifybackup version and exit.

-?  
--help

Show help about lt\_verifybackup command line arguments, and exit.

## Examples

To create a base backup of the server at mydbserver and verify the integrity of the backup:

```
$ lt_basebackup -h mydbserver -D /usr/local/lightdb-x/data  
$ lt_verifybackup /usr/local/lightdb-x/data
```

To create a base backup of the server at mydbserver, move the manifest somewhere outside the backup directory, and verify the backup:

```
$ lt_basebackup -h mydbserver -D /usr/local/lightdb-x/backup1234  
$ mv /usr/local/lightdb-x/backup1234/backup_manifest /my/secure/  
location/backup_manifest.1234  
$ lt_verifybackup -m /my/secure/location/backup_manifest.1234 /usr/  
local/lightdb-x/backup1234
```

To verify a backup while ignoring a file that was added manually to the backup directory, and also skipping checksum verification:

```
$ lt_basebackup -h mydbserver -D /usr/local/lightdb-x/data  
$ edit /usr/local/lightdb-x/data/note.to.self  
$ lt_verifybackup --ignore=note.to.self --skip-checksums /usr/  
local/lightdb-x/data
```

## See Also

lt\_basebackup

---

# ltbench

ltbench — run a benchmark test on LightDB

## Synopsis

```
ltbench -i [option...] [dbname]
```

```
ltbench [option...] [dbname]
```

## Description

ltbench is a simple program for running benchmark tests on LightDB. It runs the same sequence of SQL commands over and over, possibly in multiple concurrent database sessions, and then calculates the average transaction rate (transactions per second). By default, ltbench tests a scenario that is loosely based on TPC-B, involving five SELECT, UPDATE, and INSERT commands per transaction. However, it is easy to test other cases by writing your own transaction script files.

Typical output from ltbench looks like:

```
transaction type: <builtin: TPC-B (sort of)>
scaling factor: 10
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
tps = 85.184871 (including connections establishing)
tps = 85.296346 (excluding connections establishing)
```

The first six lines report some of the most important parameter settings. The next line reports the number of transactions completed and intended (the latter being just the product of number of clients and number of transactions per client); these will be equal unless the run failed before completion. (In -T mode, only the actual number of transactions is printed.) The last two lines report the number of transactions per second, figured with and without counting the time to start database sessions.

The default TPC-B-like transaction test requires specific tables to be set up beforehand. ltbench should be invoked with the -i (initialize) option to create and populate these tables. (When you are testing a custom script, you don't need this step, but will instead need to do whatever setup your test needs.) Initialization looks like:

```
ltbench -i [ other-options ] dbname
```

where *dbname* is the name of the already-created database to test in. (You may also need -h, -p, and/or -U options to specify how to connect to the database server.)

### Caution

ltbench -i creates four tables `ltbench_accounts`, `ltbench_branches`, `ltbench_history`, and `ltbench_tellers`, destroying any existing tables of these names. Be very careful to use another database if you have tables having these names!

At the default “scale factor” of 1, the tables initially contain this many rows:

table	# of rows
ltbench_branches	1
ltbench_tellers	10
ltbench_accounts	100000
ltbench_history	0

You can (and, for most purposes, probably should) increase the number of rows by using the `-s` (scale factor) option. The `-F` (fillfactor) option might also be used at this point.

Once you have done the necessary setup, you can run your benchmark with a command that doesn't include `-i`, that is

```
ltbench [ options ] dbname
```

In nearly all cases, you'll need some options to make a useful test. The most important options are `-c` (number of clients), `-t` (number of transactions), `-T` (time limit), and `-f` (specify a custom script file). See below for a full list.

## Options

The following is divided into three subsections. Different options are used during database initialization and while running benchmarks, but some options are useful in both cases.

### Initialization Options

ltbench accepts the following command-line initialization arguments:

*dbname*

Specifies the name of the database to test in. If this is not specified, the environment variable `LTDATABASE` is used. If that is not set, the user name specified for the connection is used.

`-i`  
`--initialize`

Required to invoke initialization mode.

`-I init_steps`  
`--init-steps=init_steps`

Perform just a selected set of the normal initialization steps. *init\_steps* specifies the initialization steps to be performed, using one character per step. Each step is invoked in the specified order. The default is `dtgvp`. The available steps are:

**d** (Drop)

Drop any existing ltbench tables.

**t** (create Tables)

Create the tables used by the standard ltbench scenario, namely `ltbench_accounts`, `ltbench_branches`, `ltbench_history`, and `ltbench_tellers`.

**g** or **G** (Generate data, client-side or server-side)

Generate data and load it into the standard tables, replacing any data already present.

With `g` (client-side data generation), data is generated in `ltbench` client and then sent to the server. This uses the client/server bandwidth extensively through a `COPY`. Using `g` causes logging to print one message every 100,000 rows while generating data for the `ltbench_accounts` table.

With `G` (server-side data generation), only small queries are sent from the `ltbench` client and then data is actually generated in the server. No significant bandwidth is required for this variant, but the server will do more work. Using `G` causes logging not to print any progress message while generating data.

The default initialization behavior uses client-side data generation (equivalent to `g`).

`v` (Vacuum)

Invoke `VACUUM` on the standard tables.

`p` (create Primary keys)

Create primary key indexes on the standard tables.

`f` (create Foreign keys)

Create foreign key constraints between the standard tables. (Note that this step is not performed by default.)

`-F fillfactor`

`--fillfactor=fillfactor`

Create the `ltbench_accounts`, `ltbench_tellers` and `ltbench_branches` tables with the given fillfactor. Default is 100.

`-n`

`--no-vacuum`

Perform no vacuuming during initialization. (This option suppresses the `v` initialization step, even if it was specified in `-I`.)

`-q`

`--quiet`

Switch logging to quiet mode, producing only one progress message per 5 seconds. The default logging prints one message each 100,000 rows, which often outputs many lines per second (especially on good hardware).

This setting has no effect if `G` is specified in `-I`.

`-s scale_factor`

`--scale=scale_factor`

Multiply the number of rows generated by the scale factor. For example, `-s 100` will create 10,000,000 rows in the `ltbench_accounts` table. Default is 1. When the scale is 20,000 or larger, the columns used to hold account identifiers (`aid` columns) will switch to using larger integers (`bigint`), in order to be big enough to hold the range of account identifiers.

`--foreign-keys`

Create foreign key constraints between the standard tables. (This option adds the `f` step to the initialization step sequence, if it is not already present.)

`--index-tablespace=index_tablespace`

Create indexes in the specified tablespace, rather than the default tablespace.



`--partition-method=NAME`

Create a partitioned `ltbench_accounts` table with *NAME* method. Expected values are `range` or `hash`. This option requires that `--partitions` is set to non-zero. If unspecified, default is `range`.

`--partitions=NUM`

Create a partitioned `ltbench_accounts` table with *NUM* partitions of nearly equal size for the scaled number of accounts. Default is 0, meaning no partitioning.

`--tablespace=tablespace`

Create tables in the specified tablespace, rather than the default tablespace.

`--unlogged-tables`

Create all tables as unlogged tables, rather than permanent tables.

## Benchmarking Options

ltbench accepts the following command-line benchmarking arguments:

`-b scriptname[@weight]`

`--builtin=scriptname[@weight]`

Add the specified built-in script to the list of scripts to be executed. Available built-in scripts are: `tpcb-like`, `simple-update` and `select-only`. Unambiguous prefixes of built-in names are accepted. With the special name `list`, show the list of built-in scripts and exit immediately.

Optionally, write an integer weight after `@` to adjust the probability of selecting this script versus other ones. The default weight is 1. See below for details.

`-c clients`

`--client=clients`

Number of clients simulated, that is, number of concurrent database sessions. Default is 1.

`-C`

`--connect`

Establish a new connection for each transaction, rather than doing it just once per client session. This is useful to measure the connection overhead.

`-d`

`--debug`

Print debugging output.

`-D varname=value`

`--define=varname=value`

Define a variable for use by a custom script (see below). Multiple `-D` options are allowed.

`-f filename[@weight]`

`--file=filename[@weight]`

Add a transaction script read from *filename* to the list of scripts to be executed.

Optionally, write an integer weight after `@` to adjust the probability of selecting this script versus other ones. The default weight is 1. (To use a script file name that includes an `@` character, append a weight so that there is no ambiguity, for example `filen@me@1`.) See below for details.

`-j threads`  
`--jobs=threads`

Number of worker threads within ltpbench. Using more than one thread can be helpful on multi-CPU machines. Clients are distributed as evenly as possible among available threads. Default is 1.

`-l`  
`--log`

Write information about each transaction to a log file. See below for details.

`-L limit`  
`--latency-limit=limit`

Transactions that last more than *limit* milliseconds are counted and reported separately, as *late*.

When throttling is used (`--rate=...`), transactions that lag behind schedule by more than *limit* ms, and thus have no hope of meeting the latency limit, are not sent to the server at all. They are counted and reported separately as *skipped*.

`-M querymode`  
`--protocol=querymode`

Protocol to use for submitting queries to the server:

- `simple`: use simple query protocol.
- `extended`: use extended query protocol.
- `prepared`: use extended query protocol with prepared statements.

In the `prepared` mode, ltpbench reuses the parse analysis result starting from the second query iteration, so ltpbench runs faster than in other modes.

The default is simple query protocol. (See Chapter 49 for more information.)

`-n`  
`--no-vacuum`

Perform no vacuuming before running the test. This option is *necessary* if you are running a custom test scenario that does not include the standard tables `ltpbench_accounts`, `ltpbench_branches`, `ltpbench_history`, and `ltpbench_tellers`.

`-N`  
`--skip-some-updates`

Run built-in simple-update script. Shorthand for `-b simple-update`.

`-P sec`  
`--progress=sec`

Show progress report every *sec* seconds. The report includes the time since the beginning of the run, the TPS since the last report, and the transaction latency average and standard deviation since the last report. Under throttling (`-R`), the latency is computed with respect to the transaction scheduled start time, not the actual transaction beginning time, thus it also includes the average schedule lag time.

`-r`  
`--report-latencies`

Report the average per-statement latency (execution time from the perspective of the client) of each command after the benchmark finishes. See below for details.

`-R rate`  
`--rate=rate`

Execute transactions targeting the specified rate instead of running as fast as possible (the default). The rate is given in transactions per second. If the targeted rate is above the maximum possible rate, the rate limit won't impact the results.

The rate is targeted by starting transactions along a Poisson-distributed schedule time line. The expected start time schedule moves forward based on when the client first started, not when the previous transaction ended. That approach means that when transactions go past their original scheduled end time, it is possible for later ones to catch up again.

When throttling is active, the transaction latency reported at the end of the run is calculated from the scheduled start times, so it includes the time each transaction had to wait for the previous transaction to finish. The wait time is called the schedule lag time, and its average and maximum are also reported separately. The transaction latency with respect to the actual transaction start time, i.e., the time spent executing the transaction in the database, can be computed by subtracting the schedule lag time from the reported latency.

If `--latency-limit` is used together with `--rate`, a transaction can lag behind so much that it is already over the latency limit when the previous transaction ends, because the latency is calculated from the scheduled start time. Such transactions are not sent to the server, but are skipped altogether and counted separately.

A high schedule lag time is an indication that the system cannot process transactions at the specified rate, with the chosen number of clients and threads. When the average transaction execution time is longer than the scheduled interval between each transaction, each successive transaction will fall further behind, and the schedule lag time will keep increasing the longer the test run is. When that happens, you will have to reduce the specified transaction rate.

`-s scale_factor`  
`--scale=scale_factor`

Report the specified scale factor in ltbench's output. With the built-in tests, this is not necessary; the correct scale factor will be detected by counting the number of rows in the `ltbench_branches` table. However, when testing only custom benchmarks (`-f` option), the scale factor will be reported as 1 unless this option is used.

`-S`  
`--select-only`

Run built-in select-only script. Shorthand for `-b select-only`.

`-t transactions`  
`--transactions=transactions`

Number of transactions each client runs. Default is 10.

`-T seconds`  
`--time=seconds`

Run the test for this many seconds, rather than a fixed number of transactions per client. `-t` and `-T` are mutually exclusive.

`-v`  
`--vacuum-all`

Vacuum all four standard tables before running the test. With neither `-n` nor `-v`, ltbench will vacuum the `ltbench_tellers` and `ltbench_branches` tables, and will truncate `ltbench_history`.

`--aggregate-interval=seconds`

Length of aggregation interval (in seconds). May be used only with `-l` option. With this option, the log contains per-interval summary data, as described below.

`--log-prefix=prefix`

Set the filename prefix for the log files created by `--log`. The default is `ltbench_log`.

`--progress-timestamp`

When showing progress (option `-P`), use a timestamp (Unix epoch) instead of the number of seconds since the beginning of the run. The unit is in seconds, with millisecond precision after the dot. This helps compare logs generated by various tools.

`--random-seed=seed`

Set random generator seed. Seeds the system random number generator, which then produces a sequence of initial generator states, one for each thread. Values for `seed` may be: `time` (the default, the seed is based on the current time), `rand` (use a strong random source, failing if none is available), or an unsigned decimal integer value. The random generator is invoked explicitly from a `ltbench` script (`random...` functions) or implicitly (for instance option `--rate` uses it to schedule transactions). When explicitly set, the value used for seeding is shown on the terminal. Any value allowed for `seed` may also be provided through the environment variable `LTBENCH_RANDOM_SEED`. To ensure that the provided seed impacts all possible uses, put this option first or use the environment variable.

Setting the seed explicitly allows to reproduce a `ltbench` run exactly, as far as random numbers are concerned. As the random state is managed per thread, this means the exact same `ltbench` run for an identical invocation if there is one client per thread and there are no external or data dependencies. From a statistical viewpoint reproducing runs exactly is a bad idea because it can hide the performance variability or improve performance unduly, e.g., by hitting the same pages as a previous run. However, it may also be of great help for debugging, for instance re-running a tricky case which leads to an error. Use wisely.

`--sampling-rate=rate`

Sampling rate, used when writing data into the log, to reduce the amount of log generated. If this option is given, only the specified fraction of transactions are logged. 1.0 means all transactions will be logged, 0.05 means only 5% of the transactions will be logged.

Remember to take the sampling rate into account when processing the log file. For example, when computing TPS values, you need to multiply the numbers accordingly (e.g., with 0.01 sample rate, you'll only get 1/100 of the actual TPS).

`--show-script=scriptname`

Show the actual code of builtin script `scriptname` on `stderr`, and exit immediately.

## Common Options

`ltbench` also accepts the following common command-line arguments for connection parameters:

`-h hostname`

`--host=hostname`

The database server's host name

`-p port`

`--port=port`

The database server's port number

`-U login`  
`--username=login`

The user name to connect as

`-V`  
`--version`

Print the ltbench version and exit.

`-?`  
`--help`

Show help about ltbench command line arguments, and exit.

## Exit Status

A successful run will exit with status 0. Exit status 1 indicates static problems such as invalid command-line options. Errors during the run such as database errors or problems in the script will result in exit status 2. In the latter case, ltbench will print partial results.

## Environment

LTDATABASE  
LTHOST  
LTPORT  
LTUSER

Default connection parameters.

This utility, like most other LightDB utilities, uses the environment variables supported by libpq (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

### What Is the “Transaction” Actually Performed in ltbench?

ltbench executes test scripts chosen randomly from a specified list. The scripts may include built-in scripts specified with `-b` and user-provided scripts specified with `-f`. Each script may be given a relative weight specified after an `@` so as to change its selection probability. The default weight is 1. Scripts with a weight of 0 are ignored.

The default built-in transaction script (also invoked with `-b tpcb-like`) issues seven commands per transaction over randomly chosen `aid`, `tid`, `bid` and `delta`. The scenario is inspired by the TPC-B benchmark, but is not actually TPC-B, hence the name.

1. `BEGIN;`
2. `UPDATE ltbench_accounts SET abalance = abalance + :delta WHERE aid = :aid;`
3. `SELECT abalance FROM ltbench_accounts WHERE aid = :aid;`
4. `UPDATE ltbench_tellers SET tbalance = tbalance + :delta WHERE tid = :tid;`
5. `UPDATE ltbench_branches SET bbalance = bbalance + :delta WHERE bid = :bid;`

```

6. INSERT INTO ltbench_history (tid, bid, aid, delta, mtime) VALUES
   (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);

7. END;

```

If you select the `simple-update` built-in (also `-N`), steps 4 and 5 aren't included in the transaction. This will avoid update contention on these tables, but it makes the test case even less like TPC-B.

If you select the `select-only` built-in (also `-S`), only the `SELECT` is issued.

## Custom Scripts

ltbench has support for running custom benchmark scenarios by replacing the default transaction script (described above) with a transaction script read from a file (`-f` option). In this case a “transaction” counts as one execution of a script file.

A script file contains one or more SQL commands terminated by semicolons. Empty lines and lines beginning with `--` are ignored. Script files can also contain “meta commands”, which are interpreted by ltbench itself, as described below.

### Note

Before LightDB 9.6, SQL commands in script files were terminated by newlines, and so they could not be continued across lines. Now a semicolon is *required* to separate consecutive SQL commands (though a SQL command does not need one if it is followed by a meta command). If you need to create a script file that works with both old and new versions of ltbench, be sure to write each SQL command on a single line ending with a semicolon.

There is a simple variable-substitution facility for script files. Variable names must consist of letters (including non-Latin letters), digits, and underscores, with the first character not being a digit. Variables can be set by the command-line `-D` option, explained above, or by the meta commands explained below. In addition to any variables preset by `-D` command-line options, there are a few variables that are preset automatically, listed in Table 273. A value specified for these variables using `-D` takes precedence over the automatic presets. Once set, a variable's value can be inserted into a SQL command by writing `:variablename`. When running more than one client session, each session has its own set of variables. ltbench supports up to 255 variable uses in one statement.

**Table 273. ltbench Automatic Variables**

Variable	Description
<code>client_id</code>	unique number identifying the client session (starts from zero)
<code>default_seed</code>	seed used in hash functions by default
<code>random_seed</code>	random generator seed (unless overwritten with <code>-D</code> )
<code>scale</code>	current scale factor

Script file meta commands begin with a backslash (`\`) and normally extend to the end of the line, although they can be continued to additional lines by writing backslash-return. Arguments to a meta command are separated by white space. These meta commands are supported:

```
\gset [prefix] \aset [prefix]
```

These commands may be used to end SQL queries, taking the place of the terminating semicolon (`;`).

When the `\gset` command is used, the preceding SQL query is expected to return one row, the columns of which are stored into variables named after column names, and prefixed with `prefix` if provided.

When the `\aset` command is used, all combined SQL queries (separated by `\;`) have their columns stored into variables named after column names, and prefixed with *prefix* if provided. If a query returns no row, no assignment is made and the variable can be tested for existence to detect this. If a query returns more than one row, the last value is kept.

The following example puts the final account balance from the first query into variable *abalance*, and fills variables *p\_two* and *p\_three* with integers from the third query. The result of the second query is discarded. The result of the two last combined queries are stored in variables *four* and *five*.

```
UPDATE ltbench_accounts
  SET abalance = abalance + :delta
  WHERE aid = :aid
  RETURNING abalance \gset
-- compound of two queries
SELECT 1 \;
SELECT 2 AS two, 3 AS three \gset p_
SELECT 4 AS four \; SELECT 5 AS five \aset
```

```
\if expression
\elif expression
\else
\endif
```

This group of commands implements nestable conditional blocks, similarly to `ltsql`'s `\if expression`. Conditional expressions are identical to those with `\set`, with non-zero values interpreted as true.

```
\set varname expression
```

Sets variable *varname* to a value calculated from *expression*. The expression may contain the `NULL` constant, Boolean constants `TRUE` and `FALSE`, integer constants such as `5432`, double constants such as `3.14159`, references to variables `:variablename`, operators with their usual SQL precedence and associativity, function calls, SQL `CASE` generic conditional expressions and parentheses.

Functions and most operators return `NULL` on `NULL` input.

For conditional purposes, non zero numerical values are `TRUE`, zero numerical values and `NULL` are `FALSE`.

Too large or small integer and double constants, as well as integer arithmetic operators (`+`, `-`, `*` and `/`) raise errors on overflows.

When no final `ELSE` clause is provided to a `CASE`, the default value is `NULL`.

Examples:

```
\set ntellers 10 * :scale
\set aid (1021 * random(1, 100000 * :scale)) % \
        (100000 * :scale) + 1
\set divx CASE WHEN :x <> 0 THEN :y/:x ELSE NULL END
```

```
\sleep number [ us | ms | s ]
```

Causes script execution to sleep for the specified duration in microseconds (`us`), milliseconds (`ms`) or seconds (`s`). If the unit is omitted then seconds are the default. *number* can be either an integer constant or a `:variablename` reference to a variable having an integer value.

Example:

```
\sleep 10 ms
```

```
\setshell varname command [ argument ... ]
```

Sets variable *varname* to the result of the shell command *command* with the given *argument(s)*. The command must return an integer value through its standard output.

*command* and each *argument* can be either a text constant or a *:variablename* reference to a variable. If you want to use an *argument* starting with a colon, write an additional colon at the beginning of *argument*.

Example:

```
\setshell variable_to_be_assigned command
literal_argument :variable ::literal_starting_with_colon
```

```
\shell command [ argument ... ]
```

Same as `\setshell`, but the result of the command is discarded.

Example:

```
\shell command
literal_argument :variable ::literal_starting_with_colon
```

## Built-in Operators

The arithmetic, bitwise, comparison and logical operators listed in Table 274 are built into ltbench and may be used in expressions appearing in `\set`. The operators are listed in increasing precedence order. Except as noted, operators taking two numeric inputs will produce a double value if either input is double, otherwise they produce an integer result.

**Table 274. ltbench Operators**

Operator	Description	Example(s)
<i>boolean</i> OR <i>boolean</i> → <i>boolean</i>	Logical OR	5 or 0 → TRUE
<i>boolean</i> AND <i>boolean</i> → <i>boolean</i>	Logical AND	3 and 0 → FALSE
NOT <i>boolean</i> → <i>boolean</i>	Logical NOT	not false → TRUE
<i>boolean</i> IS [NOT] (NULL   TRUE   FALSE) → <i>boolean</i>	Boolean value tests	1 is null → FALSE
<i>value</i> ISNULL   NOTNULL → <i>boolean</i>	Nullness tests	1 notnull → TRUE



<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
	<i>number</i> = <i>number</i> → <i>boolean</i> Equal	5 = 4 → FALSE
	<i>number</i> <> <i>number</i> → <i>boolean</i> Not equal	5 <> 4 → TRUE
	<i>number</i> != <i>number</i> → <i>boolean</i> Not equal	5 != 5 → FALSE
	<i>number</i> < <i>number</i> → <i>boolean</i> Less than	5 < 4 → FALSE
	<i>number</i> <= <i>number</i> → <i>boolean</i> Less than or equal to	5 <= 4 → FALSE
	<i>number</i> > <i>number</i> → <i>boolean</i> Greater than	5 > 4 → TRUE
	<i>number</i> >= <i>number</i> → <i>boolean</i> Greater than or equal to	5 >= 4 → TRUE
	<i>integer</i>   <i>integer</i> → <i>integer</i> Bitwise OR	1   2 → 3
	<i>integer</i> # <i>integer</i> → <i>integer</i> Bitwise XOR	1 # 3 → 2
	<i>integer</i> & <i>integer</i> → <i>integer</i> Bitwise AND	1 & 3 → 1
	~ <i>integer</i> → <i>integer</i> Bitwise NOT	~ 1 → -2
	<i>integer</i> << <i>integer</i> → <i>integer</i> Bitwise shift left	1 << 2 → 4
	<i>integer</i> >> <i>integer</i> → <i>integer</i> Bitwise shift right	8 >> 2 → 2
	<i>number</i> + <i>number</i> → <i>number</i>	

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
	Addition	$5 + 4 \rightarrow 9$
	<i>number</i> - <i>number</i> → <i>number</i> Subtraction	$3 - 2.0 \rightarrow 1.0$
	<i>number</i> * <i>number</i> → <i>number</i> Multiplication	$5 * 4 \rightarrow 20$
	<i>number</i> / <i>number</i> → <i>number</i> Division (truncates the result towards zero if both inputs are integers)	$5 / 3 \rightarrow 1$
	<i>integer</i> % <i>integer</i> → <i>integer</i> Modulo (remainder)	$3 \% 2 \rightarrow 1$
	- <i>number</i> → <i>number</i> Negation	$- 2.0 \rightarrow -2.0$

## Built-In Functions

The functions listed in Table 275 are built into ltbench and may be used in expressions appearing in \set.

**Table 275. ltbench Functions**

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>abs ( number )</code>	→ same type as input Absolute value	<code>abs (-17) → 17</code>
<code>debug ( number )</code>	→ same type as input Prints the argument to stderr, and returns the argument.	<code>debug (5432.1) → 5432.1</code>
<code>double ( number )</code>	→ double Casts to double.	<code>double (5432) → 5432.0</code>
<code>exp ( number )</code>	→ double Exponential (e raised to the given power)	<code>exp (1.0) → 2.718281828459045</code>
<code>greatest ( number [, ... ] )</code>	→ double if any argument is double, else integer Selects the largest value among the arguments.	<code>greatest (5, 4, 3, 2) → 5</code>

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>hash ( value [, seed ] )</code>	→ integer This is an alias for <code>hash_murmur2</code> .	<code>hash(10, 5432) → -5817877081768721676</code>
<code>hash_fnv1a ( value [, seed ] )</code>	→ integer Computes FNV-1a hash <sup>1</sup> .	<code>hash_fnv1a(10, 5432) → -7793829335365542153</code>
<code>hash_murmur2 ( value [, seed ] )</code>	→ integer Computes MurmurHash2 hash <sup>2</sup> .	<code>hash_murmur2(10, 5432) → -5817877081768721676</code>
<code>int ( number )</code>	→ integer Casts to integer.	<code>int(5.4 + 3.8) → 9</code>
<code>least ( number [, ... ] )</code>	→ double if any argument is double, else integer Selects the smallest value among the arguments.	<code>least(5, 4, 3, 2.1) → 2.1</code>
<code>ln ( number )</code>	→ double Natural logarithm	<code>ln(2.718281828459045) → 1.0</code>
<code>mod ( integer, integer )</code>	→ integer Modulo (remainder)	<code>mod(54, 32) → 22</code>
<code>pi ()</code>	→ double Approximate value of $\pi$	<code>pi() → 3.14159265358979323846</code>
<code>pow ( x, y )</code>	→ double power ( x, y ) → double x raised to the power of y	<code>pow(2.0, 10) → 1024.0</code>
<code>random ( lb, ub )</code>	→ integer Computes a uniformly-distributed random integer in [ lb, ub ].	<code>random(1, 10) → an integer between 1 and 10</code>
<code>random_exponential ( lb, ub, parameter )</code>	→ integer Computes an exponentially-distributed random integer in [ lb, ub ], see below.	<code>random_exponential(1, 10, 3.0) → an integer between 1 and 10</code>
<code>random_gaussian ( lb, ub, parameter )</code>	→ integer Computes a Gaussian-distributed random integer in [ lb, ub ], see below.	<code>random_gaussian(1, 10, 2.5) → an integer between 1 and 10</code>
<code>random_zipfian ( lb, ub, parameter )</code>	→ integer	

<sup>1</sup> [https://en.wikipedia.org/wiki/Fowler%E2%80%93Noll%E2%80%93Vo\\_hash\\_function](https://en.wikipedia.org/wiki/Fowler%E2%80%93Noll%E2%80%93Vo_hash_function)

<sup>2</sup> <https://en.wikipedia.org/wiki/MurmurHash>

Function
<b>Description</b> <b>Example(s)</b>
Computes a Zipfian-distributed random integer in $[lb, ub]$ , see below. <code>random_zipfian(1, 10, 1.5)</code> → an integer between 1 and 10
<code>sqrt(number)</code> → double Square root <code>sqrt(2.0)</code> → 1.414213562

The random function generates values using a uniform distribution, that is all the values are drawn within the specified range with equal probability. The `random_exponential`, `random_gaussian` and `random_zipfian` functions require an additional double parameter which determines the precise shape of the distribution.

- For an exponential distribution, *parameter* controls the distribution by truncating a quickly-decreasing exponential distribution at *parameter*, and then projecting onto integers between the bounds. To be precise, with

$$f(x) = \exp(-\text{parameter} * (x - \text{min}) / (\text{max} - \text{min} + 1)) / (1 - \exp(-\text{parameter}))$$

Then value *i* between *min* and *max* inclusive is drawn with probability:  $f(i) - f(i + 1)$ .

Intuitively, the larger the *parameter*, the more frequently values close to *min* are accessed, and the less frequently values close to *max* are accessed. The closer to 0 *parameter* is, the flatter (more uniform) the access distribution. A crude approximation of the distribution is that the most frequent 1% values in the range, close to *min*, are drawn *parameter*% of the time. The *parameter* value must be strictly positive.

- For a Gaussian distribution, the interval is mapped onto a standard normal distribution (the classical bell-shaped Gaussian curve) truncated at  $-\text{parameter}$  on the left and  $+\text{parameter}$  on the right. Values in the middle of the interval are more likely to be drawn. To be precise, if  $\text{PHI}(x)$  is the cumulative distribution function of the standard normal distribution, with mean  $\mu$  defined as  $(\text{max} + \text{min}) / 2.0$ , with

$$f(x) = \text{PHI}(2.0 * \text{parameter} * (x - \mu) / (\text{max} - \text{min} + 1)) / (2.0 * \text{PHI}(\text{parameter}) - 1)$$

then value *i* between *min* and *max* inclusive is drawn with probability:  $f(i + 0.5) - f(i - 0.5)$ . Intuitively, the larger the *parameter*, the more frequently values close to the middle of the interval are drawn, and the less frequently values close to the *min* and *max* bounds. About 67% of values are drawn from the middle  $1.0 / \text{parameter}$ , that is a relative  $0.5 / \text{parameter}$  around the mean, and 95% in the middle  $2.0 / \text{parameter}$ , that is a relative  $1.0 / \text{parameter}$  around the mean; for instance, if *parameter* is 4.0, 67% of values are drawn from the middle quarter ( $1.0/4.0$ ) of the interval (i.e., from  $3.0 / 8.0$  to  $5.0 / 8.0$ ) and 95% from the middle half ( $2.0 / 4.0$ ) of the interval (second and third quartiles). The minimum allowed *parameter* value is 2.0.

- `random_zipfian` generates a bounded Zipfian distribution. *parameter* defines how skewed the distribution is. The larger the *parameter*, the more frequently values closer to the beginning of the interval are drawn. The distribution is such that, assuming the range starts from 1, the ratio of the probability of drawing *k* versus drawing *k+1* is  $((k+1)/k) ** \text{parameter}$ . For example, `random_zipfian(1, ..., 2.5)` produces the value 1 about  $(2/1) ** 2.5 = 5.66$  times more frequently than 2, which itself is produced  $(3/2) ** 2.5 = 2.76$  times more frequently than 3, and so on.

ltbench's implementation is based on "Non-Uniform Random Variate Generation", Luc Devroye, p. 550-551, Springer 1986. Due to limitations of that algorithm, the *parameter* value is restricted to the range [1.001, 1000].

Hash functions `hash`, `hash_murmur2` and `hash_fnv1a` accept an input value and an optional seed parameter. In case the seed isn't provided the value of `:default_seed` is used, which is initialized randomly unless set by the command-line `-D` option. Hash functions can be used to scatter the distribution of random functions such as `random_zipfian` or `random_exponential`. For instance, the following ltbench script simulates possible real world workload typical for social media and blogging platforms where few accounts generate excessive load:

```
\set r random_zipfian(0, 100000000, 1.07)
\set k abs(hash(:r)) % 1000000
```

In some cases several distinct distributions are needed which don't correlate with each other and this is when implicit seed parameter comes in handy:

```
\set k1 abs(hash(:r, :default_seed + 123)) % 1000000
\set k2 abs(hash(:r, :default_seed + 321)) % 1000000
```

As an example, the full definition of the built-in TPC-B-like transaction is:

```
\set aid random(1, 100000 * :scale)
\set bid random(1, 1 * :scale)
\set tid random(1, 10 * :scale)
\set delta random(-5000, 5000)
BEGIN;
UPDATE ltbench_accounts SET abalance = abalance + :delta WHERE aid
 = :aid;
SELECT abalance FROM ltbench_accounts WHERE aid = :aid;
UPDATE ltbench_tellers SET tbalance = tbalance + :delta WHERE tid
 = :tid;
UPDATE ltbench_branches SET bbalance = bbalance + :delta WHERE bid
 = :bid;
INSERT INTO ltbench_history (tid, bid, aid, delta, mtime) VALUES
 (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);
END;
```

This script allows each iteration of the transaction to reference different, randomly-chosen rows. (This example also shows why it's important for each client session to have its own variables — otherwise they'd not be independently touching different rows.)

## Per-Transaction Logging

With the `-l` option (but without the `--aggregate-interval` option), ltbench writes information about each transaction to a log file. The log file will be named *prefix.nnn*, where *prefix* defaults to `ltbench_log`, and *nnn* is the PID of the ltbench process. The prefix can be changed by using the `--log-prefix` option. If the `-j` option is 2 or higher, so that there are multiple worker threads, each will have its own log file. The first worker will use the same name for its log file as in the standard single worker case. The additional log files for the other workers will be named *prefix.nnn.mmm*, where *mmm* is a sequential number for each worker starting with 1.

The format of the log is:

```
client_id transaction_no time script_no time_epoch time_us
 [ schedule_lag ]
```

where *client\_id* indicates which client session ran the transaction, *transaction\_no* counts how many transactions have been run by that session, *time* is the total elapsed transaction time in microseconds, *script\_no* identifies which script file was used (useful when multiple scripts were specified with *-f* or *-b*), and *time\_epoch/time\_us* are a Unix-epoch time stamp and an offset in microseconds (suitable for creating an ISO 8601 time stamp with fractional seconds) showing when the transaction completed. The *schedule\_lag* field is the difference between the transaction's scheduled start time, and the time it actually started, in microseconds. It is only present when the *--rate* option is used. When both *--rate* and *--latency-limit* are used, the *time* for a skipped transaction will be reported as *skipped*.

Here is a snippet of a log file generated in a single-client run:

```
0 199 2241 0 1175850568 995598
0 200 2465 0 1175850568 998079
0 201 2513 0 1175850569 608
0 202 2038 0 1175850569 2663
```

Another example with *--rate=100* and *--latency-limit=5* (note the additional *schedule\_lag* column):

```
0 81 4621 0 1412881037 912698 3005
0 82 6173 0 1412881037 914578 4304
0 83 skipped 0 1412881037 914578 5217
0 83 skipped 0 1412881037 914578 5099
0 83 4722 0 1412881037 916203 3108
0 84 4142 0 1412881037 918023 2333
0 85 2465 0 1412881037 919759 740
```

In this example, transaction 82 was late, because its latency (6.173 ms) was over the 5 ms limit. The next two transactions were skipped, because they were already late before they were even started.

When running a long test on hardware that can handle a lot of transactions, the log files can become very large. The *--sampling-rate* option can be used to log only a random sample of transactions.

## Aggregated Logging

With the *--aggregate-interval* option, a different format is used for the log files:

```
interval_start num_transactions
 sum_latency sum_latency_2 min_latency max_latency
 [ sum_lag sum_lag_2 min_lag max_lag [ skipped ] ]
```

where *interval\_start* is the start of the interval (as a Unix epoch time stamp), *num\_transactions* is the number of transactions within the interval, *sum\_latency* is the sum of the transaction latencies within the interval, *sum\_latency\_2* is the sum of squares of the transaction latencies within the interval, *min\_latency* is the minimum latency within the interval, and *max\_latency* is the maximum latency within the interval. The next fields, *sum\_lag*, *sum\_lag\_2*, *min\_lag*, and *max\_lag*, are only present if the *--rate* option is used. They provide statistics about the time each transaction had to wait for the previous one to finish, i.e., the difference between each transaction's scheduled start time and the time it actually started. The very last field, *skipped*, is only present if the *--latency-limit* option is used, too. It counts the number of transactions skipped because they would have started too late. Each transaction is counted in the interval when it was committed.

Here is some example output:

```
1345828501 5601 1542744 483552416 61 2573
1345828503 7884 1979812 565806736 60 1479
1345828505 7208 1979422 567277552 59 1391
1345828507 7685 1980268 569784714 60 1398
1345828509 7073 1979779 573489941 236 1411
```

Notice that while the plain (unaggregated) log file shows which script was used for each transaction, the aggregated log does not. Therefore if you need per-script data, you need to aggregate the data on your own.

## Per-Statement Latencies

With the `-r` option, ltbench collects the elapsed transaction time of each statement executed by every client. It then reports an average of those values, referred to as the latency for each statement, after the benchmark has finished.

For the default script, the output will look similar to this:

```
starting vacuum...end.
transaction type: <builtin: TPC-B (sort of)>
scaling factor: 1
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
latency average = 15.844 ms
latency stddev = 2.715 ms
tps = 618.764555 (including connections establishing)
tps = 622.977698 (excluding connections establishing)
statement latencies in milliseconds:
    0.002  \set aid random(1, 100000 * :scale)
    0.005  \set bid random(1, 1 * :scale)
    0.002  \set tid random(1, 10 * :scale)
    0.001  \set delta random(-5000, 5000)
    0.326  BEGIN;
    0.603  UPDATE ltbench_accounts SET abalance = abalance
+ :delta WHERE aid = :aid;
    0.454  SELECT abalance FROM ltbench_accounts WHERE aid
= :aid;
    5.528  UPDATE ltbench_tellers SET tbalance = tbalance
+ :delta WHERE tid = :tid;
    7.335  UPDATE ltbench_branches SET bbalance = bbalance
+ :delta WHERE bid = :bid;
    0.371  INSERT INTO ltbench_history (tid, bid, aid, delta,
mtime) VALUES (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);
    1.212  END;
```

If multiple script files are specified, the averages are reported separately for each script file.

Note that collecting the additional timing information needed for per-statement latency computation adds some overhead. This will slow average execution speed and lower the computed TPS. The amount of slowdown varies significantly depending on platform and hardware. Comparing average TPS values with and without latency reporting enabled is a good way to measure if the timing overhead is significant.

## Good Practices

It is very easy to use ltbench to produce completely meaningless numbers. Here are some guidelines to help you get useful results.

In the first place, *never* believe any test that runs for only a few seconds. Use the `-t` or `-T` option to make the run last at least a few minutes, so as to average out noise. In some cases you could need hours to get numbers that are reproducible. It's a good idea to try the test run a few times, to find out if your numbers are reproducible or not.

For the default TPC-B-like test scenario, the initialization scale factor (`-s`) should be at least as large as the largest number of clients you intend to test (`-c`); else you'll mostly be measuring update contention. There are only `-s` rows in the `ltbench_branches` table, and every transaction wants to update one of them, so `-c` values in excess of `-s` will undoubtedly result in lots of transactions blocked waiting for other transactions.

The default test scenario is also quite sensitive to how long it's been since the tables were initialized: accumulation of dead rows and dead space in the tables changes the results. To understand the results you must keep track of the total number of updates and when vacuuming happens. If autovacuum is enabled it can result in unpredictable changes in measured performance.

A limitation of ltbench is that it can itself become the bottleneck when trying to test a large number of client sessions. This can be alleviated by running ltbench on a different machine from the database server, although low network latency will be essential. It might even be useful to run several ltbench instances concurrently, on several client machines, against the same database server.

## Security

If untrusted users have access to a database that has not adopted a secure schema usage pattern, do not run ltbench in that database. ltbench uses unqualified names and does not manipulate the search path.



---

# Itcenter

Itcenter — Itcenter is a command-line admin tool for observing and troubleshooting LightDB

## Main goal

LightDB provides various activity statistics about its runtime, such as connections, statements, database operations, replication, resources usage and more. The general purpose of the statistics is to help DBAs to monitor and troubleshoot LightDB. However, these statistics provided in textual form retrieved from SQL functions and views, and LightDB doesn't provide native tools for working with statistics views.

Itcenter's main goal is to help LightDB DBA working with statistics and provide a convenient way to observe LightDB in runtime.

## Key features

- Top-like interface that allows you to monitor stats changes as you go.
- Configuration management function allows viewing and editing of current configuration files and reloading the service, if needed.
- Logfiles functions allow you to quickly check LightDB logs without stopping statistics monitoring.
- "Poor man's monitoring" allows you to collect LightDB statistics into files and build reports later on.
- Wait events profiler allows seeing what wait events occur during queries execution.

## Supported statistics

### LightDB statistics

- summary activity - a compilation/selection of metrics from different sources - LightDB uptime, version, recovery status, number of clients grouped by their states, number of (auto)vacuums, statements per second, age of the longest transaction and the longest vacuum;
- `pg_stat_activity`<sup>1</sup> - activity of connected clients and background processes.
- `pg_stat_database`<sup>2</sup> - database-wide and sessions statistics, such as number of commits/rollbacks, processed tuples, deadlocks, temporary files, etc.
- `pg_stat_replication`<sup>3</sup> - replication statistics, like connected standbys, their activity and replication lag.
- `pg_stat_user_tables`<sup>4</sup>, `pg_statio_user_tables`<sup>5</sup> - statistics on accesses (including IO) to tables.
- `pg_stat_user_indexes`<sup>6</sup>, `pg_statio_user_indexes`<sup>7</sup> - statistics on accesses (including IO) to indexes.
- `pg_stat_user_functions`<sup>8</sup> - statistics on execution of functions.

---

<sup>1</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ACTIVITY-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ACTIVITY-VIEW)

<sup>2</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-DATABASE-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-DATABASE-VIEW)

<sup>3</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-REPLICATION-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-REPLICATION-VIEW)

<sup>4</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ALL-TABLES-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ALL-TABLES-VIEW)

<sup>5</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STATIO-ALL-TABLES-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STATIO-ALL-TABLES-VIEW)

<sup>6</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ALL-INDEXES-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-ALL-INDEXES-VIEW)

<sup>7</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STATIO-ALL-INDEXES-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STATIO-ALL-INDEXES-VIEW)

<sup>8</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-USER-FUNCTIONS-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-USER-FUNCTIONS-VIEW)

- `pg_stat_wal`<sup>9</sup> - WAL usage statistics.
- `lt_stat_statements`<sup>10</sup> - statistics on SQL statements executed including time and resources usage.
- statistics on tables sizes based on `pg_relation_size()` and `pg_total_relation_size()` functions;
- `pg_stat_progress_vacuum`<sup>11</sup> - progress of (auto)vacuums operations.
- `pg_stat_progress_cluster`<sup>12</sup> - progress of CLUSTER and VACUUM FULL operations.
- `pg_stat_progress_create_index`<sup>13</sup> - progress of CREATE INDEX and REINDEX operations.
- `pg_stat_progress_analyze`<sup>14</sup> - progress of ANALYZE operations.
- `pg_stat_progress_basebackup`<sup>15</sup> - progress of basebackup operations.
- `pg_stat_progress_copy`<sup>16</sup> - progress of COPY operations.

## System statistics

`ltcenter top` also provides system usage information based on statistics from `procfs` filesystem:

- load average and CPU usage time (user, system, nice, idle, iowait, software, and hardware interrupts, steal);
- memory and swap usage, amount of cached and dirty memory, writeback activity;
- storage devices statistics: IOPS, throughput, latencies, average queue and requests size, devices utilization;
- network interfaces statistics: throughput in bytes and packets, different kind of errors, saturation and utilization.
- mounted filesystems' usage statistics: total size, amount of free/used/reserved space and inodes.

In the case of connecting to remote LightDB, there is possibility to use additional SQL functions used for retrieving `/proc` statistics from a remote host.

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<sup>9</sup> [www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-WAL-VIEW](http://www.hs.net/lightdb/docs/current/monitoring-stats.html#PG-STAT-WAL-VIEW)

<sup>10</sup> [www.hs.net/lightdb/docs/current/pgstatstatements.html](http://www.hs.net/lightdb/docs/current/pgstatstatements.html)

<sup>11</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#VACUUM-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#VACUUM-PROGRESS-REPORTING)

<sup>12</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#CLUSTER-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#CLUSTER-PROGRESS-REPORTING)

<sup>13</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#CREATE-INDEX-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#CREATE-INDEX-PROGRESS-REPORTING)

<sup>14</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#ANALYZE-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#ANALYZE-PROGRESS-REPORTING)

<sup>15</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#BASEBACKUP-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#BASEBACKUP-PROGRESS-REPORTING)

<sup>16</sup> [www.hs.net/lightdb/docs/current/progress-reporting.html#COPY-PROGRESS-REPORTING](http://www.hs.net/lightdb/docs/current/progress-reporting.html#COPY-PROGRESS-REPORTING)

---

# Itsql

Itsql — LightDB interactive terminal

## Synopsis

```
ltsql [option...] [dbname [username]]
```

## Description

Itsql is a terminal-based front-end to LightDB. It enables you to type in queries interactively, issue them to LightDB, and see the query results. Alternatively, input can be from a file or from command line arguments. In addition, Itsql provides a number of meta-commands and various shell-like features to facilitate writing scripts and automating a wide variety of tasks.

## Options

```
-a  
--echo-all
```

Print all nonempty input lines to standard output as they are read. (This does not apply to lines read interactively.) This is equivalent to setting the variable `ECHO` to `all`.

```
-A  
--no-align
```

Switches to unaligned output mode. (The default output mode is `aligned`.) This is equivalent to `\pset format unaligned`.

```
-b  
--echo-errors
```

Print failed SQL commands to standard error output. This is equivalent to setting the variable `ECHO` to `errors`.

```
-c command  
--command=command
```

Specifies that Itsql is to execute the given command string, *command*. This option can be repeated and combined in any order with the `-f` option. When either `-c` or `-f` is specified, Itsql does not read commands from standard input; instead it terminates after processing all the `-c` and `-f` options in sequence.

*command* must be either a command string that is completely parsable by the server (i.e., it contains no Itsql-specific features), or a single backslash command. Thus you cannot mix SQL and Itsql meta-commands within a `-c` option. To achieve that, you could use repeated `-c` options or pipe the string into Itsql, for example:

```
ltsql -c '\x' -c 'SELECT * FROM foo;'
```

or

```
echo '\x \ SELECT * FROM foo;' | ltsql
```

(`\` is the separator meta-command.)

Each SQL command string passed to `-c` is sent to the server as a single request. Because of this, the server executes it as a single transaction even if the string contains multiple SQL commands, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. (See Section 49.2.2.1 for more details about how the server handles multi-query strings.) Also, `Itsql` only prints the result of the last SQL command in the string. This is different from the behavior when the same string is read from a file or fed to `Itsql`'s standard input, because then `Itsql` sends each SQL command separately.

Because of this behavior, putting more than one SQL command in a single `-c` string often has unexpected results. It's better to use repeated `-c` commands or feed multiple commands to `Itsql`'s standard input, either using `echo` as illustrated above, or via a shell here-document, for example:

```
ltsql <<EOF
\x
SELECT * FROM foo;
EOF
```

`--csv`

Switches to CSV (Comma-Separated Values) output mode. This is equivalent to `\pset format csv`.

`-d dbname`

`--dbname=dbname`

Specifies the name of the database to connect to. This is equivalent to specifying `dbname` as the first non-option argument on the command line. The `dbname` can be a connection string. If so, connection string parameters will override any conflicting command line options.

`-e`

`--echo-queries`

Copy all SQL commands sent to the server to standard output as well. This is equivalent to setting the variable `ECHO` to `queries`.

`-E`

`--echo-hidden`

Echo the actual queries generated by `\d` and other backslash commands. You can use this to study `Itsql`'s internal operations. This is equivalent to setting the variable `ECHO_HIDDEN` to `on`.

`-f filename`

`--file=filename`

Read commands from the file `filename`, rather than standard input. This option can be repeated and combined in any order with the `-c` option. When either `-c` or `-f` is specified, `Itsql` does not read commands from standard input; instead it terminates after processing all the `-c` and `-f` options in sequence. Except for that, this option is largely equivalent to the meta-command `\i`.

If `filename` is `-` (hyphen), then standard input is read until an EOF indication or `\q` meta-command. This can be used to intersperse interactive input with input from files. Note however that `Readline` is not used in this case (much as if `-n` had been specified).

Using this option is subtly different from writing `ltsql < filename`. In general, both will do what you expect, but using `-f` enables some nice features such as error messages with line numbers. There is also a slight chance that using this option will reduce the start-up overhead. On the other hand, the variant using the shell's input redirection is (in theory) guaranteed to yield exactly the same output you would have received had you entered everything by hand.

`-F separator`  
`--field-separator=separator`

Use *separator* as the field separator for unaligned output. This is equivalent to `\pset fieldsep` or `\f`.

`-h hostname`  
`--host=hostname`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

`-H`  
`--html`

Switches to HTML output mode. This is equivalent to `\pset format html` or the `\H` command.

`-l`  
`--list`

List all available databases, then exit. Other non-connection options are ignored. This is similar to the meta-command `\list`.

When this option is used, `itsql` will connect to the database `postgres`, unless a different database is named on the command line (option `-d` or non-option argument, possibly via a service entry, but not via an environment variable).

`-L filename`  
`--log-file=filename`

Write all query output into file *filename*, in addition to the normal output destination.

`-n`  
`--no-readline`

Do not use Readline for line editing and do not use the command history. This can be useful to turn off tab expansion when cutting and pasting.

`-o filename`  
`--output=filename`

Put all query output into file *filename*. This is equivalent to the command `\o`.

`-p port`  
`--port=port`

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the `LTPORT` environment variable or, if not set, to the port specified at compile time, usually 5432.

`-P assignment`  
`--pset=assignment`

Specifies printing options, in the style of `\pset`. Note that here you have to separate name and value with an equal sign instead of a space. For example, to set the output format to LaTeX, you could write `-P format=latex`.

`-q`  
`--quiet`

Specifies that `itsql` should do its work quietly. By default, it prints welcome messages and various informational output. If this option is used, none of this happens. This is useful with the `-c` option. This is equivalent to setting the variable `QUIET` to `on`.

-R *separator*  
 --record-separator=*separator*

Use *separator* as the record separator for unaligned output. This is equivalent to `\pset recordsep`.

-s  
 --single-step

Run in single-step mode. That means the user is prompted before each command is sent to the server, with the option to cancel execution as well. Use this to debug scripts.

-S  
 --single-line

Runs in single-line mode where a newline terminates an SQL command, as a semicolon does.

**Note**

This mode is provided for those who insist on it, but you are not necessarily encouraged to use it. In particular, if you mix SQL and meta-commands on a line the order of execution might not always be clear to the inexperienced user.

-t  
 --tuples-only

Turn off printing of column names and result row count footers, etc. This is equivalent to `\t` or `\pset tuples_only`.

-T *table\_options*  
 --table-attr=*table\_options*

Specifies options to be placed within the HTML `table` tag. See `\pset tableattr` for details.

-U *username*  
 --username=*username*

Connect to the database as the user *username* instead of the default. (You must have permission to do so, of course.)

-v *assignment*  
 --set=*assignment*  
 --variable=*assignment*

Perform a variable assignment, like the `\set` meta-command. Note that you must separate name and value, if any, by an equal sign on the command line. To unset a variable, leave off the equal sign. To set a variable with an empty value, use the equal sign but leave off the value. These assignments are done during command line processing, so variables that reflect connection state will get overwritten later.

-V  
 --version

Print the Itsql version and exit.

-w  
 --no-password

Never issue a password prompt. If the server requires password authentication and a password is not available from other sources such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-W`  
`--password`

Force ltsql to prompt for a password before connecting to a database, even if the password will not be used.

If the server requires password authentication and a password is not available from other sources such as a `.pgpass` file, ltsql will prompt for a password in any case. However, ltsql will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-x`  
`--expanded`

Turn on the expanded table formatting mode. This is equivalent to `\x` or `\pset expanded`.

`-X,`  
`--no-ltsqlrc`

Do not read the start-up file (neither the system-wide `ltsqlrc` file nor the user's `~/.ltsqlrc` file).

`-z`  
`--field-separator-zero`

Set the field separator for unaligned output to a zero byte. This is equivalent to `\pset fieldsep_zero`.

`-0`  
`--record-separator-zero`

Set the record separator for unaligned output to a zero byte. This is useful for interfacing, for example, with `xargs -0`. This is equivalent to `\pset recordsep_zero`.

`-1`  
`--single-transaction`

This option can only be used in combination with one or more `-c` and/or `-f` options. It causes ltsql to issue a `BEGIN` command before the first such option and a `COMMIT` command after the last one, thereby wrapping all the commands into a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.

If the commands themselves contain `BEGIN`, `COMMIT`, or `ROLLBACK`, this option will not have the desired effects. Also, if an individual command cannot be executed inside a transaction block, specifying this option will cause the whole transaction to fail.

`-?`  
`--help[=topic]`

Show help about ltsql and exit. The optional `topic` parameter (defaulting to `options`) selects which part of ltsql is explained: `commands` describes ltsql's backslash commands; `options` describes the command-line options that can be passed to ltsql; and `variables` shows help about ltsql configuration variables.

## Exit Status

ltsql returns 0 to the shell if it finished normally, 1 if a fatal error of its own occurs (e.g., out of memory, file not found), 2 if the connection to the server went bad and the session was not interactive, and 3 if an error occurred in a script and the variable `ON_ERROR_STOP` was set.

## Usage

### Connecting to a Database

ltsql is a regular LightDB client application. In order to connect to a database you need to know the name of your target database, the host name and port number of the server, and what user name you want to connect as. ltsql can be told about those parameters via command line options, namely `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option it will be interpreted as the database name (or the user name, if the database name is already given). Not all of these options are required; there are useful defaults. If you omit the host name, ltsql will connect via a Unix-domain socket to a server on the local host, or via TCP/IP to `localhost` on machines that don't have Unix-domain sockets. The default port number is determined at compile time. Since the database server uses the same default, you will not have to specify the port in most cases. The default user name is your operating-system user name, as is the default database name. Note that you cannot just connect to any database under any user name. Your database administrator should have informed you about your access rights.

When the defaults aren't quite right, you can save yourself some typing by setting the environment variables `LTDATABASE`, `LTHOST`, `LTPORT` and/or `LTUSER` to appropriate values. (For additional environment variables, see Section 32.14.) It is also convenient to have a `~/ .pgpass` file to avoid regularly having to type in passwords. See Section 32.15 for more information.

An alternative way to specify connection parameters is in a `conninfo` string or a URI, which is used instead of a database name. This mechanism give you very wide control over the connection. For example:

```
$ ltsql "service=myservice sslmode=require"
$ ltsql postgresql://dbmaster:5433/mydb?sslmode=require
```

This way you can also use LDAP for connection parameter lookup as described in Section 32.17. See Section 32.1.2 for more information on all the available connection options.

If the connection could not be made for any reason (e.g., insufficient privileges, server is not running on the targeted host, etc.), ltsql will return an error and terminate.

If both standard input and standard output are a terminal, then ltsql sets the client encoding to "auto", which will detect the appropriate client encoding from the locale settings (`LC_CTYPE` environment variable on Unix systems). If this doesn't work out as expected, the client encoding can be overridden using the environment variable `LTCLIENTENCODING`.

## Entering SQL Commands

In normal operation, ltsql provides a prompt with the name of the database to which ltsql is currently connected, followed by the string `=>`. For example:

```
$ ltsql test
ltsql (13.8-23.4)
compatible type: postgresql
Type "help" for help.
```



```
test=>
```

At the prompt, the user can type in SQL commands. Ordinarily, input lines are sent to the server when a command-terminating semicolon is reached. An end of line does not terminate a command. Thus commands can be spread over several lines for clarity. If the command was sent and executed without error, the results of the command are displayed on the screen.

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin your session by removing publicly-writable schemas from `search_path`. One can add `options=-csearch_path=` to the connection string or issue `SELECT pg_catalog.set_config('search_path', '', false)` before other SQL commands. This consideration is not specific to ltsql; it applies to every interface for executing arbitrary SQL commands.

Whenever a command is executed, ltsql also polls for asynchronous notification events generated by `LISTEN` and `NOTIFY`.

While C-style block comments are passed to the server for processing and removal, SQL-standard comments are removed by ltsql.

## prompt command

The prompt command print the prompt text to standard output, that can be useful to intersperse information in the output of scripts, that be used by the way of ltsql `-f filename`, as well as that can be used in ltsql's interactive mode. The prompt command is case-insensitive and allows spaces, tabs and blank lines in front of the command. For example:

```
lightdb@postgres=# prompt create table start
create table start
lightdb@postgres=# create table test(id int);
CREATE TABLE
lightdb@postgres=# Prompt select start
select start
lightdb@postgres=# select count(*) from test;
 count
-----
      0
(1 row)
```

## spool command

The spool command derives from sqlplus tool of oracle. It could redirect the output of sqlplus to a specified file under interactive mode. This case-insensitive instruction would associate the path of file or with keyword 'off' to redirect back to the standard output. It ignores any redundant blanks inside itself but should be noticed that it would stop when met a semicolon or line break. For example:

```
lightdb@postgres=# spool test_spool.log;
lightdb@postgres=# create table spool1(spool int);
lightdb@postgres=# insert into spool1 values(5);
lightdb@postgres=# select * from spool1;
lightdb@postgres=# spool off;
-- check if test_spool.log has records
lightdb@postgres=# \! cat test_spool.log
 spool
-----
      5
```

```
(1 row)

lightdb@postgres=# select * from spool1;
 spool
-----
      5
(1 row)

lightdb@postgres=# spool;
lightdb@postgres=# select * from spool1;
 spool
-----
      5
(1 row)
```

## rename command

The rename command derives from sqlplus tool of oracle. It could rename a table or view which given by parameter "old\_table" and "new\_table" under interactive mode. This case-insensitive instruction would ignores any redundant blanks inside itself but stopped when met a semicolon or line break. So users couldn't use that across multi-lines. For example:

```
lightdb@test_mysql_select=# rename table_oldname to table_newname;
ALTER TABLE
```

## Meta-Commands

Anything you enter in ltsql that begins with an unquoted backslash is a ltsql meta-command that is processed by ltsql itself. These commands make ltsql more useful for administration or scripting. Meta-commands are often called slash or backslash commands.

The format of a ltsql command is the backslash, followed immediately by a command verb, then any arguments. The arguments are separated from the command verb and each other by any number of whitespace characters.

To include whitespace in an argument you can quote it with single quotes. To include a single quote in an argument, write two single quotes within single-quoted text. Anything contained in single quotes is furthermore subject to C-like substitutions for `\n` (new line), `\t` (tab), `\b` (backspace), `\r` (carriage return), `\f` (form feed), `\digits` (octal), and `\xdigits` (hexadecimal). A backslash preceding any other character within single-quoted text quotes that single character, whatever it is.

If an unquoted colon (`:`) followed by a ltsql variable name appears within an argument, it is replaced by the variable's value, as described in SQL Interpolation below. The forms `:'variable_name'` and `:"variable_name"` described there work as well. The `:{?variable_name}` syntax allows testing whether a variable is defined. It is substituted by TRUE or FALSE. Escaping the colon with a backslash protects it from substitution.

Within an argument, text that is enclosed in backquotes (```) is taken as a command line that is passed to the shell. The output of the command (with any trailing newline removed) replaces the backquoted text. Within the text enclosed in backquotes, no special quoting or other processing occurs, except that appearances of `:variable_name` where `variable_name` is a ltsql variable name are replaced by the variable's value. Also, appearances of `:'variable_name'` are replaced by the variable's value suitably quoted to become a single shell command argument. (The latter form is almost always preferable, unless you are very sure of what is in the variable.) Because carriage return and line feed characters cannot be safely quoted on all platforms, the `:'variable_name'` form prints an error message and does not substitute the variable value when such characters appear in the value.

Some commands take an SQL identifier (such as a table name) as argument. These arguments follow the syntax rules of SQL: Unquoted letters are forced to lowercase, while double quotes (") protect letters from case conversion and allow incorporation of whitespace into the identifier. Within double quotes, paired double quotes reduce to a single double quote in the resulting name. For example, FOO"BAR"BAZ is interpreted as foobarbaz, and "A weird" name becomes A weird name.

Parsing for arguments stops at the end of the line, or when another unquoted backslash is found. An unquoted backslash is taken as the beginning of a new meta-command. The special sequence \\ (two backslashes) marks the end of arguments and continues parsing SQL commands, if any. That way SQL and Itsql commands can be freely mixed on a line. But in any case, the arguments of a meta-command cannot continue beyond the end of the line.

Many of the meta-commands act on the *current query buffer*. This is simply a buffer holding whatever SQL command text has been typed but not yet sent to the server for execution. This will include previous input lines as well as any text appearing before the meta-command on the same line.

The following meta-commands are defined:

`\a`

If the current table output format is unaligned, it is switched to aligned. If it is not unaligned, it is set to unaligned. This command is kept for backwards compatibility. See `\pset` for a more general solution.

`\c` or `\connect` [ `-reuse-previous=on/off` ] [ *dbname* [ *username* ] [ *host* ] [ *port* ] | *conninfo* ]

Establishes a new connection to a LightDB server. The connection parameters to use can be specified either using a positional syntax (one or more of database name, user, host, and port), or using a *conninfo* connection string as detailed in Section 32.1.1. If no arguments are given, a new connection is made using the same parameters as before.

Specifying any of *dbname*, *username*, *host* or *port* as - is equivalent to omitting that parameter.

The new connection can re-use connection parameters from the previous connection; not only database name, user, host, and port, but other settings such as *sslmode*. By default, parameters are re-used in the positional syntax, but not when a *conninfo* string is given. Passing a first argument of `-reuse-previous=on` or `-reuse-previous=off` overrides that default. If parameters are re-used, then any parameter not explicitly specified as a positional parameter or in the *conninfo* string is taken from the existing connection's parameters. An exception is that if the *host* setting is changed from its previous value using the positional syntax, any *hostaddr* setting present in the existing connection's parameters is dropped. Also, any password used for the existing connection will be re-used only if the user, host, and port settings are not changed. When the command neither specifies nor reuses a particular parameter, the libpq default is used.

If the new connection is successfully made, the previous connection is closed. If the connection attempt fails (wrong user name, access denied, etc.), the previous connection will be kept if Itsql is in interactive mode. But when executing a non-interactive script, processing will immediately stop with an error. This distinction was chosen as a user convenience against typos on the one hand, and a safety mechanism that scripts are not accidentally acting on the wrong database on the other hand.

Examples:

```
=> \c mydb myuser host.dom 6432
=> \c service=foo
```

```
=> \c "host=localhost port=5432 dbname=mydb connect_timeout=10
    sslmode=disable"
=> \c -reuse-previous=on sslmode=require      -- changes only
    sslmode
=> \c postgresql://tom@localhost/mydb?application_name=myapp
```

`\C [ title ]`

Sets the title of any tables being printed as the result of a query or unset any such title. This command is equivalent to `\pset title title`. (The name of this command derives from “caption”, as it was previously only used to set the caption in an HTML table.)

`\cd [ directory ]`

Changes the current working directory to *directory*. Without argument, changes to the current user's home directory.

**Tip**

To print your current working directory, use `\! pwd`.

`\conninfo`

Outputs information about the current database connection.

```
\copy { table [ ( column_list ) ] } from { 'filename' | program
'command' | stdin | pstdin } [ [ with ] ( option [, ...] ) ] [ where
condition ]
\copy { table [ ( column_list ) ] | ( query ) } to { 'filename' |
program 'command' | stdout | pstdout } [ [ with ] ( option [, ...] ) ]
```

Performs a frontend (client) copy. This is an operation that runs an SQL COPY command, but instead of the server reading or writing the specified file, ltsql reads or writes the file and routes the data between the server and the local file system. This means that file accessibility and privileges are those of the local user, not the server, and no SQL superuser privileges are required.

When `program` is specified, `command` is executed by ltsql and the data passed from or to `command` is routed between the server and the client. Again, the execution privileges are those of the local user, not the server, and no SQL superuser privileges are required.

For `\copy ... from stdin`, data rows are read from the same source that issued the command, continuing until `\.` is read or the stream reaches EOF. This option is useful for populating tables in-line within a SQL script file. For `\copy ... to stdout`, output is sent to the same place as ltsql command output, and the COPY `count` command status is not printed (since it might be confused with a data row). To read/write ltsql's standard input or output regardless of the current command source or `\o` option, write `from pstdin` or `to pstdout`.

The syntax of this command is similar to that of the SQL COPY command. All options other than the data source/destination are as specified for COPY. Because of this, special parsing rules apply to the `\copy` meta-command. Unlike most other meta-commands, the entire remainder of the line is always taken to be the arguments of `\copy`, and neither variable interpolation nor backquote expansion are performed in the arguments.

**Tip**

Another way to obtain the same result as `\copy ... to` is to use the SQL COPY `... TO STDOUT` command and terminate it with `\g filename` or `\g`

| *program*. Unlike `\copy`, this method allows the command to span multiple lines; also, variable interpolation and backquote expansion can be used.

### Tip

These operations are not as efficient as the SQL `COPY` command with a file or program data source or destination, because all data must pass through the client/server connection. For large amounts of data the SQL command might be preferable.

`\copyright`

Shows the copyright and distribution terms of LightDB.

`\crosstabview [ colV [ colH [ colD [ sortcolH ] ] ] ]`

Executes the current query buffer (like `\g`) and shows the results in a crosstab grid. The query must return at least three columns. The output column identified by `colV` becomes a vertical header and the output column identified by `colH` becomes a horizontal header. `colD` identifies the output column to display within the grid. `sortcolH` identifies an optional sort column for the horizontal header.

Each column specification can be a column number (starting at 1) or a column name. The usual SQL case folding and quoting rules apply to column names. If omitted, `colV` is taken as column 1 and `colH` as column 2. `colH` must differ from `colV`. If `colD` is not specified, then there must be exactly three columns in the query result, and the column that is neither `colV` nor `colH` is taken to be `colD`.

The vertical header, displayed as the leftmost column, contains the values found in column `colV`, in the same order as in the query results, but with duplicates removed.

The horizontal header, displayed as the first row, contains the values found in column `colH`, with duplicates removed. By default, these appear in the same order as in the query results. But if the optional `sortcolH` argument is given, it identifies a column whose values must be integer numbers, and the values from `colH` will appear in the horizontal header sorted according to the corresponding `sortcolH` values.

Inside the crosstab grid, for each distinct value `x` of `colH` and each distinct value `y` of `colV`, the cell located at the intersection `(x, y)` contains the value of the `colD` column in the query result row for which the value of `colH` is `x` and the value of `colV` is `y`. If there is no such row, the cell is empty. If there are multiple such rows, an error is reported.

`\d[S+] [ pattern ]`

For each relation (table, view, materialized view, index, sequence, or foreign table) or composite type matching the `pattern`, show all columns, their types, the tablespace (if not the default) and any special attributes such as NOT NULL or defaults. Associated indexes, constraints, rules, and triggers are also shown. For foreign tables, the associated foreign server is shown as well. (“Matching the pattern” is defined in Patterns below.)

For some types of relation, `\d` shows additional information for each column: column values for sequences, indexed expressions for indexes, and foreign data wrapper options for foreign tables.

The command form `\d+` is identical, except that more information is displayed: any comments associated with the columns of the table are shown, as is the presence of OIDs in the table, the view definition if the relation is a view, a non-default replica identity setting.

By default, only user-created objects are shown; supply a pattern or the S modifier to include system objects.

**Note**

If \d is used without a *pattern* argument, it is equivalent to \dtvmsE which will show a list of all visible tables, views, materialized views, sequences and foreign tables. This is purely a convenience measure.

\da[S] [ *pattern* ]

Lists aggregate functions, together with their return type and the data types they operate on. If *pattern* is specified, only aggregates whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the S modifier to include system objects.

\dA[+] [ *pattern* ]

Lists access methods. If *pattern* is specified, only access methods whose names match the pattern are shown. If + is appended to the command name, each access method is listed with its associated handler function and description.

\dAc[+] [ *access-method-pattern* [ *input-type-pattern* ] ]

Lists operator classes (see Section 36.16.1). If *access-method-pattern* is specified, only operator classes associated with access methods whose names match that pattern are listed. If *input-type-pattern* is specified, only operator classes associated with input types whose names match that pattern are listed. If + is appended to the command name, each operator class is listed with its associated operator family and owner.

\dAf[+] [ *access-method-pattern* [ *input-type-pattern* ] ]

Lists operator families (see Section 36.16.5). If *access-method-pattern* is specified, only operator families associated with access methods whose names match that pattern are listed. If *input-type-pattern* is specified, only operator families associated with input types whose names match that pattern are listed. If + is appended to the command name, each operator family is listed with its owner.

\dAo[+] [ *access-method-pattern* [ *operator-family-pattern* ] ]

Lists operators associated with operator families (see Section 36.16.2). If *access-method-pattern* is specified, only members of operator families associated with access methods whose names match that pattern are listed. If *operator-family-pattern* is specified, only members of operator families whose names match that pattern are listed. If + is appended to the command name, each operator is listed with its sort operator family (if it is an ordering operator).

\dAp[+] [ *access-method-pattern* [ *operator-family-pattern* ] ]

Lists support functions associated with operator families (see Section 36.16.3). If *access-method-pattern* is specified, only functions of operator families associated with access methods whose names match that pattern are listed. If *operator-family-pattern* is specified, only functions of operator families whose names match that pattern are listed. If + is appended to the command name, functions are displayed verbosely, with their actual parameter lists.

\db[+] [ *pattern* ]

Lists tablespaces. If *pattern* is specified, only tablespaces whose names match the pattern are shown. If + is appended to the command name, each tablespace is listed with its associated options, on-disk size, permissions and description.

`\dc[S+] [ pattern ]`

Lists conversions between character-set encodings. If *pattern* is specified, only conversions whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If *+* is appended to the command name, each object is listed with its associated description.

`\dC[+] [ pattern ]`

Lists type casts. If *pattern* is specified, only casts whose source or target types match the pattern are listed. If *+* is appended to the command name, each object is listed with its associated description.

`\dd[S] [ pattern ]`

Shows the descriptions of objects of type `constraint`, `operator class`, `operator family`, `rule`, and `trigger`. All other comments may be viewed by the respective backslash commands for those object types.

`\dd` displays descriptions for objects matching the *pattern*, or of visible objects of the appropriate type if no argument is given. But in either case, only objects that have a description are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

Descriptions for objects can be created with the `COMMENT SQL` command.

`\dD[S+] [ pattern ]`

Lists domains. If *pattern* is specified, only domains whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If *+* is appended to the command name, each object is listed with its associated permissions and description.

`\ddp [ pattern ]`

Lists default access privilege settings. An entry is shown for each role (and schema, if applicable) for which the default privilege settings have been changed from the built-in defaults. If *pattern* is specified, only entries whose role name or schema name matches the pattern are listed.

The `ALTER DEFAULT PRIVILEGES` command is used to set default access privileges. The meaning of the privilege display is explained in Section 5.7.

`\dE[S+] [ pattern ]`

`\di[S+] [ pattern ]`

`\dm[S+] [ pattern ]`

`\ds[S+] [ pattern ]`

`\dt[S+] [ pattern ]`

`\dv[S+] [ pattern ]`

In this group of commands, the letters *E*, *i*, *m*, *s*, *t*, and *v* stand for foreign table, index, materialized view, sequence, table, and view, respectively. You can specify any or all of these letters, in any order, to obtain a listing of objects of these types. For example, `\dti` lists tables and indexes. If *+* is appended to the command name, each object is listed with its persistence status (permanent, temporary, or unlogged), physical size on disk, and associated description if any. If *pattern* is specified, only objects whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

`\des[+] [ pattern ]`

Lists foreign servers (mnemonic: “external servers”). If *pattern* is specified, only those servers whose name matches the pattern are listed. If the form `\des+` is used, a full description of each server is shown, including the server’s access privileges, type, version, options, and description.

`\det[+] [ pattern ]`

Lists foreign tables (mnemonic: “external tables”). If *pattern* is specified, only entries whose table name or schema name matches the pattern are listed. If the form `\det+` is used, generic options and the foreign table description are also displayed.

`\deu[+] [ pattern ]`

Lists user mappings (mnemonic: “external users”). If *pattern* is specified, only those mappings whose user names match the pattern are listed. If the form `\deu+` is used, additional information about each mapping is shown.

**Caution**

`\deu+` might also display the user name and password of the remote user, so care should be taken not to disclose them.

`\dew[+] [ pattern ]`

Lists foreign-data wrappers (mnemonic: “external wrappers”). If *pattern* is specified, only those foreign-data wrappers whose name matches the pattern are listed. If the form `\dew+` is used, the access privileges, options, and description of the foreign-data wrapper are also shown.

`\df[anptwS+] [ pattern ]`

Lists functions, together with their result data types, argument data types, and function types, which are classified as “agg” (aggregate), “normal”, “procedure”, “trigger”, or “window”. To display only functions of specific type(s), add the corresponding letters a, n, p, t, or w to the command. If *pattern* is specified, only functions whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the S modifier to include system objects. If the form `\df+` is used, additional information about each function is shown, including volatility, parallel safety, owner, security classification, access privileges, language, source code and description.

**Tip**

To look up functions taking arguments or returning values of a specific data type, use your pager's search capability to scroll through the `\df` output.

`\dF[+] [ pattern ]`

Lists text search configurations. If *pattern* is specified, only configurations whose names match the pattern are shown. If the form `\dF+` is used, a full description of each configuration is shown, including the underlying text search parser and the dictionary list for each parser token type.

`\dFd[+] [ pattern ]`

Lists text search dictionaries. If *pattern* is specified, only dictionaries whose names match the pattern are shown. If the form `\dFd+` is used, additional information is shown about each selected dictionary, including the underlying text search template and the option values.

`\dFp[+] [ pattern ]`

Lists text search parsers. If *pattern* is specified, only parsers whose names match the pattern are shown. If the form `\dFp+` is used, a full description of each parser is shown, including the underlying functions and the list of recognized token types.



`\dFt[+] [ pattern ]`

Lists text search templates. If *pattern* is specified, only templates whose names match the pattern are shown. If the form `\dFt+` is used, additional information is shown about each template, including the underlying function names.

`\dg[S+] [ pattern ]`

Lists database roles. (Since the concepts of “users” and “groups” have been unified into “roles”, this command is now equivalent to `\du`.) By default, only user-created roles are shown; supply the *S* modifier to include system roles. If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\dg+` is used, additional information is shown about each role; currently this adds the comment for each role.

`\dl`

This is an alias for `\lo_list`, which shows a list of large objects.

`\dL[S+] [ pattern ]`

Lists procedural languages. If *pattern* is specified, only languages whose names match the pattern are listed. By default, only user-created languages are shown; supply the *S* modifier to include system objects. If `+` is appended to the command name, each language is listed with its call handler, validator, access privileges, and whether it is a system object.

`\dn[S+] [ pattern ]`

Lists schemas (namespaces). If *pattern* is specified, only schemas whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated permissions and description, if any.

`\do[S+] [ pattern ]`

Lists operators with their operand and result types. If *pattern* is specified, only operators whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, additional information about each operator is shown, currently just the name of the underlying function.

`\dO[S+] [ pattern ]`

Lists collations. If *pattern* is specified, only collations whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, each collation is listed with its associated description, if any. Note that only collations usable with the current database's encoding are shown, so the results may vary in different databases of the same installation.

`\dp [ pattern ]`

Lists tables, views and sequences with their associated access privileges. If *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

The `GRANT` and `REVOKE` commands are used to set access privileges. The meaning of the privilege display is explained in Section 5.7.

`\dP[itn+] [ pattern ]`

Lists partitioned relations. If *pattern* is specified, only entries whose name matches the pattern are listed. The modifiers `t` (tables) and `i` (indexes) can be appended to the command, filtering the kind of relations to list. By default, partitioned tables and indexes are listed.

If the modifier *n* (“nested”) is used, or a pattern is specified, then non-root partitioned relations are included, and a column is shown displaying the parent of each partitioned relation.

If *+* is appended to the command name, the sum of the sizes of each relation's partitions is also displayed, along with the relation's description. If *n* is combined with *+*, two sizes are shown: one including the total size of directly-attached leaf partitions, and another showing the total size of all partitions, including indirectly attached sub-partitions.

`\drds [ role-pattern [ database-pattern ] ]`

Lists defined configuration settings. These settings can be role-specific, database-specific, or both. *role-pattern* and *database-pattern* are used to select specific roles and databases to list, respectively. If omitted, or if *\** is specified, all settings are listed, including those not role-specific or database-specific, respectively.

The ALTER ROLE and ALTER DATABASE commands are used to define per-role and per-database configuration settings.

`\drp[+] [ pattern ]`

Lists replication publications. If *pattern* is specified, only those publications whose names match the pattern are listed. If *+* is appended to the command name, the tables associated with each publication are shown as well.

`\dRs[+] [ pattern ]`

Lists replication subscriptions. If *pattern* is specified, only those subscriptions whose names match the pattern are listed. If *+* is appended to the command name, additional properties of the subscriptions are shown.

`\dT[S+] [ pattern ]`

Lists data types. If *pattern* is specified, only types whose names match the pattern are listed. If *+* is appended to the command name, each type is listed with its internal name and size, its allowed values if it is an enum type, and its associated permissions. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

`\du[S+] [ pattern ]`

Lists database roles. (Since the concepts of “users” and “groups” have been unified into “roles”, this command is now equivalent to `\dG`.) By default, only user-created roles are shown; supply the *S* modifier to include system roles. If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\du+` is used, additional information is shown about each role; currently this adds the comment for each role.

`\dx[+] [ pattern ]`

Lists installed extensions. If *pattern* is specified, only those extensions whose names match the pattern are listed. If the form `\dx+` is used, all the objects belonging to each matching extension are listed.

`\dy[+] [ pattern ]`

Lists event triggers. If *pattern* is specified, only those event triggers whose names match the pattern are listed. If *+* is appended to the command name, each object is listed with its associated description.

`\e or \edit [ filename ] [ line_number ]`

If *filename* is specified, the file is edited; after the editor exits, the file's content is copied into the current query buffer. If no *filename* is given, the current query buffer is copied to a

temporary file which is then edited in the same fashion. Or, if the current query buffer is empty, the most recently executed query is copied to a temporary file and edited in the same fashion.

The new contents of the query buffer are then re-parsed according to the normal rules of Itsql, treating the whole buffer as a single line. Any complete queries are immediately executed; that is, if the query buffer contains or ends with a semicolon, everything up to that point is executed and removed from the query buffer. Whatever remains in the query buffer is redisplayed. Type semicolon or `\g` to send it, or `\r` to cancel it by clearing the query buffer.

Treating the buffer as a single line primarily affects meta-commands: whatever is in the buffer after a meta-command will be taken as argument(s) to the meta-command, even if it spans multiple lines. (Thus you cannot make meta-command-using scripts this way. Use `\i` for that.)

If a line number is specified, Itsql will position the cursor on the specified line of the file or query buffer. Note that if a single all-digits argument is given, Itsql assumes it is a line number, not a file name.

**Tip**

See Environment, below, for how to configure and customize your editor.

`\echo text [ ... ]`

Prints the evaluated arguments to standard output, separated by spaces and followed by a newline. This can be useful to intersperse information in the output of scripts. For example:

```
=> \echo `date`
Tue Oct 26 21:40:57 CEST 1999
```

If the first argument is an unquoted `-n` the trailing newline is not written (nor is the first argument).

**Tip**

If you use the `\o` command to redirect your query output you might wish to use `\qecho` instead of this command. See also `\warn`.

`\ef [ function_description [ line_number ] ]`

This command fetches and edits the definition of the named function or procedure, in the form of a `CREATE OR REPLACE FUNCTION` or `CREATE OR REPLACE PROCEDURE` command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command is executed immediately if you added a semicolon to it. Otherwise it is redisplayed; type semicolon or `\g` to send it, or `\r` to cancel.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If no function is specified, a blank `CREATE FUNCTION` template is presented for editing.

If a line number is specified, Itsql will position the cursor on the specified line of the function body. (Note that the function body typically does not begin on the first line of the file.)

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\ef`, and neither variable interpolation nor backquote expansion are performed in the arguments.

**Tip**

See Environment, below, for how to configure and customize your editor.

`\encoding [ encoding ]`

Sets the client character set encoding. Without an argument, this command shows the current encoding.

`\errverbose`

Repeats the most recent server error message at maximum verbosity, as though VERBOSITY were set to verbose and SHOW\_CONTEXT were set to always.

`\ev [ view_name [ line_number ] ]`

This command fetches and edits the definition of the named view, in the form of a CREATE OR REPLACE VIEW command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command is executed immediately if you added a semicolon to it. Otherwise it is redisplayed; type semicolon or `\g` to send it, or `\r` to cancel.

If no view is specified, a blank CREATE VIEW template is presented for editing.

If a line number is specified, Itsql will position the cursor on the specified line of the view definition.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\ev`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\f [ string ]`

Sets the field separator for unaligned query output. The default is the vertical bar (|). It is equivalent to `\pset fieldsep`.

`\g [ (option=value [...]) ] [ filename ]`

`\g [ (option=value [...]) ] [ |command ]`

Sends the current query buffer to the server for execution.

If parentheses appear after `\g`, they surround a space-separated list of *option=value* formatting-option clauses, which are interpreted in the same way as `\pset option value` commands, but take effect only for the duration of this query. In this list, spaces are not allowed around = signs, but are required between option clauses. If *=value* is omitted, the named *option* is changed in the same way as for `\pset option` with no explicit *value*.

If a *filename* or *|command* argument is given, the query's output is written to the named file or piped to the given shell command, instead of displaying it as usual. The file or command is written to only if the query successfully returns zero or more tuples, not if the query fails or is a non-data-returning SQL command.

If the current query buffer is empty, the most recently sent query is re-executed instead. Except for that behavior, `\g` without any arguments is essentially equivalent to a semicolon. With arguments, `\g` provides a “one-shot” alternative to the `\o` command, and additionally allows one-shot adjustments of the output formatting options normally set by `\pset`.

When the last argument begins with |, the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

**\gdesc**

Shows the description (that is, the column names and data types) of the result of the current query buffer. The query is not actually executed; however, if it contains some type of syntax error, that error will be reported in the normal way.

If the current query buffer is empty, the most recently sent query is described instead.

**\gexec**

Sends the current query buffer to the server, then treats each column of each row of the query's output (if any) as a SQL statement to be executed. For example, to create an index on each column of `my_table`:

```
=> SELECT format('create index on my_table(%I)', attname)
-> FROM pg_attribute
-> WHERE attrelid = 'my_table'::regclass AND attnum > 0
-> ORDER BY attnum
-> \gexec
CREATE INDEX
CREATE INDEX
CREATE INDEX
CREATE INDEX
```

The generated queries are executed in the order in which the rows are returned, and left-to-right within each row if there is more than one column. NULL fields are ignored. The generated queries are sent literally to the server for processing, so they cannot be ltsql meta-commands nor contain ltsql variable references. If any individual query fails, execution of the remaining queries continues unless `ON_ERROR_STOP` is set. Execution of each query is subject to `ECHO` processing. (Setting `ECHO` to `all` or `queries` is often advisable when using `\gexec`.) Query logging, single-step mode, timing, and other query execution features apply to each generated query as well.

If the current query buffer is empty, the most recently sent query is re-executed instead.

**\gset [ *prefix* ]**

Sends the current query buffer to the server and stores the query's output into ltsql variables (see Variables below). The query to be executed must return exactly one row. Each column of the row is stored into a separate variable, named the same as the column. For example:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset
=> \echo :var1 :var2
hello 10
```

If you specify a *prefix*, that string is prepended to the query's column names to create the variable names to use:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset result_
=> \echo :result_var1 :result_var2
hello 10
```

If a column result is NULL, the corresponding variable is unset rather than being set.

If the query fails or does not return one row, no variables are changed.

If the current query buffer is empty, the most recently sent query is re-executed instead.

```
\gx [ (option=value [...]) ] [ filename ]
\gx [ (option=value [...]) ] [ |command ]
```

\gx is equivalent to \g, except that it forces expanded output mode for this query, as if expanded=on were included in the list of \pset options. See also \x.

```
\h or \help [ command ]
```

Gives syntax help on the specified SQL command. If *command* is not specified, then ltsql will list all the commands for which syntax help is available. If *command* is an asterisk (\*), then syntax help on all SQL commands is shown.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of \help, and neither variable interpolation nor backquote expansion are performed in the arguments.

### Note

To simplify typing, commands that consists of several words do not have to be quoted. Thus it is fine to type `\help alter table`.

```
\H or \html
```

Turns on HTML query output format. If the HTML format is already on, it is switched back to the default aligned text format. This command is for compatibility and convenience, but see \pset about setting other output options.

```
\i or \include filename
```

Reads input from the file *filename* and executes it as though it had been typed on the keyboard.

If *filename* is - (hyphen), then standard input is read until an EOF indication or \q meta-command. This can be used to intersperse interactive input with input from files. Note that Readline behavior will be used only if it is active at the outermost level.

### Note

If you want to see the lines on the screen as they are read you must set the variable ECHO to all.

```
\if expression
\elif expression
\else
\endif
```

This group of commands implements nestable conditional blocks. A conditional block must begin with an \if and end with an \endif. In between there may be any number of \elif clauses, which may optionally be followed by a single \else clause. Ordinary queries and other types of backslash commands may (and usually do) appear between the commands forming a conditional block.

The \if and \elif commands read their argument(s) and evaluate them as a boolean expression. If the expression yields true then processing continues normally; otherwise, lines

are skipped until a matching `\elif`, `\else`, or `\endif` is reached. Once an `\if` or `\elif` test has succeeded, the arguments of later `\elif` commands in the same block are not evaluated but are treated as false. Lines following an `\else` are processed only if no earlier matching `\if` or `\elif` succeeded.

The *expression* argument of an `\if` or `\elif` command is subject to variable interpolation and backquote expansion, just like any other backslash command argument. After that it is evaluated like the value of an on/off option variable. So a valid value is any unambiguous case-insensitive match for one of: `true`, `false`, `1`, `0`, `on`, `off`, `yes`, `no`. For example, `t`, `T`, and `tR` will all be considered to be `true`.

Expressions that do not properly evaluate to true or false will generate a warning and be treated as false.

Lines being skipped are parsed normally to identify queries and backslash commands, but queries are not sent to the server, and backslash commands other than conditionals (`\if`, `\elif`, `\else`, `\endif`) are ignored. Conditional commands are checked only for valid nesting. Variable references in skipped lines are not expanded, and backquote expansion is not performed either.

All the backslash commands of a given conditional block must appear in the same source file. If EOF is reached on the main input file or an `\include`-ed file before all local `\if`-blocks have been closed, then ltsql will raise an error.

Here is an example:

```
-- check for the existence of two separate records in the
-- database and store
-- the results in separate ltsql variables
SELECT
    EXISTS(SELECT 1 FROM customer WHERE customer_id = 123) as
    is_customer,
    EXISTS(SELECT 1 FROM employee WHERE employee_id = 456) as
    is_employee
\gset
\if :is_customer
    SELECT * FROM customer WHERE customer_id = 123;
\elif :is_employee
    \echo 'is not a customer but is an employee'
    SELECT * FROM employee WHERE employee_id = 456;
\else
    \if yes
        \echo 'not a customer or employee'
    \else
        \echo 'this will never print'
    \endif
\endif
```

`\ir` or `\include_relative filename`

The `\ir` command is similar to `\i`, but resolves relative file names differently. When executing in interactive mode, the two commands behave identically. However, when invoked from a script, `\ir` interprets file names relative to the directory in which the script is located, rather than the current working directory.

`\l[+]` or `\list[+] [ pattern ]`

List the databases in the server and show their names, owners, character set encodings, and access privileges. If *pattern* is specified, only databases whose names match the pattern are listed. If

+ is appended to the command name, database sizes, default tablespaces, and descriptions are also displayed. (Size information is only available for databases that the current user can connect to.)

`\lo_export loid filename`

Reads the large object with OID *loid* from the database and writes it to *filename*. Note that this is subtly different from the server function `lo_export`, which acts with the permissions of the user that the database server runs as and on the server's file system.

**Tip**

Use `\lo_list` to find out the large object's OID.

`\lo_import filename [ comment ]`

Stores the file into a LightDB large object. Optionally, it associates the given comment with the object. Example:

```
foo=> \lo_import '/home/peter/pictures/photo.xcf' 'a picture of
me'
lo_import 152801
```

The response indicates that the large object received object ID 152801, which can be used to access the newly-created large object in the future. For the sake of readability, it is recommended to always associate a human-readable comment with every object. Both OIDs and comments can be viewed with the `\lo_list` command.

Note that this command is subtly different from the server-side `lo_import` because it acts as the local user on the local file system, rather than the server's user and file system.

`\lo_list`

Shows a list of all LightDB large objects currently stored in the database, along with any comments provided for them.

`\lo_unlink loid`

Deletes the large object with OID *loid* from the database.

**Tip**

Use `\lo_list` to find out the large object's OID.

`\o or \out [ filename ]`

`\o or \out [ |command ]`

Arranges to save future query results to the file *filename* or pipe future results to the shell command *command*. If no argument is specified, the query output is reset to the standard output.

If the argument begins with `|`, then the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

“Query results” includes all tables, command responses, and notices obtained from the database server, as well as output of various backslash commands that query the database (such as `\d`); but not error messages.



**Tip**

To intersperse text output in between query results, use `\qecho`.

`\p` or `\print`

Print the current query buffer to the standard output. If the current query buffer is empty, the most recently executed query is printed instead.

`\password [ username ]`

Changes the password of the specified user (by default, the current user). This command prompts for the new password, encrypts it, and sends it to the server as an `ALTER ROLE` command. This makes sure that the new password does not appear in cleartext in the command history, the server log, or elsewhere.

`\prompt [ text ] name`

Prompts the user to supply text, which is assigned to the variable *name*. An optional prompt string, *text*, can be specified. (For multiword prompts, surround the text with single quotes.)

By default, `\prompt` uses the terminal for input and output. However, if the `-f` command line switch was used, `\prompt` uses standard input and standard output.

`\pset [ option [ value ] ]`

This command sets options affecting the output of query result tables. *option* indicates which option is to be set. The semantics of *value* vary depending on the selected option. For some options, omitting *value* causes the option to be toggled or unset, as described under the particular option. If no such behavior is mentioned, then omitting *value* just results in the current setting being displayed.

`\pset` without any arguments displays the current status of all printing options.

Adjustable printing options are:

`border`

The *value* must be a number. In general, the higher the number the more borders and lines the tables will have, but details depend on the particular format. In HTML format, this will translate directly into the `border=...` attribute. In most other formats only values 0 (no border), 1 (internal dividing lines), and 2 (table frame) make sense, and values above 2 will be treated the same as `border = 2`. The `latex` and `latex-longtable` formats additionally allow a value of 3 to add dividing lines between data rows.

`columns`

Sets the target width for the `wrapped` format, and also the width limit for determining whether output is wide enough to require the `pager` or `switch` to the vertical display in expanded auto mode. Zero (the default) causes the target width to be controlled by the environment variable `COLUMNS`, or the detected screen width if `COLUMNS` is not set. In addition, if `columns` is zero then the `wrapped` format only affects screen output. If `columns` is nonzero then file and pipe output is wrapped to that width as well.

`csv_fieldsep`

Specifies the field separator to be used in CSV output format. If the separator character appears in a field's value, that field is output within double quotes, following standard CSV rules. The default is a comma.

expanded (or x)

If *value* is specified it must be either `on` or `off`, which will enable or disable expanded mode, or `auto`. If *value* is omitted the command toggles between the on and off settings. When expanded mode is enabled, query results are displayed in two columns, with the column name on the left and the data on the right. This mode is useful if the data wouldn't fit on the screen in the normal "horizontal" mode. In the auto setting, the expanded mode is used whenever the query output has more than one column and is wider than the screen; otherwise, the regular mode is used. The auto setting is only effective in the aligned and wrapped formats. In other formats, it always behaves as if the expanded mode is off.

fieldsep

Specifies the field separator to be used in unaligned output format. That way one can create, for example, tab-separated output, which other programs might prefer. To set a tab as field separator, type `\pset fieldsep '\t'`. The default field separator is `'|'` (a vertical bar).

fieldsep\_zero

Sets the field separator to use in unaligned output format to a zero byte.

footer

If *value* is specified it must be either `on` or `off` which will enable or disable display of the table footer (the `(n rows)` count). If *value* is omitted the command toggles footer display on or off.

format

Sets the output format to one of `aligned`, `asciidoc`, `csv`, `html`, `latex`, `latex-longtable`, `troff-ms`, `unaligned`, or `wrapped`. Unique abbreviations are allowed.

`aligned` format is the standard, human-readable, nicely formatted text output; this is the default.

`unaligned` format writes all columns of a row on one line, separated by the currently active field separator. This is useful for creating output that might be intended to be read in by other programs, for example, tab-separated or comma-separated format. However, the field separator character is not treated specially if it appears in a column's value; so CSV format may be better suited for such purposes.

`csv` format writes column values separated by commas, applying the quoting rules described in RFC 4180<sup>1</sup>. This output is compatible with the CSV format of the server's `COPY` command. A header line with column names is generated unless the `tuples_only` parameter is on. Titles and footers are not printed. Each row is terminated by the system-dependent end-of-line character, which is typically a single newline (`\n`) for Unix-like systems or a carriage return and newline sequence (`\r\n`) for Microsoft Windows. Field separator characters other than comma can be selected with `\pset csv_fieldsep`.

`wrapped` format is like `aligned` but wraps wide data values across lines to make the output fit in the target column width. The target width is determined as described under the `columns` option. Note that ltsql will not attempt to wrap column header titles; therefore, `wrapped` format behaves the same as `aligned` if the total width needed for column headers exceeds the target.

The `asciidoc`, `html`, `latex`, `latex-longtable`, and `troff-ms` formats put out tables that are intended to be included in documents using the respective mark-up language. They are not complete documents! This might not be necessary in HTML, but in LaTeX you must have a complete document wrapper. The `latex` format uses LaTeX's `tabular`

---

<sup>1</sup> <https://tools.ietf.org/html/rfc4180>

environment. The `latex-longtable` format requires the LaTeX `longtable` and `booktabs` packages.

### `linestyle`

Sets the border line drawing style to one of `ascii`, `old-ascii`, or `unicode`. Unique abbreviations are allowed. (That would mean one letter is enough.) The default setting is `ascii`. This option only affects the `aligned` and `wrapped` output formats.

`ascii` style uses plain ASCII characters. Newlines in data are shown using a `+` symbol in the right-hand margin. When the `wrapped` format wraps data from one line to the next without a newline character, a dot (`.`) is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

`old-ascii` style uses plain ASCII characters, using the formatting style used in LightDB 8.4 and earlier. Newlines in data are shown using a `:` symbol in place of the left-hand column separator. When the data is wrapped from one line to the next without a newline character, a `;` symbol is used in place of the left-hand column separator.

`unicode` style uses Unicode box-drawing characters. Newlines in data are shown using a carriage return symbol in the right-hand margin. When the data is wrapped from one line to the next without a newline character, an ellipsis symbol is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

When the `border` setting is greater than zero, the `linestyle` option also determines the characters with which the border lines are drawn. Plain ASCII characters work everywhere, but Unicode characters look nicer on displays that recognize them.

### `null`

Sets the string to be printed in place of a null value. The default is to print nothing, which can easily be mistaken for an empty string. For example, one might prefer `\pset null '(null)'`.

### `numericlocale`

If `value` is specified it must be either `on` or `off` which will enable or disable display of a locale-specific character to separate groups of digits to the left of the decimal marker. If `value` is omitted the command toggles between regular and locale-specific numeric output.

### `pager`

Controls use of a pager program for query and `Itsql help` output. If the environment variable `PSQL_PAGER` or `PAGER` is set, the output is piped to the specified program. Otherwise a platform-dependent default program (such as `more`) is used.

When the `pager` option is `off`, the pager program is not used. When the `pager` option is `on`, the pager is used when appropriate, i.e., when the output is to a terminal and will not fit on the screen. The `pager` option can also be set to `always`, which causes the pager to be used for all terminal output regardless of whether it fits on the screen. `\pset pager` without a `value` toggles pager use on and off.

### `pager_min_lines`

If `pager_min_lines` is set to a number greater than the page height, the pager program will not be called unless there are at least this many lines of output to show. The default setting is 0.

### `recordsep`

Specifies the record (line) separator to use in unaligned output format. The default is a newline character.

`recordsep_zero`

Sets the record separator to use in unaligned output format to a zero byte.

`tableattr` (or `T`)

In HTML format, this specifies attributes to be placed inside the `table` tag. This could for example be `cellpadding` or `bgcolor`. Note that you probably don't want to specify `border` here, as that is already taken care of by `\pset border`. If no *value* is given, the table attributes are unset.

In `latex-longtable` format, this controls the proportional width of each column containing a left-aligned data type. It is specified as a whitespace-separated list of values, e.g., `'0.2 0.2 0.6'`. Unspecified output columns use the last specified value.

`title` (or `C`)

Sets the table title for any subsequently printed tables. This can be used to give your output descriptive tags. If no *value* is given, the title is unset.

`tuples_only` (or `t`)

If *value* is specified it must be either `on` or `off` which will enable or disable tuples-only mode. If *value* is omitted the command toggles between regular and tuples-only output. Regular output includes extra information such as column headers, titles, and various footers. In tuples-only mode, only actual table data is shown.

`unicode_border_linestyle`

Sets the border drawing style for the unicode line style to one of `single` or `double`.

`unicode_column_linestyle`

Sets the column drawing style for the unicode line style to one of `single` or `double`.

`unicode_header_linestyle`

Sets the header drawing style for the unicode line style to one of `single` or `double`.

Illustrations of how these different formats look can be seen in Examples, below.

**Tip**

There are various shortcut commands for `\pset`. See `\a`, `\C`, `\f`, `\H`, `\t`, `\T`, and `\x`.

`\q` or `\quit`

Quits the ltsql program. In a script file, only execution of that script is terminated.

`\qecho text [ ... ]`

This command is identical to `\echo` except that the output will be written to the query output channel, as set by `\o`.

`\r` or `\reset`

Resets (clears) the query buffer.

`\s [ filename ]`

Print Itsql's command line history to *filename*. If *filename* is omitted, the history is written to the standard output (using the pager if appropriate). This command is not available if Itsql was built without Readline support.

`\set [ name [ value [ ... ] ] ]`

Sets the Itsql variable *name* to *value*, or if more than one value is given, to the concatenation of all of them. If only one argument is given, the variable is set to an empty-string value. To unset a variable, use the `\unset` command.

`\set` without any arguments displays the names and values of all currently-set Itsql variables.

Valid variable names can contain letters, digits, and underscores. See Variables below for details. Variable names are case-sensitive.

Certain variables are special, in that they control Itsql's behavior or are automatically set to reflect connection state. These variables are documented in Variables, below.

**Note**

This command is unrelated to the SQL command SET.

`\setenv name [ value ]`

Sets the environment variable *name* to *value*, or if the *value* is not supplied, unsets the environment variable. Example:

```
test=> \setenv PAGER less
test=> \setenv LESS -imx4F
```

`\sf[+] function_description`

This command fetches and shows the definition of the named function or procedure, in the form of a CREATE OR REPLACE FUNCTION or CREATE OR REPLACE PROCEDURE command. The definition is printed to the current query output channel, as set by `\o`.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If `+` is appended to the command name, then the output lines are numbered, with the first line of the function body being line 1.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\sf`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\sv[+] view_name`

This command fetches and shows the definition of the named view, in the form of a CREATE OR REPLACE VIEW command. The definition is printed to the current query output channel, as set by `\o`.

If `+` is appended to the command name, then the output lines are numbered from 1.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\sv`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\t`

Toggles the display of output column name headings and row count footer. This command is equivalent to `\pset tuples_only` and is provided for convenience.

`\T table_options`

Specifies attributes to be placed within the `table` tag in HTML output format. This command is equivalent to `\pset tableattr table_options`.

`\timing [ on | off ]`

With a parameter, turns displaying of how long each SQL statement takes on or off. Without a parameter, toggles the display between on and off. The display is in milliseconds; intervals longer than 1 second are also shown in minutes:seconds format, with hours and days fields added if needed.

`\unset name`

Unsets (deletes) the ltsql variable *name*.

Most variables that control ltsql's behavior cannot be unset; instead, an `\unset` command is interpreted as setting them to their default values. See Variables below.

`\w` or `\write filename`

`\w` or `\write |command`

Writes the current query buffer to the file *filename* or pipes it to the shell command *command*. If the current query buffer is empty, the most recently executed query is written instead.

If the argument begins with `|`, then the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

`\warn text [ ... ]`

This command is identical to `\echo` except that the output will be written to ltsql's standard error channel, rather than standard output.

`\watch [ seconds ]`

Repeatedly execute the current query buffer (as `\g` does) until interrupted or the query fails. Wait the specified number of seconds (default 2) between executions. Each query result is displayed with a header that includes the `\pset title` string (if any), the time as of query start, and the delay interval.

If the current query buffer is empty, the most recently sent query is re-executed instead.

`\x [ on | off | auto ]`

Sets or toggles expanded table formatting mode. As such it is equivalent to `\pset expanded`.

`\z [ pattern ]`

Lists tables, views and sequences with their associated access privileges. If a *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

This is an alias for `\dp` ("display privileges").

`\!` [ *command* ]

With no argument, escapes to a sub-shell; Itsql resumes when the sub-shell exits. With an argument, executes the shell *command*.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\!`, and neither variable interpolation nor backquote expansion are performed in the arguments. The rest of the line is simply passed literally to the shell.

`\?` [ *topic* ]

Shows help information. The optional *topic* parameter (defaulting to `commands`) selects which part of Itsql is explained: `commands` describes Itsql's backslash commands; `options` describes the command-line options that can be passed to Itsql; and `variables` shows help about Itsql configuration variables.

`\;`

Backslash-semicolon is not a meta-command in the same way as the preceding commands; rather, it simply causes a semicolon to be added to the query buffer without any further processing.

Normally, Itsql will dispatch a SQL command to the server as soon as it reaches the command-ending semicolon, even if more input remains on the current line. Thus for example entering

```
select 1; select 2; select 3;
```

will result in the three SQL commands being individually sent to the server, with each one's results being displayed before continuing to the next command. However, a semicolon entered as `\;` will not trigger command processing, so that the command before it and the one after are effectively combined and sent to the server in one request. So for example

```
select 1\; select 2\; select 3;
```

results in sending the three SQL commands to the server in a single request, when the non-backslashed semicolon is reached. The server executes such a request as a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. (See Section 49.2.2.1 for more details about how the server handles multi-query strings.) Itsql prints only the last query result it receives for each request; in this example, although all three `SELECTs` are indeed executed, Itsql only prints the 3.

## Patterns

The various `\d` commands accept a *pattern* parameter to specify the object name(s) to be displayed. In the simplest case, a pattern is just the exact name of the object. The characters within a pattern are normally folded to lower case, just as in SQL names; for example, `\dt FOO` will display the table named `foo`. As in SQL names, placing double quotes around a pattern stops folding to lower case. Should you need to include an actual double quote character in a pattern, write it as a pair of double quotes within a double-quote sequence; again this is in accord with the rules for SQL quoted identifiers. For example, `\dt "FOO" "BAR"` will display the table named `FOO"BAR` (not `foo"bar`). Unlike the normal rules for SQL names, you can put double quotes around just part of a pattern, for instance `\dt FOO"FOO"BAR` will display the table named `fooFOObar`.

Whenever the *pattern* parameter is omitted completely, the `\d` commands display all objects that are visible in the current schema search path — this is equivalent to using `*` as the pattern. (An object is said to be *visible* if its containing schema is in the search path and no object of the same kind and name appears earlier in the search path. This is equivalent to the statement that the object can be referenced by name without explicit schema qualification.) To see all objects in the database regardless of visibility, use `*.*` as the pattern.

Within a pattern, `*` matches any sequence of characters (including no characters) and `?` matches any single character. (This notation is comparable to Unix shell file name patterns.) For example, `\dt int*` displays tables whose names begin with `int`. But within double quotes, `*` and `?` lose these special meanings and are just matched literally.

A pattern that contains a dot (`.`) is interpreted as a schema name pattern followed by an object name pattern. For example, `\dt foo*.bar*` displays all tables whose table name includes `bar` that are in schemas whose schema name starts with `foo`. When no dot appears, then the pattern matches only objects that are visible in the current schema search path. Again, a dot within double quotes loses its special meaning and is matched literally.

Advanced users can use regular-expression notations such as character classes, for example `[0-9]` to match any digit. All regular expression special characters work as specified in Section 9.7.3, except for `.` which is taken as a separator as mentioned above, `*` which is translated to the regular-expression notation `.`, `?` which is translated to `.`, and `$` which is matched literally. You can emulate these pattern characters at need by writing `?` for `.`, `(R+|)` for `R*`, or `(R|)` for `R?`. `$` is not needed as a regular-expression character since the pattern must match the whole name, unlike the usual interpretation of regular expressions (in other words, `$` is automatically appended to your pattern). Write `*` at the beginning and/or end if you don't wish the pattern to be anchored. Note that within double quotes, all regular expression special characters lose their special meanings and are matched literally. Also, the regular expression special characters are matched literally in operator name patterns (i.e., the argument of `\do`).

## Advanced Features

### Variables

Itsql provides variable substitution features similar to common Unix command shells. Variables are simply name/value pairs, where the value can be any string of any length. The name must consist of letters (including non-Latin letters), digits, and underscores.

To set a variable, use the Itsql meta-command `\set`. For example,

```
test=> \set foo bar
```

sets the variable `foo` to the value `bar`. To retrieve the content of the variable, precede the name with a colon, for example:

```
test=> \echo :foo
bar
```

This works in both regular SQL commands and meta-commands; there is more detail in SQL Interpolation, below.

If you call `\set` without a second argument, the variable is set to an empty-string value. To unset (i.e., delete) a variable, use the command `\unset`. To show the values of all variables, call `\set` without any argument.

#### Note

The arguments of `\set` are subject to the same substitution rules as with other commands. Thus you can construct interesting references such as `\set :foo 'something'` and get “soft links” or “variable variables” of Perl or PHP fame, respectively. Unfortunately (or fortunately?), there is no way to do anything useful with these constructs. On the other hand, `\set bar :foo` is a perfectly valid way to copy a variable.



A number of these variables are treated specially by ltsql. They represent certain option settings that can be changed at run time by altering the value of the variable, or in some cases represent changeable state of ltsql. By convention, all specially treated variables' names consist of all upper-case ASCII letters (and possibly digits and underscores). To ensure maximum compatibility in the future, avoid using such variable names for your own purposes.

Variables that control ltsql's behavior generally cannot be unset or set to invalid values. An `\unset` command is allowed but is interpreted as setting the variable to its default value. A `\set` command without a second argument is interpreted as setting the variable to `on`, for control variables that accept that value, and is rejected for others. Also, control variables that accept the values `on` and `off` will also accept other common spellings of Boolean values, such as `true` and `false`.

The specially treated variables are:

#### AUTOCOMMIT

When `on` (the default), each SQL command is automatically committed upon successful completion. To postpone commit in this mode, you must enter a `BEGIN` or `START TRANSACTION SQL` command. When `off` or `unset`, SQL commands are not committed until you explicitly issue `COMMIT` or `END`. The autocommit-off mode works by issuing an implicit `BEGIN` for you, just before any command that is not already in a transaction block and is not itself a `BEGIN` or other transaction-control command, nor a command that cannot be executed inside a transaction block (such as `VACUUM`).

**Note**

In autocommit-off mode, you must explicitly abandon any failed transaction by entering `ABORT` or `ROLLBACK`. Also keep in mind that if you exit the session without committing, your work will be lost.

**Note**

The autocommit-on mode is LightDB's traditional behavior, but autocommit-off is closer to the SQL spec. If you prefer autocommit-off, you might wish to set it in the system-wide `ltsqlrc` file or your `~/.ltsqlrc` file.

#### COMP\_KEYWORD\_CASE

Determines which letter case to use when completing an SQL key word. If set to `lower` or `upper`, the completed word will be in lower or upper case, respectively. If set to `preserve-lower` or `preserve-upper` (the default), the completed word will be in the case of the word already entered, but words being completed without anything entered will be in lower or upper case, respectively.

#### DBNAME

The name of the database you are currently connected to. This is set every time you connect to a database (including program start-up), but can be changed or unset.

#### ECHO

If set to `all`, all nonempty input lines are printed to standard output as they are read. (This does not apply to lines read interactively.) To select this behavior on program start-up, use the switch `-a`. If set to `queries`, ltsql prints each query to standard output as it is sent to the server. The switch to select this behavior is `-e`. If set to `errors`, then only failed queries are displayed on standard error output. The switch for this behavior is `-b`. If set to `none` (the default), then no queries are displayed.

**ECHO\_HIDDEN**

When this variable is set to `on` and a backslash command queries the database, the query is first shown. This feature helps you to study LightDB internals and provide similar functionality in your own programs. (To select this behavior on program start-up, use the switch `-E`.) If you set this variable to the value `noexec`, the queries are just shown but are not actually sent to the server and executed. The default value is `off`.

**ENCODING**

The current client character set encoding. This is set every time you connect to a database (including program start-up), and when you change the encoding with `\encoding`, but it can be changed or unset.

**ERROR**

`true` if the last SQL query failed, `false` if it succeeded. See also `SQLSTATE`.

**FETCH\_COUNT**

If this variable is set to an integer value greater than zero, the results of `SELECT` queries are fetched and displayed in groups of that many rows, rather than the default behavior of collecting the entire result set before display. Therefore only a limited amount of memory is used, regardless of the size of the result set. Settings of 100 to 1000 are commonly used when enabling this feature. Keep in mind that when using this feature, a query might fail after having already displayed some rows.

**Tip**

Although you can use any output format with this feature, the default `aligned` format tends to look bad because each group of `FETCH_COUNT` rows will be formatted separately, leading to varying column widths across the row groups. The other output formats work better.

**HIDE\_TABLEAM**

If this variable is set to `true`, a table's access method details are not displayed. This is mainly useful for regression tests.

**HISTCONTROL**

If this variable is set to `ignoreospace`, lines which begin with a space are not entered into the history list. If set to a value of `ignoredups`, lines matching the previous history line are not entered. A value of `ignoreboth` combines the two options. If set to `none` (the default), all lines read in interactive mode are saved on the history list.

**Note**

This feature was shamelessly plagiarized from Bash.

**HISTFILE**

The file name that will be used to store the history list. If unset, the file name is taken from the `PSQL_HISTORY` environment variable. If that is not set either, the default is `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows. For example, putting:

```
\set HISTFILE ~/.psql_history- :DBNAME
```

in `~/.ltsqlrc` will cause ltsql to maintain a separate history for each database.

**Note**

This feature was shamelessly plagiarized from Bash.

HISTSIZE

The maximum number of commands to store in the command history (default 500). If set to a negative value, no limit is applied.

**Note**

This feature was shamelessly plagiarized from Bash.

HOST

The database server host you are currently connected to. This is set every time you connect to a database (including program start-up), but can be changed or unset.

IGNOREEOF

If set to 1 or less, sending an EOF character (usually **Control+D**) to an interactive session of ltsql will terminate the application. If set to a larger numeric value, that many consecutive EOF characters must be typed to make an interactive session terminate. If the variable is set to a non-numeric value, it is interpreted as 10. The default is 0.

**Note**

This feature was shamelessly plagiarized from Bash.

LASTOID

The value of the last affected OID, as returned from an `INSERT` or `\lo_import` command. This variable is only guaranteed to be valid until after the result of the next SQL command has been displayed. LightDB servers since version 12 do not support OID system columns anymore, thus LASTOID will always be 0 following `INSERT` when targeting such servers.

LAST\_ERROR\_MESSAGE

LAST\_ERROR\_SQLSTATE

The primary error message and associated SQLSTATE code for the most recent failed query in the current ltsql session, or an empty string and 00000 if no error has occurred in the current session.

ON\_ERROR\_ROLLBACK

When set to `on`, if a statement in a transaction block generates an error, the error is ignored and the transaction continues. When set to `interactive`, such errors are only ignored in interactive sessions, and not when reading script files. When set to `off` (the default), a statement in a transaction block that generates an error aborts the entire transaction. The error rollback mode works by issuing an implicit `SAVEPOINT` for you, just before each command that is in a transaction block, and then rolling back to the savepoint if the command fails.

ON\_ERROR\_STOP

By default, command processing continues after an error. When this variable is set to `on`, processing will instead stop immediately. In interactive mode, `itsql` will return to the command prompt; otherwise, `itsql` will exit, returning error code 3 to distinguish this case from fatal error conditions, which are reported using error code 1. In either case, any currently running scripts (the top-level script, if any, and any other scripts which it may have invoked) will be terminated immediately. If the top-level command string contained multiple SQL commands, processing will stop with the current command.

PORT

The database server port to which you are currently connected. This is set every time you connect to a database (including program start-up), but can be changed or unset.

PROMPT1

PROMPT2

PROMPT3

These specify what the prompts `itsql` issues should look like. See Prompting below.

QUIET

Setting this variable to `on` is equivalent to the command line option `-q`. It is probably not too useful in interactive mode.

ROW\_COUNT

The number of rows returned or affected by the last SQL query, or 0 if the query failed or did not report a row count.

SERVER\_VERSION\_NAME

SERVER\_VERSION\_NUM

The server's version number as a string, for example `9.6.2`, `10.1` or `11beta1`, and in numeric form, for example `90602` or `100001`. These are set every time you connect to a database (including program start-up), but can be changed or unset.

SHOW\_CONTEXT

This variable can be set to the values `never`, `errors`, or `always` to control whether `CONTEXT` fields are displayed in messages from the server. The default is `errors` (meaning that context will be shown in error messages, but not in notice or warning messages). This setting has no effect when `VERBOSITY` is set to `terse` or `sqlstate`. (See also `\errverbose`, for use when you want a verbose version of the error you just got.)

SINGLELINE

Setting this variable to `on` is equivalent to the command line option `-S`.

SINGLESTEP

Setting this variable to `on` is equivalent to the command line option `-s`.

SQLSTATE

The error code (see Appendix A) associated with the last SQL query's failure, or `00000` if it succeeded.

USER

The database user you are currently connected as. This is set every time you connect to a database (including program start-up), but can be changed or unset.

## VERBOSITY

This variable can be set to the values `default`, `verbose`, `terse`, or `sqlstate` to control the verbosity of error reports. (See also `\errverbose`, for use when you want a verbose version of the error you just got.)

## VERSION

### VERSION\_NAME

### VERSION\_NUM

These variables are set at program start-up to reflect Itsql's version, respectively as a verbose string, a short string (e.g., `9.6.2`, `10.1`, or `11beta1`), and a number (e.g., `90602` or `100001`). They can be changed or unset.

## SQL Interpolation

A key feature of Itsql variables is that you can substitute (“interpolate”) them into regular SQL statements, as well as the arguments of meta-commands. Furthermore, Itsql provides facilities for ensuring that variable values used as SQL literals and identifiers are properly quoted. The syntax for interpolating a value without any quoting is to prepend the variable name with a colon (`:`). For example,

```
test=> \set foo 'my_table'
test=> SELECT * FROM :foo;
```

would query the table `my_table`. Note that this may be unsafe: the value of the variable is copied literally, so it can contain unbalanced quotes, or even backslash commands. You must make sure that it makes sense where you put it.

When a value is to be used as an SQL literal or identifier, it is safest to arrange for it to be quoted. To quote the value of a variable as an SQL literal, write a colon followed by the variable name in single quotes. To quote the value as an SQL identifier, write a colon followed by the variable name in double quotes. These constructs deal correctly with quotes and other special characters embedded within the variable value. The previous example would be more safely written this way:

```
test=> \set foo 'my_table'
test=> SELECT * FROM :"foo";
```

Variable interpolation will not be performed within quoted SQL literals and identifiers. Therefore, a construction such as `':foo'` doesn't work to produce a quoted literal from a variable's value (and it would be unsafe if it did work, since it wouldn't correctly handle quotes embedded in the value).

One example use of this mechanism is to copy the contents of a file into a table column. First load the file into a variable and then interpolate the variable's value as a quoted string:

```
test=> \set content `cat my_file.txt`
test=> INSERT INTO my_table VALUES (: 'content');
```

(Note that this still won't work if `my_file.txt` contains NUL bytes. Itsql does not support embedded NUL bytes in variable values.)

Since colons can legally appear in SQL commands, an apparent attempt at interpolation (that is, `:name`, `:'name'`, or `:"name"`) is not replaced unless the named variable is currently set. In any case, you can escape a colon with a backslash to protect it from substitution.

The `:{?name}` special syntax returns `TRUE` or `FALSE` depending on whether the variable exists or not, and is thus always substituted, unless the colon is backslash-escaped.

The colon syntax for variables is standard SQL for embedded query languages, such as ECPG. The colon syntaxes for array slices and type casts are LightDB extensions, which can sometimes conflict with the standard usage. The colon-quote syntax for escaping a variable's value as an SQL literal or identifier is a Itsql extension.

## Prompting

The prompts Itsql issues can be customized to your preference. The three variables `PROMPT1`, `PROMPT2`, and `PROMPT3` contain strings and special escape sequences that describe the appearance of the prompt. Prompt 1 is the normal prompt that is issued when Itsql requests a new command. Prompt 2 is issued when more input is expected during command entry, for example because the command was not terminated with a semicolon or a quote was not closed. Prompt 3 is issued when you are running an `SQL COPY FROM STDIN` command and you need to type in a row value on the terminal.

The value of the selected prompt variable is printed literally, except where a percent sign (`%`) is encountered. Depending on the next character, certain other text is substituted instead. Defined substitutions are:

`%M`

The full host name (with domain name) of the database server, or `[local]` if the connection is over a Unix domain socket, or `[local:/dir/name]`, if the Unix domain socket is not at the compiled in default location.

`%m`

The host name of the database server, truncated at the first dot, or `[local]` if the connection is over a Unix domain socket.

`%>`

The port number at which the database server is listening.

`%n`

The database session user name. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%/`

The name of the current database.

`%~`

Like `%/`, but the output is `~` (tilde) if the database is your default database.

`%#`

If the session user is a database superuser, then a `#`, otherwise a `>`. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%p`

The process ID of the backend currently connected to.

`%R`

In prompt 1 normally `=`, but `@` if the session is in an inactive branch of a conditional block, or `^` if in single-line mode, or `!` if the session is disconnected from the database (which can happen if `\connect` fails). In prompt 2 `%R` is replaced by a character that depends on why Itsql expects

more input: - if the command simply wasn't terminated yet, but \* if there is an unfinished / \* . . . \*/ comment, a single quote if there is an unfinished quoted string, a double quote if there is an unfinished quoted identifier, a dollar sign if there is an unfinished dollar-quoted string, or ( if there is an unmatched left parenthesis. In prompt 3 %R doesn't produce anything.

%x

Transaction status: an empty string when not in a transaction block, or \* when in a transaction block, or ! when in a failed transaction block, or ? when the transaction state is indeterminate (for example, because there is no connection).

%l

The line number inside the current statement, starting from 1.

%*digits*

The character with the indicated octal code is substituted.

%: *name* :

The value of the Itsql variable *name*. See Variables, above, for details.

%`*command*`

The output of *command*, similar to ordinary “back-tick” substitution.

%[ ... %]

Prompts can contain terminal control characters which, for example, change the color, background, or style of the prompt text, or change the title of the terminal window. In order for the line editing features of Readline to work properly, these non-printing control characters must be designated as invisible by surrounding them with %[ and %]. Multiple pairs of these can occur within the prompt. For example:

```
test=> \set PROMPT1 '%[%033[1;33;40m%]n@%/%R[%033[0m%]## '
```

results in a boldfaced (1;) yellow-on-black (33;40) prompt on VT100-compatible, color-capable terminals.

%w

Whitespace of the same width as the most recent output of PROMPT1. This can be used as a PROMPT2 setting, so that multi-line statements are aligned with the first line, but there is no visible secondary prompt.

To insert a percent sign into your prompt, write %%. The default prompts are '%/%R%x%# ' for prompts 1 and 2, and '>> ' for prompt 3.

### Note

This feature was shamelessly plagiarized from tcsh.

## Command-Line Editing

Itsql supports the Readline library for convenient line editing and retrieval. The command history is automatically saved when Itsql exits and is reloaded when Itsql starts up. Tab-completion is

also supported, although the completion logic makes no claim to be an SQL parser. The queries generated by tab-completion can also interfere with other SQL commands, e.g., SET TRANSACTION ISOLATION LEVEL. If for some reason you do not like the tab completion, you can turn it off by putting this in a file named `.inputrc` in your home directory:

```
$if ltsql
set disable-completion on
$endif
```

(This is not a ltsql but a Readline feature. Read its documentation for further details.)

## set define on/off command

The `set define on/off` command is derived from oracle's sqlplus tool. The `set define on/off` command currently supports only the `SELECT` statement in oracle mode. You can use substitution variables anywhere in a `SELECT` statement (except for `SELECT`). You can use `&` Tag variable, `&&` Tag variables are not supported. Encounter more than three consecutive Tag variable takes the last `&`. The variable name can be a combination of numbers, letters, and underscores. allow There are Spaces between variable names. When a ltsql execution of a SQL statement encounters a replacement variable, ltsql prompts you for that value. You can enter any string at the prompt, even one that contains Spaces and punctuation. The input string cannot exceed 240 characters.

This example shows how to use the substitution variable function:

```
lightdb@oracle=# select &a
lightdb@oracle-# from &a;
Enter value for a : 123
Enter value for a : dual
old 1: select &a
new 1: select 123
old 2: from &a;
new 2: from dual;
?column?
-----
      123
(1 row)
```

Substituting variables is not supported in this example#

```
lightdb@oracle=# prepare stmt as select '&name';
PREPARE
```

## Environment

### COLUMNS

If `\pset columns` is zero, controls the width for the wrapped format and width for determining if wide output requires the pager or should be switched to the vertical format in expanded auto mode.

```
LTDATABASE
LTHOST
LTPORT
LTUSER
```

Default connection parameters (see Section 32.14).



LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

PSQL\_EDITOR

EDITOR

VISUAL

Editor used by the `\e`, `\ef`, and `\ev` commands. These variables are examined in the order listed; the first that is set is used. If none of them is set, the default is to use `vi` on Unix systems or `notepad.exe` on Windows systems.

PSQL\_EDITOR\_LINENUMBER\_ARG

When `\e`, `\ef`, or `\ev` is used with a line number argument, this variable specifies the command-line argument used to pass the starting line number to the user's editor. For editors such as Emacs or `vi`, this is a plus sign. Include a trailing space in the value of the variable if there needs to be space between the option name and the line number. Examples:

```
PSQL_EDITOR_LINENUMBER_ARG= '+'
PSQL_EDITOR_LINENUMBER_ARG= '--line '
```

The default is `+` on Unix systems (corresponding to the default editor `vi`, and useful for many other common editors); but there is no default on Windows systems.

PSQL\_HISTORY

Alternative location for the command history file. Tilde (`~`) expansion is performed.

PSQL\_PAGER

PAGER

If a query's results do not fit on the screen, they are piped through this command. Typical values are `more` or `less`. Use of the pager can be disabled by setting `PSQL_PAGER` or `PAGER` to an empty string, or by adjusting the pager-related options of the `\pset` command. These variables are examined in the order listed; the first that is set is used. If none of them is set, the default is to use `more` on most platforms, but `less` on Cygwin.

PSQLRC

Alternative location of the user's `.ltsqlrc` file. Tilde (`~`) expansion is performed.

SHELL

Command executed by the `\!` command.

TMPDIR

Directory for storing temporary files. The default is `/tmp`.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

## Files

`ltsqlrc` and `~/.ltsqlrc`

Unless it is passed an `-X` option, `Itsql` attempts to read and execute commands from the system-wide startup file (`ltsqlrc`) and then the user's personal startup file (`~/.ltsqlrc`), after

connecting to the database but before accepting normal commands. These files can be used to set up the client and/or the server to taste, typically with `\set` and `SET` commands.

The system-wide startup file is named `ltsqlrc` and is sought in the installation's "system configuration" directory, which is most reliably identified by running `lt_config --sysconfdir`. By default this directory will be `./etc/` relative to the directory containing the LightDB executables. The name of this directory can be set explicitly via the `LTSYSCONFDIR` environment variable.

The user's personal startup file is named `.ltsqlrc` and is sought in the invoking user's home directory. On Windows, which lacks such a concept, the personal startup file is named `%APPDATA%\postgresql\ltsqlrc.conf`. The location of the user's startup file can be set explicitly via the `PSQLRC` environment variable.

Both the system-wide startup file and the user's personal startup file can be made Itsql-version-specific by appending a dash and the LightDB major or minor release number to the file name, for example `~/.ltsqlrc-9.2` or `~/.ltsqlrc-9.2.5`. The most specific version-matching file will be read in preference to a non-version-specific file.

### `.psql_history`

The command-line history is stored in the file `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows.

The location of the history file can be set explicitly via the `HISTFILE` Itsql variable or the `PSQL_HISTORY` environment variable.

## Notes

- Itsql works best with servers of the same or an older major version. Backslash commands are particularly likely to fail if the server is of a newer version than Itsql itself. However, backslash commands of the `\d` family should work with servers of versions back to 7.4, though not necessarily with servers newer than Itsql itself. The general functionality of running SQL commands and displaying query results should also work with servers of a newer major version, but this cannot be guaranteed in all cases.

If you want to use Itsql to connect to several servers of different major versions, it is recommended that you use the newest version of Itsql. Alternatively, you can keep around a copy of Itsql from each major version and be sure to use the version that matches the respective server. But in practice, this additional complication should not be necessary.

- Before LightDB 9.6, the `-c` option implied `-X (--no-ltsqlrc)`; this is no longer the case.
- Before LightDB 8.4, Itsql allowed the first argument of a single-letter backslash command to start directly after the command, without intervening whitespace. Now, some whitespace is required.

## Notes for Windows Users

Itsql is built as a "console application". Since the Windows console windows use a different encoding than the rest of the system, you must take special care when using 8-bit characters within Itsql. If Itsql detects a problematic console code page, it will warn you at startup. To change the console code page, two things are necessary:

- Set the code page by entering `cmd.exe /c chcp 1252`. (1252 is a code page that is appropriate for German; replace it with your value.) If you are using Cygwin, you can put this command in `/etc/profile`.
- Set the console font to `Lucida Console`, because the raster font does not work with the ANSI code page.

## Notes for LightDB

- In order to be compatible with Oracle Database, Itsql allows users to enter a slash on a single line and ignore it. This feature is only available in Oracle compatibility mode.

```
lightdb@oracle_test=# show
  lightdb_dblevel_syntax_compatible_type ;
  lightdb_dblevel_syntax_compatible_type
-----
Oracle
(1 row)

lightdb@oracle_test=#
lightdb@oracle_test=#
lightdb@oracle_test=# /
lightdb@oracle_test=# /
lightdb@oracle_test=# /
lightdb@oracle_test=# ;
```

## Examples

The first example shows how to spread a command over several lines of input. Notice the changing prompt:

```
test=> CREATE TABLE my_table (
test(>  first integer not null default 0,
test(>  second text)
test-> ;
CREATE TABLE
```

Now look at the table definition again:

```
test=> \d my_table
          Table "public.my_table"
Column | Type      | Collation | Nullable | Default
-----+-----+-----+-----+-----
first  | integer   |           | not null | 0
second | text      |           |          |
```

Now we change the prompt to something more interesting:

```
test=> \set PROMPT1 '%n@m %~%R%# '
peter@localhost test=>
```

Let's assume you have filled the table with data and want to take a look at it:

```
peter@localhost test=> SELECT * FROM my_table;
 first | second
-----+-----
     1 | one
     2 | two
     3 | three
     4 | four
```

(4 rows)

You can display tables in different ways by using the `\pset` command:

```

peter@localhost test=> \pset border 2
Border style is 2.
peter@localhost test=> SELECT * FROM my_table;
+-----+-----+
| first | second |
+-----+-----+
|      1 | one    |
|      2 | two    |
|      3 | three  |
|      4 | four   |
+-----+-----+
(4 rows)

peter@localhost test=> \pset border 0
Border style is 0.
peter@localhost test=> SELECT * FROM my_table;
first second
-----
      1 one
      2 two
      3 three
      4 four
(4 rows)

peter@localhost test=> \pset border 1
Border style is 1.
peter@localhost test=> \pset format csv
Output format is csv.
peter@localhost test=> \pset tuples_only
Tuples only is on.
peter@localhost test=> SELECT second, first FROM my_table;
one,1
two,2
three,3
four,4
peter@localhost test=> \pset format unaligned
Output format is unaligned.
peter@localhost test=> \pset fieldsep '\t'
Field separator is "  ".
peter@localhost test=> SELECT second, first FROM my_table;
one      1
two      2
three    3
four     4

```

Alternatively, use the short commands:

```

peter@localhost test=> \a \t \x
Output format is aligned.
Tuples only is off.
Expanded display is on.
peter@localhost test=> SELECT * FROM my_table;
-[ RECORD 1 ]-

```

```

first | 1
second | one
-[ RECORD 2 ]-
first | 2
second | two
-[ RECORD 3 ]-
first | 3
second | three
-[ RECORD 4 ]-
first | 4
second | four

```

Also, these output format options can be set for just one query by using \g:

```

peter@localhost test=> SELECT * FROM my_table
peter@localhost test-> \g (format=aligned tuples_only=off
  expanded=on)
-[ RECORD 1 ]-
first | 1
second | one
-[ RECORD 2 ]-
first | 2
second | two
-[ RECORD 3 ]-
first | 3
second | three
-[ RECORD 4 ]-
first | 4
second | four

```

When suitable, query results can be shown in a crosstab representation with the \crosstabview command:

```

test=> SELECT first, second, first > 2 AS gt2 FROM my_table;
  first | second | gt2
-----+-----+-----
      1 | one    | f
      2 | two    | f
      3 | three  | t
      4 | four   | t
(4 rows)

```

```

test=> \crosstabview first second
  first | one | two | three | four
-----+-----+-----+-----+-----
      1 | f   |     |       |
      2 |     | f   |       |
      3 |     |     | t     |
      4 |     |     |       | t
(4 rows)

```

This second example shows a multiplication table with rows sorted in reverse numerical order and columns with an independent, ascending numerical order.

```

test=> SELECT t1.first as "A", t2.first+100 AS "B",
  t1.first*(t2.first+100) as "AxB",

```

---

```
test(> row_number() over(order by t2.first) AS ord
test(> FROM my_table t1 CROSS JOIN my_table t2 ORDER BY 1 DESC
test(> \crosstabview "A" "B" "AxB" ord
  A | 101 | 102 | 103 | 104
  ---+-----+-----+-----+-----
  4 | 404 | 408 | 412 | 416
  3 | 303 | 306 | 309 | 312
  2 | 202 | 204 | 206 | 208
  1 | 101 | 102 | 103 | 104
(4 rows)
```

---

# reindexdb

reindexdb — reindex a LightDB database

## Synopsis

```
reindexdb [connection-option...] [option...] [-S | --schema schema] ... [-t | --table table] ... [-i | --index index] ... [dbname]
```

```
reindexdb [connection-option...] [option...] -a | --all
```

```
reindexdb [connection-option...] [option...] -s | --system [dbname]
```

## Description

reindexdb is a utility for rebuilding indexes in a LightDB database.

reindexdb is a wrapper around the SQL command REINDEX. There is no effective difference between reindexing databases via this utility and via other methods for accessing the server.

## Options

reindexdb accepts the following command-line arguments:

```
-a  
--all
```

Reindex all databases.

```
--concurrently
```

Use the CONCURRENTLY option. See REINDEX, where all the caveats of this option are explained in detail.

```
[-d] dbname  
[--dbname=]dbname
```

Specifies the name of the database to be reindexed, when *-a/--all* is not used. If this is not specified, the database name is read from the environment variable `LTDATABASE`. If that is not set, the user name specified for the connection is used. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options.

```
-e  
--echo
```

Echo the commands that reindexdb generates and sends to the server.

```
-i index  
--index=index
```

Recreate *index* only. Multiple indexes can be recreated by writing multiple *-i* switches.

```
-j njobs  
--jobs=njobs
```

Execute the reindex commands in parallel by running *njobs* commands simultaneously. This option may reduce the processing time but it also increases the load on the database server.

reindexdb will open *njobs* connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Note that this option is incompatible with the `--index` and `--system` options.

`-q`  
`--quiet`

Do not display progress messages.

`-s`  
`--system`

Reindex database's system catalogs only.

`-S schema`  
`--schema=schema`

Reindex *schema* only. Multiple schemas can be reindexed by writing multiple `-S` switches.

`-t table`  
`--table=table`

Reindex *table* only. Multiple tables can be reindexed by writing multiple `-t` switches.

`-v`  
`--verbose`

Print detailed information during processing.

`-V`  
`--version`

Print the reindexdb version and exit.

`-?`  
`--help`

Show help about reindexdb command line arguments, and exit.

reindexdb also accepts the following command-line arguments for connection parameters:

`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.



`-W`  
`--password`

Force reindexdb to prompt for a password before connecting to a database.

This option is never essential, since reindexdb will automatically prompt for a password if the server demands password authentication. However, reindexdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to to discover which databases should be reindexed, when `-a/--all` is used. If not specified, the `postgres` database will be used, or if that does not exist, `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options. Also, connection string parameters other than the database name itself will be re-used when connecting to other databases.

## Environment

`LTDATABASE`  
`LTHOST`  
`LTPORT`  
`LTUSER`

Default connection parameters

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see `REINDEX` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

## Notes

reindexdb might need to connect several times to the LightDB server, asking for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 32.15 for more information.

## Examples

To reindex the database `test`:

```
$ reindexdb test
```

To reindex the table `foo` and the index `bar` in a database named `abcd`:

```
$ reindexdb --table=foo --index=bar abcd
```

## See Also

REINDEX

---

# vacuumdb

vacuumdb — garbage-collect and analyze a LightDB database

## Synopsis

```
vacuumdb [connection-option...] [option...] [-t|--table table [(column [...])]] ...  
[dbname]
```

```
vacuumdb [connection-option...] [option...] -a|--all
```

## Description

vacuumdb is a utility for cleaning a LightDB database. vacuumdb will also generate internal statistics used by the LightDB query optimizer.

vacuumdb is a wrapper around the SQL command VACUUM. There is no effective difference between vacuuming and analyzing databases via this utility and via other methods for accessing the server.

## Options

vacuumdb accepts the following command-line arguments:

-a  
--all

Vacuum all databases.

[-d] *dbname*  
[--dbname=] *dbname*

Specifies the name of the database to be cleaned or analyzed, when -a/--all is not used. If this is not specified, the database name is read from the environment variable LTDATABASE. If that is not set, the user name specified for the connection is used. The *dbname* can be a connection string. If so, connection string parameters will override any conflicting command line options.

--disable-page-skipping

Disable skipping pages based on the contents of the visibility map.

### Note

This option is only available for servers running LightDB 9.6 and later.

-e  
--echo

Echo the commands that vacuumdb generates and sends to the server.

-f  
--full

Perform “full” vacuuming.

-F  
--freeze

Aggressively “freeze” tuples.

`-j njobs`  
`--jobs=njobs`

Execute the vacuum or analyze commands in parallel by running *njobs* commands simultaneously. This option may reduce the processing time but it also increases the load on the database server.

vacuumdb will open *njobs* connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Note that using this mode together with the `-f (FULL)` option might cause deadlock failures if certain system catalogs are processed in parallel.

`--min-mxid-age mxid_age`

Only execute the vacuum or analyze commands on tables with a multixact ID age of at least *mxid\_age*. This setting is useful for prioritizing tables to process to prevent multixact ID wraparound (see Section 22.1.5.1).

For the purposes of this option, the multixact ID age of a relation is the greatest of the ages of the main relation and its associated TOAST table, if one exists. Since the commands issued by vacuumdb will also process the TOAST table for the relation if necessary, it does not need to be considered separately.

**Note**

This option is only available for servers running LightDB 9.6 and later.

`--min-xid-age xid_age`

Only execute the vacuum or analyze commands on tables with a transaction ID age of at least *xid\_age*. This setting is useful for prioritizing tables to process to prevent transaction ID wraparound (see Section 22.1.5).

For the purposes of this option, the transaction ID age of a relation is the greatest of the ages of the main relation and its associated TOAST table, if one exists. Since the commands issued by vacuumdb will also process the TOAST table for the relation if necessary, it does not need to be considered separately.

**Note**

This option is only available for servers running LightDB 9.6 and later.

`-P parallel_workers`  
`--parallel=parallel_workers`

Specify the number of parallel workers for *parallel vacuum*. This allows the vacuum to leverage multiple CPUs to process indexes. See VACUUM.

**Note**

This option is only available for servers running LightDB 13 and later.

`-q`  
`--quiet`

Do not display progress messages.

`--skip-locked`

Skip relations that cannot be immediately locked for processing.

**Note**

This option is only available for servers running LightDB 12 and later.

`-t table [ (column [,...]) ]`  
`--table=table [ (column [,...]) ]`

Clean or analyze *table* only. Column names can be specified only in conjunction with the `--analyze` or `--analyze-only` options. Multiple tables can be vacuumed by writing multiple `-t` switches.

**Tip**

If you specify columns, you probably have to escape the parentheses from the shell. (See examples below.)

`-v`  
`--verbose`

Print detailed information during processing.

`-V`  
`--version`

Print the vacuumdb version and exit.

`-z`  
`--analyze`

Also calculate statistics for use by the optimizer.

`-Z`  
`--analyze-only`

Only calculate statistics for use by the optimizer (no vacuum).

`--analyze-in-stages`

Only calculate statistics for use by the optimizer (no vacuum), like `--analyze-only`. Run several (currently three) stages of analyze with different configuration settings, to produce usable statistics faster.

This option is useful to analyze a database that was newly populated from a restored dump or by `lt_upgrade`. This option will try to create some statistics as fast as possible, to make the database usable, and then produce full statistics in the subsequent stages.

`-?`  
`--help`

Show help about vacuumdb command line arguments, and exit.

vacuumdb also accepts the following command-line arguments for connection parameters:

`-h host`  
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`  
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force vacuumdb to prompt for a password before connecting to a database.

This option is never essential, since vacuumdb will automatically prompt for a password if the server demands password authentication. However, vacuumdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to to discover which databases should be vacuumed, when `-a/--all` is used. If not specified, the `postgres` database will be used, or if that does not exist, `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options. Also, connection string parameters other than the database name itself will be re-used when connecting to other databases.

## Environment

LTDATABASE  
LTHOST  
LTPORT  
LTUSER

Default connection parameters

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Diagnostics

In case of difficulty, see `VACUUM` and `ltsql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

## Notes

`vacuumdb` might need to connect several times to the LightDB server, asking for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 32.15 for more information.

## Examples

To clean the database `test`:

```
$ vacuumdb test
```

To clean and analyze for the optimizer a database named `bigdb`:

```
$ vacuumdb --analyze bigdb
```

To clean a single table `foo` in a database named `xyzyzy`, and analyze a single column `bar` of the table for the optimizer:

```
$ vacuumdb --analyze --verbose --table='foo(bar)' xyzyzy
```

## See Also

`VACUUM`

---

# LightDB Server Applications

This part contains reference information for LightDB server applications and support utilities. These commands can only be run usefully on the host where the database server resides. Other utility programs are listed in LightDB Client Applications.

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---

# initdb

initdb — create a new LightDB database cluster

## Synopsis

```
initdb [option...] [ --pgdata | -D ] directory
```

## Description

`initdb` creates a new LightDB database cluster. A database cluster is a collection of databases that are managed by a single server instance.

Creating a database cluster consists of creating the directories in which the database data will live, generating the shared catalog tables (tables that belong to the whole cluster rather than to any particular database), and creating the `template1` and `postgres` databases. When you later create a new database, everything in the `template1` database is copied. (Therefore, anything installed in `template1` is automatically copied into each database created later.) The `postgres` database is a default database meant for use by users, utilities and third party applications.

Although `initdb` will attempt to create the specified data directory, it might not have permission if the parent directory of the desired data directory is root-owned. To initialize in such a setup, create an empty data directory as root, then use `chown` to assign ownership of that directory to the database user account, then `su` to become the database user to run `initdb`.

`initdb` must be run as the user that will own the server process, because the server needs to have access to the files and directories that `initdb` creates. Since the server cannot be run as root, you must not run `initdb` as root either. (It will in fact refuse to do so.)

For security reasons the new cluster created by `initdb` will only be accessible by the cluster owner by default. The `--allow-group-access` option allows any user in the same group as the cluster owner to read files in the cluster. This is useful for performing backups as a non-privileged user.

`initdb` initializes the database cluster's default locale and character set encoding. The character set encoding, collation order (`LC_COLLATE`) and character set classes (`LC_CTYPE`, e.g., upper, lower, digit) can be set separately for a database when it is created. `initdb` determines those settings for the `template1` database, which will serve as the default for all other databases.

To alter the default collation order or character set classes, use the `--lc-collate` and `--lc-ctype` options. Collation orders other than `C` or `POSIX` also have a performance penalty. For these reasons it is important to choose the right locale when running `initdb`.

The remaining locale categories can be changed later when the server is started. You can also use `--locale` to set the default for all locale categories, including collation order and character set classes. All server locale values (`lc_*`) can be displayed via `SHOW ALL`. More details can be found in Section 21.1.

To alter the default encoding, use the `--encoding`. More details can be found in Section 21.3.

After `initdb` initializes the database cluster, `initdb` records the directory where the database cluster is stored in `$LTHOME/instance_list.conf`.

## Options

`-A authmethod`

`--auth=authmethod`

This option specifies the default authentication method for local users used in `lt_hba.conf` (host and local lines). `initdb` will prepopulate `lt_hba.conf` entries using the specified authentication method for non-replication as well as replication connections.

Do not use `trust` unless you trust all local users on your system. `trust` is the default for ease of installation.

`--auth-host=authmethod`

This option specifies the authentication method for local users via TCP/IP connections used in `lt_hba.conf` (host lines).

`--auth-local=authmethod`

This option specifies the authentication method for local users via Unix-domain socket connections used in `lt_hba.conf` (local lines).

`-p port`

This option specifies the port for the database cluster.

`-D directory`

`--pgdata=directory`

This option specifies the directory where the database cluster should be stored. This is the only information required by `initdb`, but you can avoid writing it by setting the `LTDATA` environment variable, which can be convenient since the database server (`lightdb`) can find the database directory later by the same variable.

`-E encoding`

`--encoding=encoding`

Selects the encoding of the template database. This will also be the default encoding of any database you create later, unless you override it there. The default is derived from the locale, or `SQL_ASCII` if that does not work. The character sets supported by the LightDB server are described in Section 21.3.1.

`-g`

`--allow-group-access`

Allows users in the same group as the cluster owner to read all cluster files created by `initdb`. This option is ignored on Windows as it does not support POSIX-style group permissions.

`-k`

`--data-checksums`

Use checksums on data pages to help detect corruption by the I/O system that would otherwise be silent. Enabling checksums may incur a noticeable performance penalty. If set, checksums are calculated for all objects, in all databases. All checksum failures will be reported in the `pg_stat_database` view.

`-K`

`--encryption-key-command`

Used for Transparent Data Encryption. Before creating your database instance, you have to write some code to make sure that the key can be read by the database during startup and instance creation. The key is a 32-byte hex string.

Here is the most simplistic example possible:

```
cat /somewhere/provide_key.sh
#!/bin/sh
echo 882fb7c12e80280fd664c69d2d636913
```

All you need is a program that prints the key to stdout. Make sure that LightDB is able to execute this program:

```
chmod +x /somewhere/provide_key.sh
```

Note: You don't have to write a shell script – you can use any kind of executable such as a C, Go or Python.

Create the database instance:

```
initdb -p 5432 -D ./data -K /somewhere/provide_key.sh
```

`--locale=locale`

Sets the default locale for the database cluster. If this option is not specified, the locale is inherited from the environment that `initdb` runs in. Locale support is described in Section 21.1.

```
--lc-collate=locale
--lc-ctype=locale
--lc-messages=locale
--lc-monetary=locale
--lc-numeric=locale
--lc-time=locale
```

Like `--locale`, but only sets the locale in the specified category.

`--no-locale`

Equivalent to `--locale=C`.

`-N`

`--no-sync`

By default, `initdb` will wait for all files to be written safely to disk. This option causes `initdb` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the data directory corrupt. Generally, this option is useful for testing, but should not be used when creating a production installation.

`--pwfile=filename`

Makes `initdb` read the database superuser's password from a file. The first line of the file is taken as the password.

`-S`

`--sync-only`

Safely write all database files to disk and exit. This does not perform any of the normal `initdb` operations.

`-T config`  
`--text-search-config=config`

Sets the default text search configuration. See `default_text_search_config` for further information.

`-U username`  
`--username=username`

Selects the user name of the database superuser. This defaults to the name of the effective user running `initdb`. It is really not important what the superuser's name is, but one might choose to keep the customary name `lightdb`, even if the operating system user's name is different.

`-W`  
`--pwprompt`

Makes `initdb` prompt for a password to give the database superuser. If you don't plan on using password authentication, this is not important. Otherwise you won't be able to use password authentication until you have a password set up.

`-X directory`  
`--waldir=directory`

This option specifies the directory where the write-ahead log should be stored.

`--wal-segsize=size`

Set the *WAL segment size*, in megabytes. This is the size of each individual file in the WAL log. The default size is 16 megabytes. The value must be a power of 2 between 1 and 1024 (megabytes). This option can only be set during initialization, and cannot be changed later.

It may be useful to adjust this size to control the granularity of WAL log shipping or archiving. Also, in databases with a high volume of WAL, the sheer number of WAL files per directory can become a performance and management problem. Increasing the WAL file size will reduce the number of WAL files.

Other, less commonly used, options are also available:

`-d`  
`--debug`

Print debugging output from the bootstrap backend and a few other messages of lesser interest for the general public. The bootstrap backend is the program `initdb` uses to create the catalog tables. This option generates a tremendous amount of extremely boring output.

`-L directory`

Specifies where `initdb` should find its input files to initialize the database cluster. This is normally not necessary. You will be told if you need to specify their location explicitly.

`-n`  
`--no-clean`

By default, when `initdb` determines that an error prevented it from completely creating the database cluster, it removes any files it might have created before discovering that it cannot finish the job. This option inhibits tidying-up and is thus useful for debugging.

Other options:

`-V`  
`--version`

Print the `initdb` version and exit.

-?  
--help

Show help about initdb command line arguments, and exit.

## Environment

LTDATA

Specifies the directory where the database cluster is to be stored; can be overridden using the `-D` option.

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

TZ

Specifies the default time zone of the created database cluster. The value should be a full time zone name (see Section 8.5.3).

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Notes

`initdb` can also be invoked via `lt_ctl initdb`.

## See Also

`lt_ctl`, `lightdb`

---

# lt\_initdb

lt\_initdb — initdb package, create a new LightDB database cluster

## Synopsis

```
lt_initdb [option...][ --pgdata | -D ] directory
```

## Description

lt\_initdb initdb package, creates a new LightDB database cluster. A database cluster is a collection of databases that are managed by a single server instance.

## Options

-A *authmethod*

--auth=*authmethod*

This option specifies the default authentication method for local users used in `lt_hba.conf` (host and local lines). `initdb` will prepopulate `lt_hba.conf` entries using the specified authentication method for non-replication as well as replication connections.

Do not use `trust` unless you trust all local users on your system. `trust` is the default for ease of installation.

--auth-host=*authmethod*

This option specifies the authentication method for local users via TCP/IP connections used in `lt_hba.conf` (host lines).

--auth-local=*authmethod*

This option specifies the authentication method for local users via Unix-domain socket connections used in `lt_hba.conf` (local lines).

-p *port*

This option specifies the port for the database cluster. The default port is 5432.

-D *directory*

--pgdata=*directory*

This option specifies the directory where the database cluster should be stored. This is the only information required by `initdb`, but you can avoid writing it by setting the `LTDATA` environment variable, which can be convenient since the database server (`lightdb`) can find the database directory later by the same variable.

-E *encoding*

--encoding=*encoding*

Selects the encoding of the template database. This will also be the default encoding of any database you create later, unless you override it there. The default is derived from the locale, or `SQL_ASCII` if that does not work. The character sets supported by the LightDB server are described in Section 21.3.1.

-g

--allow-group-access

Allows users in the same group as the cluster owner to read all cluster files created by `initdb`. This option is ignored on Windows as it does not support POSIX-style group permissions.

-u  
--upgrade-mode

Create a database cluster without extensions, which is equivalent to using `initdb` directly.

-k  
--data-checksums

Use checksums on data pages to help detect corruption by the I/O system that would otherwise be silent. Enabling checksums may incur a noticeable performance penalty. If set, checksums are calculated for all objects, in all databases. All checksum failures will be reported in the `pg_stat_database` view.

-K  
--encryption-key-command

Used for Transparent Data Encryption. Before creating your database instance, you have to write some code to make sure that the key can be read by the database during startup and instance creation. The key is a 32-byte hex string.

Here is the most simplistic example possible:

```
cat /somewhere/provide_key.sh
#!/bin/sh
echo 882fb7c12e80280fd664c69d2d636913
```

All you need is a program that prints the key to stdout. Make sure that LightDB is able to execute this program:

```
chmod +x /somewhere/provide_key.sh
```

Note: You don't have to write a shell script – you can use any kind of executable such as a C, Go or Python.

Create the database instance:

```
lt_initdb -p 5432 -D ./data -K /somewhere/provide_key.sh
```

--locale=*locale*

Sets the default locale for the database cluster. If this option is not specified, the locale is inherited from the environment that `initdb` runs in. Locale support is described in Section 21.1.

--lc-collate=*locale*  
--lc-ctype=*locale*  
--lc-messages=*locale*  
--lc-monetary=*locale*  
--lc-numeric=*locale*  
--lc-time=*locale*

Like `--locale`, but only sets the locale in the specified category.

--no-locale

Equivalent to `--locale=C`.

-N

--no-sync

By default, `initdb` will wait for all files to be written safely to disk. This option causes `initdb` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the data directory corrupt. Generally, this option is useful for testing, but should not be used when creating a production installation.

--pwfile=*filename*

Makes `initdb` read the database superuser's password from a file. The first line of the file is taken as the password.

-S

--sync-only

Safely write all database files to disk and exit. This does not perform any of the normal `initdb` operations.

-T *config*

--text-search-config=*config*

Sets the default text search configuration. See `default_text_search_config` for further information.

-U *username*

--username=*username*

Selects the user name of the database superuser. This defaults to the name of the effective user running `initdb`. It is really not important what the superuser's name is, but one might choose to keep the customary name `lightdb`, even if the operating system user's name is different.

-W

--pwprompt

Makes `initdb` prompt for a password to give the database superuser. If you don't plan on using password authentication, this is not important. Otherwise you won't be able to use password authentication until you have a password set up.

-X *directory*

--waldir=*directory*

This option specifies the directory where the write-ahead log should be stored.

--wal-segsize=*size*

Set the *WAL segment size*, in megabytes. This is the size of each individual file in the WAL log. The default size is 512 megabytes. The value must be a power of 2 between 1 and 1024 (megabytes). This option can only be set during initialization, and cannot be changed later.

It may be useful to adjust this size to control the granularity of WAL log shipping or archiving. Also, in databases with a high volume of WAL, the sheer number of WAL files per directory can become a performance and management problem. Increasing the WAL file size will reduce the number of WAL files.

--install-mode=*mode*

Database cluster installation mode, there are three installation modes.

- `single`: stand-alone version.
- `ha`: high availability version.



- `distributed`: distributed version.

The default installation mode is `single`.

`--compatible-type=type`

Database cluster compatibility type, there are three compatibility types:

- `off`: not compatible with other database features.
- `mysql`: compatible with MySQL database features.
- `oracle`: compatible with Oracle database features.

The default compatibility type is `off`.

Other, less commonly used, options are also available:

`-d`  
`--debug`

Print debugging output from the bootstrap backend and a few other messages of lesser interest for the general public. The bootstrap backend is the program `initdb` uses to create the catalog tables. This option generates a tremendous amount of extremely boring output.

`-L directory`

Specifies where `initdb` should find its input files to initialize the database cluster. This is normally not necessary. You will be told if you need to specify their location explicitly.

`-n`  
`--no-clean`

By default, when `initdb` determines that an error prevented it from completely creating the database cluster, it removes any files it might have created before discovering that it cannot finish the job. This option inhibits tidying-up and is thus useful for debugging.

Other options:

`-V`  
`--version`

Print the `initdb` version and exit.

`-?`  
`--help`

Show help about `initdb` command line arguments, and exit.

## Environment

`LTDATA`

Specifies the directory where the database cluster is to be stored; can be overridden using the `-D` option.

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

TZ

Specifies the default time zone of the created database cluster. The value should be a full time zone name (see Section 8.5.3).

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

## Notes

It is recommended to use `lt_initdb`, otherwise some functions are unavailable.

If you are run `initdb` directly, you can using like:

```
$LTHOME/scripts/5_lightdb_modify_para.sh $LTHOME $LTDATA  
OLTP/OLAP shared_buffers(MB) effective_cache_size(MB) $LTPORT  
$INSTALL_MODE $COMPATIBLE_TYPE  
$LTHOME/scripts/6_lightdb_start.sh $LTHOME $LTDATA (if  
not started)  
$LTHOME/scripts/8_lightdb_create_extension.sh $LTHOME  
$LTPORT $INSTALL_MODE
```

---

# lt\_patch

lt\_patch — the LightDB patch tool

## Synopsis

```
lt_patch init [-i patchid]
```

```
lt_patch make
```

```
lt_patch install [-D ltdata] [-l lthome]
```

```
lt_patch remove [-D ltdata] [-l lthome] [-f] -i patchid
```

```
lt_patch list [-l lthome] [-i patchid]
```

## Description

lt\_patch help ensure your LightDB software stays current and secure. it enables the application and rollback of patches to database on a selected LightDB home (LTHOME).

lt\_patch parses patch configuration and performs the patching operations without user intervention. It can:

- Perform kinds of checks.
- Apply the patch.
- Rollback the patch.

## Options

```
-l  
--lthome
```

Specifies the file system location of the LightDB software. If this option is omitted, the environment variable LTHOME is used.

```
-D  
--ltdata
```

Specifies the file system location of the LightDB instance. If this option is omitted, the environment variable LTDATA is used.

```
-i  
--patch-id
```

Specifies the unique id of one patch.

```
-f  
--force
```

Ignore errors while executing uninstall shell script.

```
-V  
--version
```

Print the lt\_patch version and exit.

-?  
--help

Show help about lt\_patch command line arguments, and exit.

## Overview of the Patch Process

Obtaining the patches you need: the first step is to determine what patches you need. Care about follow items of one patch:

- Name: *patch-1.0-8085*
- Apply Version: *13.8-22.4*
- Apply CPU: *x86\_64*
- Apply OS: *kylinV10sp1*

Applying the Patch to the Desired Targets (LTHOME).

### Note

Before performing any patch task, always read the patch README file for any special patching instructions.

## Usage

Apply one patch: uncompress your obtained patch package and cd into the patch directory, then run follow command:

```
$ lt_patch install -l /home/lightdb/stage/lightdb-x
```

Rollback one patch:

```
$ lt_patch remove -l /home/lightdb/stage/lightdb-x -i  
patch-1.0-8085
```

Query patch information (list all patches information):

```
$ lt_patch list -l /home/lightdb/stage/lightdb-x
```

Query patch information (list one patch information):

```
$ lt_patch list -l /home/lightdb/stage/lightdb-x patch-1.0-8085
```

### Note

"lt\_patch init" and "lt\_patch make" is for internal developers only.

---

# lt\_check

lt\_check — the LightDB check sha256sum tool

## Synopsis

```
lt_check --check [=filename] [--lthome=$LTHOME]
```

```
lt_check --generate [--lthome="$LTHOME"] --comment="comment info"
```

## Description

lt\_check help you checks or generate sha256sum the file in directory \$LTHOME/lib \$LTHOME/bin \$LTHOME/share/extension in the LightDB.

The sha256sum file save in directory \$LTHOME/etc and start by lt\_checksum.X(X is a number).

## Options

```
--lthome=$LTHOME
```

Specifies the file system location of the LightDB software. If this option is omitted, the environment variable LTHOME is used.

```
--generate
```

Generate a sha256sum file in directory \$LTHOME/etc.

```
--check=filename
```

Use sha256sum check a given filename. If filename is omitted, will get a max number in directory \$LTHOME/etc

```
--comment="test info"
```

Save the comment message into the sha256sum file second line. This option can only be used with --generate

```
-?
```

```
--help
```

Show help about lt\_check command line arguments, and exit.

## Usage

generate a sha256sum file and add file head "test info" into \$LTHOME/etc directory.

```
$ lt_check --generate --comment="test info"
```

Check a sha256sum file. default use a file in \$LTHOME/etc/lt\_checksum.X#X is a maximum number if have many files#

```
$ lt_check --check
```

Specify the lthome environment variable and check a given sha256sum file.

```
$ lt_check --lthome=/usr/local/lightdb/lightdb-x --check=/usr/  
local/lightdb/lightdb-x/etc/lt_checksum.1
```

Specify the lthome environment variable and generate a sha256sum file in \$LTHOME/etc directory.

```
$ lt_check --lthome=/usr/local/lightdb/lightdb-x --generate --  
comment="test info"
```

---

# lt\_archivecleanup

lt\_archivecleanup — clean up LightDB WAL archive files

## Synopsis

```
lt_archivecleanup [option...] archive_location oldestkeptwalfile
```

## Description

lt\_archivecleanup is designed to be used as an `archive_cleanup_command` to clean up WAL file archives when running as a standby server (see Section 24.2). lt\_archivecleanup can also be used as a standalone program to clean WAL file archives.

To configure a standby server to use lt\_archivecleanup, put this into its `lightdb.conf` configuration file:

```
archive_cleanup_command = 'lt_archivecleanup archive_location %r'
```

where *archive\_location* is the directory from which WAL segment files should be removed.

When used within `archive_cleanup_command`, all WAL files logically preceding the value of the `%r` argument will be removed from *archive\_location*. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the *archive\_location* is a transient staging area for this particular standby server, but *not* when the *archive\_location* is intended as a long-term WAL archive area, or when multiple standby servers are recovering from the same archive location.

When used as a standalone program all WAL files logically preceding the *oldestkeptwalfile* will be removed from *archive\_location*. In this mode, if you specify a `.partial` or `.backup` file name, then only the file prefix will be used as the *oldestkeptwalfile*. This treatment of `.backup` file name allows you to remove all WAL files archived prior to a specific base backup without error. For example, the following example will remove all files older than WAL file name 000000010000003700000010:

```
lt_archivecleanup -d archive
000000010000003700000010.00000020.backup
```

```
lt_archivecleanup: keep WAL file
"archive/000000010000003700000010" and later
lt_archivecleanup: removing file
"archive/00000001000000370000000F"
lt_archivecleanup: removing file
"archive/00000001000000370000000E"
```

lt\_archivecleanup assumes that *archive\_location* is a directory readable and writable by the server-owning user.

## Options

lt\_archivecleanup accepts the following command-line arguments:

-d

Print lots of debug logging output on `stderr`.

-n

Print the names of the files that would have been removed on `stdout` (performs a dry run).

-V

--version

Print the `lt_archivecleanup` version and exit.

-x *extension*

Provide an extension that will be stripped from all file names before deciding if they should be deleted. This is typically useful for cleaning up archives that have been compressed during storage, and therefore have had an extension added by the compression program. For example: -x `.gz`.

-?

--help

Show help about `lt_archivecleanup` command line arguments, and exit.

## Environment

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

`lt_archivecleanup` is designed to work with LightDB 8.0 and later when used as a standalone utility, or with LightDB 9.0 and later when used as an archive cleanup command.

`lt_archivecleanup` is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

## Examples

On Linux or Unix systems, you might use:

```
archive_cleanup_command = 'lt_archivecleanup -d /mnt/standby/  
archive %r 2>>cleanup.log'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby. This will:

- produce debugging output in `cleanup.log`
- remove no-longer-needed files from the archive directory

## See Also

`lt_standby`



---

# lt\_checksums

lt\_checksums — enable, disable or check data checksums in a LightDB database cluster

## Synopsis

```
lt_checksums [option...] [[ -D | --pgdata ]datadir]
```

## Description

lt\_checksums checks, enables or disables data checksums in a LightDB cluster. The server must be shut down cleanly before running lt\_checksums. When verifying checksums, the exit status is zero if there are no checksum errors, and nonzero if at least one checksum failure is detected. When enabling or disabling checksums, the exit status is nonzero if the operation failed.

When verifying checksums, every file in the cluster is scanned. When enabling checksums, every file in the cluster is rewritten in-place. Disabling checksums only updates the file `lt_control`.

## Options

The following command-line options are available:

```
-D directory  
--pgdata=directory
```

Specifies the directory where the database cluster is stored.

```
-c  
--check
```

Checks checksums. This is the default mode if nothing else is specified.

```
-d  
--disable
```

Disables checksums.

```
-e  
--enable
```

Enables checksums.

```
-f filenode  
--filenode=filenode
```

Only validate checksums in the relation with filenode *filenode*.

```
-N  
--no-sync
```

By default, `lt_checksums` will wait for all files to be written safely to disk. This option causes `lt_checksums` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the updated data directory corrupt. Generally, this option is useful for testing but should not be used on a production installation. This option has no effect when using `--check`.

-P

--progress

Enable progress reporting. Turning this on will deliver a progress report while checking or enabling checksums.

-v

--verbose

Enable verbose output. Lists all checked files.

-V

--version

Print the lt\_checksums version and exit.

-?

--help

Show help about lt\_checksums command line arguments, and exit.

## Environment

LTDATA

Specifies the directory where the database cluster is stored; can be overridden using the -D option.

LT\_COLOR

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

Enabling checksums in a large cluster can potentially take a long time. During this operation, the cluster or other programs that write to the data directory must not be started or else data loss may occur.

When using a replication setup with tools which perform direct copies of relation file blocks (for example `lt_rewind`), enabling or disabling checksums can lead to page corruptions in the shape of incorrect checksums if the operation is not done consistently across all nodes. When enabling or disabling checksums in a replication setup, it is thus recommended to stop all the clusters before switching them all consistently. Destroying all standbys, performing the operation on the primary and finally recreating the standbys from scratch is also safe.

If `lt_checksums` is aborted or killed while enabling or disabling checksums, the cluster's data checksum configuration remains unchanged, and `lt_checksums` can be re-run to perform the same operation.

---

# lt\_controldata

lt\_controldata — display control information of a LightDB database cluster

## Synopsis

```
lt_controldata [option] [[ -D | --pgdata ]datadir]
```

## Description

lt\_controldata prints information initialized during `initdb`, such as the catalog version. It also shows information about write-ahead logging and checkpoint processing. This information is cluster-wide, and not specific to any one database.

This utility can only be run by the user who initialized the cluster because it requires read access to the data directory. You can specify the data directory on the command line, or use the environment variable `LTDATA`. This utility supports the options `-V` and `--version`, which print the `lt_controldata` version and exit. It also supports options `-?` and `--help`, which output the supported arguments.

## Environment

`LTDATA`

Default data directory location

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

---

# lt\_ctl

lt\_ctl — initialize, start, stop, or control a LightDB server

## Synopsis

```
lt_ctl init[db] [-D datadir] [-s] [-o initdb-options]
```

```
lt_ctl start [-D datadir] [-l filename] [-W] [-t seconds] [-s] [-o options] [-p path] [-c]
```

```
lt_ctl stop [-D datadir] [-m s[mart] | f[ast] | i[mmediate] ] [-W] [-t seconds] [-s]
```

```
lt_ctl restart [-D datadir] [-m s[mart] | f[ast] | i[mmediate] ] [-W] [-t seconds] [-s] [-o options] [-c]
```

```
lt_ctl reload [-D datadir] [-s]
```

```
lt_ctl status [-D datadir]
```

```
lt_ctl promote [-D datadir] [-W] [-t seconds] [-s]
```

```
lt_ctl logrotate [-D datadir] [-s]
```

```
lt_ctl kill signal_name process_id
```

On Microsoft Windows, also:

```
lt_ctl register [-D datadir] [-N servicename] [-U username] [-P password] [-S a[uto] | d[emand] ] [-e source] [-W] [-t seconds] [-s] [-o options]
```

```
lt_ctl unregister [-N servicename]
```

## Description

### Note

Using lt\_ctl directly in high-availability mode may lead to unexpected switchover. It is recommended to use lightdb\_service.py instead.

lt\_ctl is a utility for initializing a LightDB database cluster, starting, stopping, or restarting the LightDB database server (lightdb), or displaying the status of a running server. Although the server can be started manually, lt\_ctl encapsulates tasks such as redirecting log output and properly detaching from the terminal and process group. It also provides convenient options for controlled shutdown.

The `init` or `initdb` mode creates a new LightDB database cluster, that is, a collection of databases that will be managed by a single server instance. This mode invokes the `initdb` command. See `initdb` for details.

`start` mode launches a new server. The server is started in the background, and its standard input is attached to `/dev/null` (or `nul` on Windows). On Unix-like systems, by default, the server's standard output and standard error are sent to lt\_ctl's standard output (not standard error). The standard

output of `lt_ctl` should then be redirected to a file or piped to another process such as a log rotating program like `rotatelogs`; otherwise `lightdb` will write its output to the controlling terminal (from the background) and will not leave the shell's process group. On Windows, by default the server's standard output and standard error are sent to the terminal. These default behaviors can be changed by using `-l` to append the server's output to a log file. Use of either `-l` or output redirection is recommended.

`stop` mode shuts down the server that is running in the specified data directory. Three different shutdown methods can be selected with the `-m` option. "Smart" mode disallows new connections, then waits for all existing clients to disconnect and any online backup to finish. If the server is in hot standby, recovery and streaming replication will be terminated once all clients have disconnected. "Fast" mode (the default) does not wait for clients to disconnect and will terminate an online backup in progress. All active transactions are rolled back and clients are forcibly disconnected, then the server is shut down. "Immediate" mode will abort all server processes immediately, without a clean shutdown. This choice will lead to a crash-recovery cycle during the next server start.

`restart` mode effectively executes a stop followed by a start. This allows changing the `lightdb` command-line options, or changing configuration-file options that cannot be changed without restarting the server. If relative paths were used on the command line during server start, `restart` might fail unless `lt_ctl` is executed in the same current directory as it was during server start.

`reload` mode simply sends the `lightdb` server process a `SIGHUP` signal, causing it to reread its configuration files (`lightdb.conf`, `lt_hba.conf`, etc.). This allows changing configuration-file options that do not require a full server restart to take effect.

`status` mode checks whether a server is running in the specified data directory. If it is, the server's PID and the command line options that were used to invoke it are displayed. If the server is not running, `lt_ctl` returns an exit status of 3. If an accessible data directory is not specified, `lt_ctl` returns an exit status of 4.

`promote` mode commands the standby server that is running in the specified data directory to end standby mode and begin read-write operations.

`logrotate` mode rotates the server log file. For details on how to use this mode with external log rotation tools, see Section 22.3.

`kill` mode sends a signal to a specified process. This is primarily valuable on Microsoft Windows which does not have a built-in kill command. Use `--help` to see a list of supported signal names.

`register` mode registers the LightDB server as a system service on Microsoft Windows. The `-S` option allows selection of service start type, either "auto" (start service automatically on system startup) or "demand" (start service on demand).

`unregister` mode unregisters a system service on Microsoft Windows. This undoes the effects of the `register` command.

## Options

`-c`  
`--core-files`

Attempt to allow server crashes to produce core files, on platforms where this is possible, by lifting any soft resource limit placed on core files. This is useful in debugging or diagnosing problems by allowing a stack trace to be obtained from a failed server process.

`-D datadir`  
`--pgdata=datadir`

Specifies the file system location of the database configuration files. If this option is omitted, the environment variable `LTDATA` is used.

---

`-l filename`  
`--log=filename`

Append the server log output to *filename*. If the file does not exist, it is created. The umask is set to 077, so access to the log file is disallowed to other users by default.

`-m mode`  
`--mode=mode`

Specifies the shutdown mode. *mode* can be *smart*, *fast*, or *immediate*, or the first letter of one of these three. If this option is omitted, *fast* is the default.

`-o options`  
`--options=options`

Specifies options to be passed directly to the `lightdb` command. `-o` can be specified multiple times, with all the given options being passed through.

The *options* should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-o initdb-options`  
`--options=initdb-options`

Specifies options to be passed directly to the `initdb` command. `-o` can be specified multiple times, with all the given options being passed through.

The *initdb-options* should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-p path`

Specifies the location of the `lightdb` executable. By default the `lightdb` executable is taken from the same directory as `lt_ctl`, or failing that, the hard-wired installation directory. It is not necessary to use this option unless you are doing something unusual and get errors that the `lightdb` executable was not found.

In `init` mode, this option analogously specifies the location of the `initdb` executable.

`-s`  
`--silent`

Print only errors, no informational messages.

`-t seconds`  
`--timeout=seconds`

Specifies the maximum number of seconds to wait when waiting for an operation to complete (see option `-w`). Defaults to the value of the `LTCTLTIMEOUT` environment variable or, if not set, to 60 seconds.

`-V`  
`--version`

Print the `lt_ctl` version and exit.

`-w`  
`--wait`

Wait for the operation to complete. This is supported for the modes `start`, `stop`, `restart`, `promote`, and `register`, and is the default for those modes.

When waiting, `lt_ctl` repeatedly checks the server's PID file, sleeping for a short amount of time between checks. Startup is considered complete when the PID file indicates that the server is ready to accept connections. Shutdown is considered complete when the server removes the PID file. `lt_ctl` returns an exit code based on the success of the startup or shutdown.

If the operation does not complete within the timeout (see option `-t`), then `lt_ctl` exits with a nonzero exit status. But note that the operation might continue in the background and eventually succeed.

`-W`  
`--no-wait`

Do not wait for the operation to complete. This is the opposite of the option `-w`.

If waiting is disabled, the requested action is triggered, but there is no feedback about its success. In that case, the server log file or an external monitoring system would have to be used to check the progress and success of the operation.

In prior releases of LightDB, this was the default except for the `stop` mode.

`-?`  
`--help`

Show help about `lt_ctl` command line arguments, and exit.

If an option is specified that is valid, but not relevant to the selected operating mode, `lt_ctl` ignores it.

## Options for Windows

`-e source`

Name of the event source for `lt_ctl` to use for logging to the event log when running as a Windows service. The default is `LightDB`. Note that this only controls messages sent from `lt_ctl` itself; once started, the server will use the event source specified by its `event_source` parameter. Should the server fail very early in startup, before that parameter has been set, it might also log using the default event source name `LightDB`.

`-N servicename`

Name of the system service to register. This name will be used as both the service name and the display name. The default is `LightDB`.

`-P password`

Password for the user to run the service as.

`-S start-type`

Start type of the system service. `start-type` can be `auto`, or `demand`, or the first letter of one of these two. If this option is omitted, `auto` is the default.

`-U username`

User name for the user to run the service as. For domain users, use the format `DOMAIN \username`.

## Environment

`LTCTLTIMEOUT`

Default limit on the number of seconds to wait when waiting for startup or shutdown to complete. If not set, the default is 60 seconds.

LTDATA

Default data directory location.

Most `lt_ctl` modes require knowing the data directory location; therefore, the `-D` option is required unless `LTDATA` is set.

`lt_ctl`, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

For additional variables that affect the server, see `lightdb`.

## Files

`lightdb.pid`

`lt_ctl` examines this file in the data directory to determine whether the server is currently running.

`lightdb.opts`

If this file exists in the data directory, `lt_ctl` (in `restart` mode) will pass the contents of the file as options to `lightdb`, unless overridden by the `-o` option. The contents of this file are also displayed in `status` mode.

## Examples

### Starting the Server

To start the server, waiting until the server is accepting connections:

```
$ lt_ctl start
```

To start the server using port 5433, and running without `fsync`, use:

```
$ lt_ctl -o "-F -p 5433" start
```

### Stopping the Server

To stop the server, use:

```
$ lt_ctl stop
```

The `-m` option allows control over *how* the server shuts down:

```
$ lt_ctl stop -m smart
```

### Restarting the Server

Restarting the server is almost equivalent to stopping the server and starting it again, except that by default, `lt_ctl` saves and reuses the command line options that were passed to the previously-running instance. To restart the server using the same options as before, use:

```
$ lt_ctl restart
```



But if `-o` is specified, that replaces any previous options. To restart using port 5433, disabling `fsync` upon restart:

```
$ lt_ctl -o "-F -p 5433" restart
```

## Showing the Server Status

Here is sample status output from `lt_ctl`:

```
$ lt_ctl status
```

```
lt_ctl: server is running (PID: 13718)
/usr/local/lightdb-x/bin/lightdb "-D" "/usr/local/lightdb-x/data"
"-p" "5433" "-B" "128"
```

The second line is the command that would be invoked in restart mode.

## See Also

`initdb`, `lightdb`

---

# lt\_resetwal

lt\_resetwal — reset the write-ahead log and other control information of a LightDB database cluster

## Synopsis

```
lt_resetwal [ -f | --force ] [ -n | --dry-run ] [option...] [ -D | --pgdata ] datadir
```

## Description

lt\_resetwal clears the write-ahead log (WAL) and optionally resets some other control information stored in the lt\_control file. This function is sometimes needed if these files have become corrupted. It should be used only as a last resort, when the server will not start due to such corruption.

After running this command, it should be possible to start the server, but bear in mind that the database might contain inconsistent data due to partially-committed transactions. You should immediately dump your data, run initdb, and restore. After restore, check for inconsistencies and repair as needed.

This utility can only be run by the user who installed the server, because it requires read/write access to the data directory. For safety reasons, you must specify the data directory on the command line. lt\_resetwal does not use the environment variable LTDATA.

If lt\_resetwal complains that it cannot determine valid data for lt\_control, you can force it to proceed anyway by specifying the -f (force) option. In this case plausible values will be substituted for the missing data. Most of the fields can be expected to match, but manual assistance might be needed for the next OID, next transaction ID and epoch, next multitransaction ID and offset, and WAL starting location fields. These fields can be set using the options discussed below. If you are not able to determine correct values for all these fields, -f can still be used, but the recovered database must be treated with even more suspicion than usual: an immediate dump and restore is imperative. *Do not* execute any data-modifying operations in the database before you dump, as any such action is likely to make the corruption worse.

## Options

-f  
--force

Force lt\_resetwal to proceed even if it cannot determine valid data for lt\_control, as explained above.

-n  
--dry-run

The -n/--dry-run option instructs lt\_resetwal to print the values reconstructed from lt\_control and values about to be changed, and then exit without modifying anything. This is mainly a debugging tool, but can be useful as a sanity check before allowing lt\_resetwal to proceed for real.

-V  
--version

Display version information, then exit.

-?  
--help

Show help, then exit.

The following options are only needed when `lt_resetwal` is unable to determine appropriate values by reading `lt_control`. Safe values can be determined as described below. For values that take numeric arguments, hexadecimal values can be specified by using the prefix `0x`.

-c *xid,xid*  
--commit-timestamp-ids=*xid,xid*

Manually set the oldest and newest transaction IDs for which the commit time can be retrieved.

A safe value for the oldest transaction ID for which the commit time can be retrieved (first part) can be determined by looking for the numerically smallest file name in the directory `lt_commit_ts` under the data directory. Conversely, a safe value for the newest transaction ID for which the commit time can be retrieved (second part) can be determined by looking for the numerically greatest file name in the same directory. The file names are in hexadecimal.

-e *xid\_epoch*  
--epoch=*xid\_epoch*

Manually set the next transaction ID's epoch.

The transaction ID epoch is not actually stored anywhere in the database except in the field that is set by `lt_resetwal`, so any value will work so far as the database itself is concerned. You might need to adjust this value to ensure that replication systems such as Slony-I and Skytools work correctly — if so, an appropriate value should be obtainable from the state of the downstream replicated database.

-l *walfile*  
--next-wal-file=*walfile*

Manually set the WAL starting location by specifying the name of the next WAL segment file.

The name of next WAL segment file should be larger than any WAL segment file name currently existing in the directory `lt_wal` under the data directory. These names are also in hexadecimal and have three parts. The first part is the “timeline ID” and should usually be kept the same. For example, if `00000001000000320000004A` is the largest entry in `lt_wal`, use `-l 00000001000000320000004B` or higher.

Note that when using nondefault WAL segment sizes, the numbers in the WAL file names are different from the LSNs that are reported by system functions and system views. This option takes a WAL file name, not an LSN.

### Note

`lt_resetwal` itself looks at the files in `lt_wal` and chooses a default `-l` setting beyond the last existing file name. Therefore, manual adjustment of `-l` should only be needed if you are aware of WAL segment files that are not currently present in `lt_wal`, such as entries in an offline archive; or if the contents of `lt_wal` have been lost entirely.

-m *mxid,mxid*  
--multixact-ids=*mxid,mxid*

Manually set the next and oldest multitransaction ID.

A safe value for the next multitransaction ID (first part) can be determined by looking for the numerically largest file name in the directory `lt_multixact/offsets` under the data directory, adding one, and then multiplying by 65536 (0x10000). Conversely, a safe value for the oldest multitransaction ID (second part of `-m`) can be determined by looking for the numerically smallest file name in the same directory and multiplying by 65536. The file names are in hexadecimal, so the easiest way to do this is to specify the option value in hexadecimal and append four zeroes.

```
-o oid  
--next-oid=oid
```

Manually set the next OID.

There is no comparably easy way to determine a next OID that's beyond the largest one in the database, but fortunately it is not critical to get the next-OID setting right.

```
-O mxoff  
--multixact-offset=mxoff
```

Manually set the next multitransaction offset.

A safe value can be determined by looking for the numerically largest file name in the directory `lt_multixact/members` under the data directory, adding one, and then multiplying by 52352 (0xCC80). The file names are in hexadecimal. There is no simple recipe such as the ones for other options of appending zeroes.

```
--wal-segsize=wal_segment_size
```

Set the new WAL segment size, in megabytes. The value must be set to a power of 2 between 1 and 1024 (megabytes). See the same option of `initdb` for more information.

### Note

While `lt_resetwal` will set the WAL starting address beyond the latest existing WAL segment file, some segment size changes can cause previous WAL file names to be reused. It is recommended to use `-l` together with this option to manually set the WAL starting address if WAL file name overlap will cause problems with your archiving strategy.

```
-u xid  
--oldest-transaction-id=xid
```

Manually set the oldest unfrozen transaction ID.

A safe value can be determined by looking for the numerically smallest file name in the directory `pg_xact` under the data directory and then multiplying by 1048576 (0x100000). Note that the file names are in hexadecimal. It is usually easiest to specify the option value in hexadecimal too. For example, if 0007 is the smallest entry in `pg_xact`, `-u 0x700000` will work (five trailing zeroes provide the proper multiplier).

```
-x xid  
--next-transaction-id=xid
```

Manually set the next transaction ID.

A safe value can be determined by looking for the numerically largest file name in the directory `lt_xact` under the data directory, adding one, and then multiplying by 1048576 (0x100000). Note that the file names are in hexadecimal. It is usually easiest to specify the option value in

hexadecimal too. For example, if 0011 is the largest entry in `lt_xact`, `-x 0x1200000` will work (five trailing zeroes provide the proper multiplier).

## Environment

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

This command must not be used when the server is running. `lt_resetwal` will refuse to start up if it finds a server lock file in the data directory. If the server crashed then a lock file might have been left behind; in that case you can remove the lock file to allow `lt_resetwal` to run. But before you do so, make doubly certain that there is no server process still alive.

`lt_resetwal` works only with servers of the same major version.

## See Also

`lt_controldata`

---

# lt\_rewind

lt\_rewind — synchronize a LightDB data directory with another data directory that was forked from it

## Synopsis

```
lt_rewind [option...] { -D | --target-pgdata } directory { --source-pgdata=directory | --source-server=connstr }
```

## Description

lt\_rewind is a tool for synchronizing a LightDB cluster with another copy of the same cluster, after the clusters' timelines have diverged. A typical scenario is to bring an old master server back online after failover as a standby that follows the new master.

After a successful rewind, the state of the target data directory is analogous to a base backup of the source data directory. Unlike taking a new base backup or using a tool like rsync, lt\_rewind does not require comparing or copying unchanged relation blocks in the cluster. Only changed blocks from existing relation files are copied; all other files, including new relation files, configuration files, and WAL segments, are copied in full. As such the rewind operation is significantly faster than other approaches when the database is large and only a small fraction of blocks differ between the clusters.

lt\_rewind examines the timeline histories of the source and target clusters to determine the point where they diverged, and expects to find WAL in the target cluster's `lt_wal` directory reaching all the way back to the point of divergence. The point of divergence can be found either on the target timeline, the source timeline, or their common ancestor. In the typical failover scenario where the target cluster was shut down soon after the divergence, this is not a problem, but if the target cluster ran for a long time after the divergence, its old WAL files might no longer be present. In this case, you can manually copy them from the WAL archive to the `lt_wal` directory, or run lt\_rewind with the `-c` option to automatically retrieve them from the WAL archive. The use of lt\_rewind is not limited to failover, e.g., a standby server can be promoted, run some write transactions, and then rewound to become a standby again.

After running lt\_rewind, WAL replay needs to complete for the data directory to be in a consistent state. When the target server is started again it will enter archive recovery and replay all WAL generated in the source server from the last checkpoint before the point of divergence. If some of the WAL was no longer available in the source server when lt\_rewind was run, and therefore could not be copied by the lt\_rewind session, it must be made available when the target server is started. This can be done by creating a `recovery.signal` file in the target data directory and by configuring a suitable `restore_command` in `lightdb.conf`.

lt\_rewind requires that the target server either has the `wal_log_hints` option enabled in `lightdb.conf` or data checksums enabled when the cluster was initialized with `initdb`. Neither of these are currently on by default. `full_page_writes` must also be set to `on`, but is enabled by default.

### Warning

If lt\_rewind fails while processing, then the data folder of the target is likely not in a state that can be recovered. In such a case, taking a new fresh backup is recommended.

As lt\_rewind copies configuration files entirely from the source, it may be required to correct the configuration used for recovery before restarting the target server, especially if the target is reintroduced as a standby of the source. If you restart the server after the rewind operation has finished but without configuring recovery, the target may again diverge from the primary.

lt\_rewind will fail immediately if it finds files it cannot write directly to. This can happen for example when the source and the target server use the same file mapping for read-only SSL keys and certificates. If such files are present on the target server it is recommended to remove them before running lt\_rewind. After doing the rewind, some of those files may have been copied from the source, in which case it may be necessary to remove the data copied and restore back the set of links used before the rewind.

## Options

lt\_rewind accepts the following command-line arguments:

`-D directory`  
`--target-pgdata=directory`

This option specifies the target data directory that is synchronized with the source. The target server must be shut down cleanly before running lt\_rewind

`--source-pgdata=directory`

Specifies the file system path to the data directory of the source server to synchronize the target with. This option requires the source server to be cleanly shut down.

`--source-server=connstr`

Specifies a libpq connection string to connect to the source LightDB server to synchronize the target with. The connection must be a normal (non-replication) connection with a role having sufficient permissions to execute the functions used by lt\_rewind on the source server (see Notes section for details) or a superuser role. This option requires the source server to be running and not in recovery mode.

`-R`  
`--write-recovery-conf`

Create `standby.signal` and append connection settings to `lightdb.auto.conf` in the output directory. `--source-server` is mandatory with this option.

`-n`  
`--dry-run`

Do everything except actually modifying the target directory.

`-N`  
`--no-sync`

By default, lt\_rewind will wait for all files to be written safely to disk. This option causes lt\_rewind to return without waiting, which is faster, but means that a subsequent operating system crash can leave the data directory corrupt. Generally, this option is useful for testing but should not be used on a production installation.

`-P`  
`--progress`

Enables progress reporting. Turning this on will deliver an approximate progress report while copying data from the source cluster.

`-c`  
`--restore-target-wal`

Use `restore_command` defined in the target cluster configuration to retrieve WAL files from the WAL archive if these files are no longer available in the `lt_wal` directory.

--debug

Print verbose debugging output that is mostly useful for developers debugging lt\_rewind.

--no-ensure-shutdown

lt\_rewind requires that the target server is cleanly shut down before rewinding. By default, if the target server is not shut down cleanly, lt\_rewind starts the target server in single-user mode to complete crash recovery first, and stops it. By passing this option, lt\_rewind skips this and errors out immediately if the server is not cleanly shut down. Users are expected to handle the situation themselves in that case.

-V

--version

Display version information, then exit.

-?

--help

Show help, then exit.

## Environment

When `--source-server` option is used, lt\_rewind also uses the environment variables supported by libpq (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

When executing lt\_rewind using an online cluster as source, a role having sufficient permissions to execute the functions used by lt\_rewind on the source cluster can be used instead of a superuser. Here is how to create such a role, named `rewind_user` here:

```
CREATE USER rewind_user LOGIN;
GRANT EXECUTE ON function pg_catalog.pg_ls_dir(text, boolean,
boolean) TO rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_stat_file(text, boolean) TO
rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_read_binary_file(text) TO
rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_read_binary_file(text,
bigint, bigint, boolean) TO rewind_user;
```

When executing lt\_rewind using an online cluster as source which has been recently promoted, it is necessary to execute a `CHECKPOINT` after promotion such that its control file reflects up-to-date timeline information, which is used by lt\_rewind to check if the target cluster can be rewound using the designated source cluster.

## How It Works

The basic idea is to copy all file system-level changes from the source cluster to the target cluster:

1. Scan the WAL log of the target cluster, starting from the last checkpoint before the point where the source cluster's timeline history forked off from the target cluster. For each WAL record, record each data block that was touched. This yields a list of all the data blocks that were changed in the



target cluster, after the source cluster forked off. If some of the WAL files are no longer available, try re-running `lt_rewind` with the `-c` option to search for the missing files in the WAL archive.

2. Copy all those changed blocks from the source cluster to the target cluster, either using direct file system access (`--source-pgdata`) or SQL (`--source-server`). Relation files are now in a state equivalent to the moment of the last completed checkpoint prior to the point at which the WAL timelines of the source and target diverged plus the current state on the source of any blocks changed on the target after that divergence.
3. Copy all other files, including new relation files, WAL segments, `lt_xact`, and configuration files from the source cluster to the target cluster. Similarly to base backups, the contents of the directories `lt_dynshmem/`, `lt_notify/`, `lt_replslot/`, `lt_serial/`, `lt_snapshots/`, `lt_stat_tmp/`, and `lt_subtrans/` are omitted from the data copied from the source cluster. The files `backup_label`, `tablespace_map`, `lt_internal.init`, `lightdb.opts`, and `lightdb.pid`, as well as any file or directory beginning with `ltsql_tmp`, are omitted.
4. Create a `backup_label` file to begin WAL replay at the checkpoint created at failover and configure the `lt_control` file with a minimum consistency LSN defined as the result of `pg_current_wal_insert_lsn()` when rewinding from a live source or the last checkpoint LSN when rewinding from a stopped source.
5. When starting the target, LightDB replays all the required WAL, resulting in a data directory in a consistent state.

---

# lt\_test\_fsync

lt\_test\_fsync — determine fastest wal\_sync\_method for LightDB

## Synopsis

```
lt_test_fsync [option...]
```

## Description

lt\_test\_fsync is intended to give you a reasonable idea of what the fastest wal\_sync\_method is on your specific system, as well as supplying diagnostic information in the event of an identified I/O problem. However, differences shown by lt\_test\_fsync might not make any significant difference in real database throughput, especially since many database servers are not speed-limited by their write-ahead logs. lt\_test\_fsync reports average file sync operation time in microseconds for each wal\_sync\_method, which can also be used to inform efforts to optimize the value of commit\_delay.

## Options

lt\_test\_fsync accepts the following command-line options:

-f  
--filename

Specifies the file name to write test data in. This file should be in the same file system that the lt\_wal directory is or will be placed in. (lt\_wal contains the WAL files.) The default is lt\_test\_fsync.out in the current directory.

-s  
--secs-per-test

Specifies the number of seconds for each test. The more time per test, the greater the test's accuracy, but the longer it takes to run. The default is 5 seconds, which allows the program to complete in under 2 minutes.

-V  
--version

Print the lt\_test\_fsync version and exit.

-?  
--help

Show help about lt\_test\_fsync command line arguments, and exit.

## Environment

The environment variable LT\_COLOR specifies whether to use color in diagnostic messages. Possible values are always, auto and never.

## See Also

lightdb

---

# lt\_test\_timing

lt\_test\_timing — measure timing overhead

## Synopsis

```
lt_test_timing [option...]
```

## Description

lt\_test\_timing is a tool to measure the timing overhead on your system and confirm that the system time never moves backwards. Systems that are slow to collect timing data can give less accurate EXPLAIN ANALYZE results.

## Options

lt\_test\_timing accepts the following command-line options:

```
-d duration  
--duration=duration
```

Specifies the test duration, in seconds. Longer durations give slightly better accuracy, and are more likely to discover problems with the system clock moving backwards. The default test duration is 3 seconds.

```
-V  
--version
```

Print the lt\_test\_timing version and exit.

```
-?  
--help
```

Show help about lt\_test\_timing command line arguments, and exit.

## Usage

### Interpreting Results

Good results will show most (>90%) individual timing calls take less than one microsecond. Average per loop overhead will be even lower, below 100 nanoseconds. This example from an Intel i7-860 system using a TSC clock source shows excellent performance:

```
Testing timing overhead for 3 seconds.  
Per loop time including overhead: 35.96 ns  
Histogram of timing durations:  
  < us    % of total    count  
    1     96.40465    80435604  
    2      3.59518     2999652  
    4      0.00015        126  
    8      0.00002         13  
   16      0.00000          2
```

Note that different units are used for the per loop time than the histogram. The loop can have resolution within a few nanoseconds (ns), while the individual timing calls can only resolve down to one microsecond (us).

## Measuring Executor Timing Overhead

When the query executor is running a statement using `EXPLAIN ANALYZE`, individual operations are timed as well as showing a summary. The overhead of your system can be checked by counting rows with the `ltsql` program:

```
CREATE TABLE t AS SELECT * FROM generate_series(1,100000);
\timing
SELECT COUNT(*) FROM t;
EXPLAIN ANALYZE SELECT COUNT(*) FROM t;
```

The i7-860 system measured runs the count query in 9.8 ms while the `EXPLAIN ANALYZE` version takes 16.6 ms, each processing just over 100,000 rows. That 6.8 ms difference means the timing overhead per row is 68 ns, about twice what `lt_test_timing` estimated it would be. Even that relatively small amount of overhead is making the fully timed count statement take almost 70% longer. On more substantial queries, the timing overhead would be less problematic.

## Changing Time Sources

On some newer Linux systems, it's possible to change the clock source used to collect timing data at any time. A second example shows the slowdown possible from switching to the slower `acpi_pm` time source, on the same system used for the fast results above:

```
# cat /sys/devices/system/clocksource/clocksource0/
available_clocksource
tsc hpet acpi_pm
# echo acpi_pm > /sys/devices/system/clocksource/clocksource0/
current_clocksource
# lt_test_timing
Per loop time including overhead: 722.92 ns
Histogram of timing durations:
  < us   % of total   count
    1    27.84870   1155682
    2    72.05956   2990371
    4     0.07810     3241
    8     0.01357     563
   16     0.00007         3
```

In this configuration, the sample `EXPLAIN ANALYZE` above takes 115.9 ms. That's 1061 ns of timing overhead, again a small multiple of what's measured directly by this utility. That much timing overhead means the actual query itself is only taking a tiny fraction of the accounted for time, most of it is being consumed in overhead instead. In this configuration, any `EXPLAIN ANALYZE` totals involving many timed operations would be inflated significantly by timing overhead.

FreeBSD also allows changing the time source on the fly, and it logs information about the timer selected during boot:

```
# dmesg | grep "Timecounter"
Timecounter "ACPI-fast" frequency 3579545 Hz quality 900
Timecounter "i8254" frequency 1193182 Hz quality 0
Timecounters tick every 10.000 msec
Timecounter "TSC" frequency 2531787134 Hz quality 800
# sysctl kern.timecounter.hardware=TSC
kern.timecounter.hardware: ACPI-fast -> TSC
```

Other systems may only allow setting the time source on boot. On older Linux systems the "clock" kernel setting is the only way to make this sort of change. And even on some more recent ones,

the only option you'll see for a clock source is "jiffies". Jiffies are the older Linux software clock implementation, which can have good resolution when it's backed by fast enough timing hardware, as in this example:

```
$ cat /sys/devices/system/clocksource/clocksource0/
available_clocksource
jiffies
$ dmesg | grep time.c
time.c: Using 3.579545 MHz WALL PM GTOD PIT/TSC timer.
time.c: Detected 2400.153 MHz processor.
$ lt_test_timing
Testing timing overhead for 3 seconds.
Per timing duration including loop overhead: 97.75 ns
Histogram of timing durations:
  < us    % of total    count
    1      90.23734    27694571
    2       9.75277     2993204
    4       0.00981       3010
    8       0.00007         22
   16       0.00000          1
   32       0.00000          1
```

## Clock Hardware and Timing Accuracy

Collecting accurate timing information is normally done on computers using hardware clocks with various levels of accuracy. With some hardware the operating systems can pass the system clock time almost directly to programs. A system clock can also be derived from a chip that simply provides timing interrupts, periodic ticks at some known time interval. In either case, operating system kernels provide a clock source that hides these details. But the accuracy of that clock source and how quickly it can return results varies based on the underlying hardware.

Inaccurate time keeping can result in system instability. Test any change to the clock source very carefully. Operating system defaults are sometimes made to favor reliability over best accuracy. And if you are using a virtual machine, look into the recommended time sources compatible with it. Virtual hardware faces additional difficulties when emulating timers, and there are often per operating system settings suggested by vendors.

The Time Stamp Counter (TSC) clock source is the most accurate one available on current generation CPUs. It's the preferred way to track the system time when it's supported by the operating system and the TSC clock is reliable. There are several ways that TSC can fail to provide an accurate timing source, making it unreliable. Older systems can have a TSC clock that varies based on the CPU temperature, making it unusable for timing. Trying to use TSC on some older multicore CPUs can give a reported time that's inconsistent among multiple cores. This can result in the time going backwards, a problem this program checks for. And even the newest systems can fail to provide accurate TSC timing with very aggressive power saving configurations.

Newer operating systems may check for the known TSC problems and switch to a slower, more stable clock source when they are seen. If your system supports TSC time but doesn't default to that, it may be disabled for a good reason. And some operating systems may not detect all the possible problems correctly, or will allow using TSC even in situations where it's known to be inaccurate.

The High Precision Event Timer (HPET) is the preferred timer on systems where it's available and TSC is not accurate. The timer chip itself is programmable to allow up to 100 nanosecond resolution, but you may not see that much accuracy in your system clock.

Advanced Configuration and Power Interface (ACPI) provides a Power Management (PM) Timer, which Linux refers to as the `acpi_pm`. The clock derived from `acpi_pm` will at best provide 300 nanosecond resolution.

Timers used on older PC hardware include the 8254 Programmable Interval Timer (PIT), the real-time clock (RTC), the Advanced Programmable Interrupt Controller (APIC) timer, and the Cyclone timer. These timers aim for millisecond resolution.

## See Also

EXPLAIN

---

# lt\_upgrade

lt\_upgrade — upgrade a LightDB server instance

## Synopsis

```
lt_upgrade -b oldbindir [-B newbindir] -d oldconfigdir -D newconfigdir
[option...]
```

## Description

lt\_upgrade (formerly called lt\_migrator) allows data stored in LightDB data files to be upgraded to a later LightDB major version without the data dump/reload typically required for major version upgrades, e.g., from 22.1 to 22.2.

Major LightDB releases regularly add new features that often change the layout of the system tables, but the internal data storage format rarely changes. lt\_upgrade uses this fact to perform rapid upgrades by creating new system tables and simply reusing the old user data files. If a future major release ever changes the data storage format in a way that makes the old data format unreadable, lt\_upgrade will not be usable for such upgrades. (We will attempt to avoid such situations.)

lt\_upgrade does its best to make sure the old and new clusters are binary-compatible, e.g., by checking for compatible compile-time settings, including 32/64-bit binaries. It is important that any external modules are also binary compatible, though this cannot be checked by lt\_upgrade.

lt\_upgrade supports upgrades from 22.1 and later to the current major release of LightDB, including snapshot and beta releases.

## Options

lt\_upgrade accepts the following command-line arguments:

-b *bindir*

--old-bindir=*bindir*

the old LightDB executable directory; environment variable LTBINOLD

-B *bindir*

--new-bindir=*bindir*

the new LightDB executable directory; default is the directory where lt\_upgrade resides; environment variable LTBINNEW

-c

--check

check clusters only, don't change any data

-d *configdir*

--old-datadir=*configdir*

the old database cluster configuration directory; environment variable LTDATAOLD

-D *configdir*

--new-datadir=*configdir*

the new database cluster configuration directory; environment variable LTDATANEW

`-j njobs`  
`--jobs=njobs`

number of simultaneous processes or threads to use

`-k`  
`--link`

use hard links instead of copying files to the new cluster

`-o options`  
`--old-options options`

options to be passed directly to the old `lightdb` command; multiple option invocations are appended

`-O options`  
`--new-options options`

options to be passed directly to the new `lightdb` command; multiple option invocations are appended

`-p port`  
`--old-port=port`

the old cluster port number; environment variable `LTPORTOLD`

`-P port`  
`--new-port=port`

the new cluster port number; environment variable `LTPORTNEW`

`-r`  
`--retain`

retain SQL and log files even after successful completion

`-s dir`  
`--socketdir=dir`

directory to use for postmaster sockets during upgrade; default is current working directory; environment variable `LTSOCKETDIR`

`-U username`  
`--username=username`

cluster's install user name; environment variable `LTUSER`

`-v`  
`--verbose`

enable verbose internal logging

`-V`  
`--version`

display version information, then exit

`--clone`

Use efficient file cloning (also known as “reflinks” on some systems) instead of copying files to the new cluster. This can result in near-instantaneous copying of the data files, giving the speed advantages of `-k/--link` while leaving the old cluster untouched.



File cloning is only supported on some operating systems and file systems. If it is selected but not supported, the `lt_upgrade` run will error. At present, it is supported on Linux (kernel 4.5 or later) with Btrfs and XFS (on file systems created with reflink support), and on macOS with APFS.

-?

--help

show help, then exit

## Usage

These are the steps to perform an upgrade with `lt_upgrade`:

### 1. Optionally move the old cluster

It is necessary to move the current LightDB install directory so it does not interfere with the new LightDB installation. Once the current LightDB server is shut down, it is safe to rename the LightDB installation directory; assuming the old directory is `/usr/local/lightdbx`, you can do:

```
mv /usr/local/lightdbx /usr/local/lightdbx.old
```

to rename the directory.

### 2. Install the new LightDB binaries

Install the new server's binaries and support files. `lt_upgrade` is included in a default installation.

### 3. Initialize the new LightDB cluster

If your LightDB is stand-alone, initialize the new cluster using `lt_initdb`. Again, use compatible `lt_initdb` flags that match the old cluster, Then add another option `--upgrade-mode`. There is no need to start the new cluster.

```
lt_initdb -p 5432 -D /home/lightdb/lightdbx/data --upgrade-mode
```

If your LightDB is deployed in high availability or distributed. Initialize the new cluster using `lightdb-installer`. You must modify shell script `script/8_lightdb_create_extension.sh` delete all `exeuteSQL` command in it Before start `install.sh`.

### 4. Install custom shared object files

Install any custom shared object files used by the old cluster into the new cluster, e.g., `ltdcrypto.so`, whether they are from `contrib` or some other source. Do not install the schema definitions, e.g., `CREATE EXTENSION ltdcrypto`, because these will be upgraded from the old cluster.

You don't need to worry about the built-in extensions, LightDB will take care of it.

### 5. Adjust authentication

`lt_upgrade` will connect to the old and new servers several times, so you might want to set authentication to `peer` in `lt_hba.conf` or use a `~/.pgpass` file (see Section 32.15).

### 6. Stop both servers

Make sure both database servers are stopped using, on Unix, e.g.:

```
lt_ctl -D /opt/LightDB/13 stop
lt_ctl -D /opt/LightDB/13 stop
```

Streaming replication and log-shipping standby servers can remain running until a later step.

## 7. Prepare for standby server upgrades

If you are upgrading standby servers using methods outlined in section Step 9, verify that the old standby servers are caught up by running `lt_controldata` against the old primary and standby clusters. Verify that the “Latest checkpoint location” values match in all clusters. (There will be a mismatch if old standby servers were shut down before the old primary or if the old standby servers are still running.) Also, make sure `wal_level` is not set to `minimal` in the `lightdb.conf` file on the new primary cluster.

## 8. Run lt\_upgrade

Always run the `lt_upgrade` binary of the new server, not the old one. `lt_upgrade` requires the specification of the old and new cluster's data and executable (`bin`) directories. You can also specify user and port values, and whether you want the data files linked or cloned instead of the default copy behavior.

If you use link mode, the upgrade will be much faster (no file copying) and use less disk space, but you will not be able to access your old cluster once you start the new cluster after the upgrade. Link mode also requires that the old and new cluster data directories be in the same file system. (Tablespaces and `lt_wal` can be on different file systems.) Clone mode provides the same speed and disk space advantages but does not cause the old cluster to be unusable once the new cluster is started. Clone mode also requires that the old and new data directories be in the same file system. This mode is only available on certain operating systems and file systems.

The `--jobs` option allows multiple CPU cores to be used for copying/linking of files and to dump and restore database schemas in parallel; a good place to start is the maximum of the number of CPU cores and tablespaces. This option can dramatically reduce the time to upgrade a multi-database server running on a multiprocessor machine.

For Windows users, you must be logged into an administrative account, and then start a shell as the `postgres` user and set the proper path: Once started, `lt_upgrade` will verify the two clusters are compatible and then do the upgrade. You can use `lt_upgrade --check` to perform only the checks, even if the old server is still running. `lt_upgrade --check` will also outline any manual adjustments you will need to make after the upgrade. If you are going to be using link or clone mode, you should use the option `--link` or `--clone` with `--check` to enable mode-specific checks. `lt_upgrade` requires write permission in the current directory.

Obviously, no one should be accessing the clusters during the upgrade. `lt_upgrade` defaults to running servers on port 50432 to avoid unintended client connections. You can use the same port number for both clusters when doing an upgrade because the old and new clusters will not be running at the same time. However, when checking an old running server, the old and new port numbers must be different.

If an error occurs while restoring the database schema, `lt_upgrade` will exit and you will have to revert to the old cluster as outlined in Step 15 below. To try `lt_upgrade` again, you will need to modify the old cluster so the `lt_upgrade` schema restore succeeds. If the problem is a `contrib` module, you might need to uninstall the `contrib` module from the old cluster and install it in the new cluster after the upgrade, assuming the module is not being used to store user data.

## 9. Upgrade streaming replication and log-shipping standby servers

If you used link mode and have Streaming Replication (see Section 24.2.5) or Log-Shipping (see Section 24.2) standby servers, you can follow these steps to quickly upgrade them. You will not be running `lt_upgrade` on the standby servers, but rather `rsync` on the primary. Do not start any servers yet.

If you did *not* use link mode, do not have or do not want to use rsync, or want an easier solution, skip the instructions in this section and simply recreate the standby servers once lt\_upgrade completes and the new primary is running.

a. **Install the new LightDB binaries on standby servers**

Make sure the new binaries and support files are installed on all standby servers.

b. **Make sure the new standby data directories do *not* exist**

Make sure the new standby data directories do *not* exist or are empty. If initdb was run, delete the standby servers' new data directories.

c. **Install custom shared object files**

Install the same custom shared object files on the new standbys that you installed in the new primary cluster.

d. **Stop standby servers**

If the standby servers are still running, stop them now using the above instructions.

e. **Save configuration files**

Save any configuration files from the old standbys' configuration directories you need to keep, e.g., `lightdb.conf` (and any files included by it), `lightdb.auto.conf`, `lt_hba.conf`, because these will be overwritten or removed in the next step.

f. **Run rsync**

When using link mode, standby servers can be quickly upgraded using rsync. To accomplish this, from a directory on the primary server that is above the old and new database cluster directories, run this on the *primary* for each standby server:

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive old_cluster new_cluster remote_dir
```

where `old_cluster` and `new_cluster` are relative to the current directory on the primary, and `remote_dir` is *above* the old and new cluster directories on the standby. The directory structure under the specified directories on the primary and standbys must match. Consult the rsync manual page for details on specifying the remote directory, e.g.,

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive /opt/LightDB/22.1 \  
    /opt/LightDB/22.2 standby.example.com:/opt/LightDB
```

You can verify what the command will do using rsync's `--dry-run` option. While rsync must be run on the primary for at least one standby, it is possible to run rsync on an upgraded standby to upgrade other standbys, as long as the upgraded standby has not been started.

What this does is to record the links created by lt\_upgrade's link mode that connect files in the old and new clusters on the primary server. It then finds matching files in the standby's old cluster and creates links for them in the standby's new cluster. Files that were not linked on the primary are copied from the primary to the standby. (They are usually small.) This provides rapid standby upgrades. Unfortunately, rsync needlessly copies files associated with temporary and unlogged tables because these files don't normally exist on standby servers.

If you have tablespaces, you will need to run a similar rsync command for each tablespace directory, e.g.:

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive /home/lightdbx/LT_22.1_201510051 \
/home/lightdbx/LT_22.2_201608131 standby.example.com:/home/lightdbx
```

If you have relocated `lt_wal` outside the data directories, rsync must be run on those directories too.

g. **Configure streaming replication and log-shipping standby servers**

Configure the servers for log shipping. (You do not need to run `pg_start_backup()` and `pg_stop_backup()` or take a file system backup as the standbys are still synchronized with the primary.) Replication slots are not copied and must be recreated.

10. **Restore `lt_hba.conf`**

If you modified `lt_hba.conf`, restore its original settings. It might also be necessary to adjust other configuration files in the new cluster to match the old cluster, e.g., `lightdb.conf` (and any files included by it), `lightdb.auto.conf`.

11. **Start the new server**

The new server can now be safely started, and then any rsync'ed standby servers.

12. **Post-upgrade processing**

If any post-upgrade processing is required, `lt_upgrade` will issue warnings as it completes. It will also generate script files that must be run by the administrator. The script files will connect to each database that needs post-upgrade processing. Each script should be run using:

```
ltsql --username=lightdb --file=script.sql postgres
```

The scripts can be run in any order and can be deleted once they have been run.

**Caution**

In general it is unsafe to access tables referenced in rebuild scripts until the rebuild scripts have run to completion; doing so could yield incorrect results or poor performance. Tables not referenced in rebuild scripts can be accessed immediately.

13. **Statistics**

Because optimizer statistics are not transferred by `lt_upgrade`, you will be instructed to run a command to regenerate that information at the end of the upgrade. You might need to set connection parameters to match your new cluster.

14. **Delete old cluster**

Once you are satisfied with the upgrade, you can delete the old cluster's data directories by running the script mentioned when `lt_upgrade` completes. (Automatic deletion is not possible if you have user-defined tablespaces inside the old data directory.) You can also delete the old installation directories (e.g., `bin`, `share`).

## 15. Reverting to old cluster

If, after running `lt_upgrade`, you wish to revert to the old cluster, there are several options:

- If the `--check` option was used, the old cluster was unmodified; it can be restarted.
- If the `--link` option was *not* used, the old cluster was unmodified; it can be restarted.
- If the `--link` option was used, the data files might be shared between the old and new cluster:
  - If `lt_upgrade` aborted before linking started, the old cluster was unmodified; it can be restarted.
  - If you did *not* start the new cluster, the old cluster was unmodified except that, when linking started, a `.old` suffix was appended to `$LTDATA/global/lt_control`. To reuse the old cluster, remove the `.old` suffix from `$LTDATA/global/lt_control`; you can then restart the old cluster.
  - If you did start the new cluster, it has written to shared files and it is unsafe to use the old cluster. The old cluster will need to be restored from backup in this case.

## Notes

`lt_upgrade` creates various working files, such as schema dumps, in the current working directory. For security, be sure that that directory is not readable or writable by any other users.

`lt_upgrade` launches short-lived postmasters in the old and new data directories. Temporary Unix socket files for communication with these postmasters are, by default, made in the current working directory. In some situations the path name for the current directory might be too long to be a valid socket name. In that case you can use the `-s` option to put the socket files in some directory with a shorter path name. For security, be sure that that directory is not readable or writable by any other users.

All failure, rebuild, and reindex cases will be reported by `lt_upgrade` if they affect your installation; post-upgrade scripts to rebuild tables and indexes will be generated automatically. If you are trying to automate the upgrade of many clusters, you should find that clusters with identical database schemas require the same post-upgrade steps for all cluster upgrades; this is because the post-upgrade steps are based on the database schemas, and not user data.

LightDB has built-in extensions and built-in scheduled tasks. These are described in `lt_extension.dat` and `lt_cron.dat`. You cannot modify the two files, which are maintained by LightDB. `lt_upgrade` uses these two files to upgrade and update built-in extensions and scheduled tasks. Starting from LightDB 22.3, `lt_extension.dat` and `lt_cron.dat` are merged into one file `lt_builtin.dat`. But `lt_extension.dat` and `lt_cron.dat` are still reserved.

Starting from LightDB 22.3, `lt_upgrade` will check the consistency of `lightdb_syntax_compatible_type`. The value of old cluster must be same as that of the new cluster.

Starting from LightDB 22.3, `lt_upgrade` will create database `lt_test` for new cluster after the upgrade.

Starting from LightDB 22.3, An empty string is stored as null value while the value of `lightdb_syntax_compatible_type` is 'oracle'. Therefore, if you are upgrading your cluster from 22.2 to 22.3 and the compatible are both 'oracle', it is not recommended to use `lt_upgrade`.

For deployment testing, create a schema-only copy of the old cluster, insert dummy data, and upgrade that.

`lt_upgrade` does not support upgrading of databases containing table columns using these `reg*` OID-referencing system data types:

regcollation  
regconfig  
regdictionary  
regnamespace  
regoper  
regoperator  
regproc  
regprocedure

(regclass, regrole, and regtype can be upgraded.)

If you want to use link mode and you do not want your old cluster to be modified when the new cluster is started, consider using the clone mode. If that is not available, make a copy of the old cluster and upgrade that in link mode. To make a valid copy of the old cluster, use `rsync` to create a dirty copy of the old cluster while the server is running, then shut down the old server and run `rsync --checksum` again to update the copy with any changes to make it consistent. (`--checksum` is necessary because `rsync` only has file modification-time granularity of one second.) You might want to exclude some files, e.g., `lightdb.pid`, as documented in Section 23.3.3. If your file system supports file system snapshots or copy-on-write file copies, you can use that to make a backup of the old cluster and tablespaces, though the snapshot and copies must be created simultaneously or while the database server is down.

## See Also

`initdb`, `lt_ctl`, `lt_dump`, `lightdb`

---

# lt\_upgrade\_check

lt\_upgrade\_check — A pre-upgrade check tool for lt\_upgrade.

## Synopsis

```
lt_upgrade_check -b oldbindir [-B newbindir] -d oldconfigdir -D  
newconfigdir [option...]
```

## Description

This program is executed before performing the lt\_upgrade upgrade. It is used to perform pre-upgrade checks for incompatibilities and anomalies, aiming to minimize the chances of failure during the upgrade process.

The currently supported checks include:

1. Keyword check.
2. Storage space check: The upgrade is only allowed if the available free storage space exceeds the original directory size multiplied by (100 + reserved-space-percent)%. This helps ensure sufficient storage space during the upgrade process. The reserved-space-percent is an optional parameter, which will be further explained below.

## Options

lt\_upgrade\_check accepts the following command-line arguments:

`-b bindir`

`--old-bindir=bindir`

the old LightDB executable directory; environment variable LTBINOLD.

`-B bindir`

`--new-bindir=bindir`

the new LightDB executable directory; default is the directory where lt\_upgrade\_check resides; environment variable LTBINNEW.

`-d configdir`

`--old-datadir=configdir`

the old database cluster configuration directory; environment variable LTDATAOLD.

`-D configdir`

`--new-datadir=configdir`

the new database cluster configuration directory; environment variable LTDATANEW.

`-p port`

`--old-port=port`

the old cluster port number; environment variable LTPORTOLD.

`-P port`

`--new-port=port`

the new cluster port number; environment variable LTPORTNEW.

-r  
--reserved-space-percent

The percentage of remaining disk space. When calculating the required space for the new directory, the rule is to multiply the original directory size by  $(1 + \text{reserved-space-percent})\%$ . The default value is 20, indicating that the remaining disk space should be greater than the original directory size multiplied by 120%.

-s  
--strict

Enables strict mode checking. By default, it is disabled. If this option is enabled, it checks object names such as table names, column names, and function names, and also verifies if any keywords are used in the code of functions, stored procedures, views, and other compiled elements. If this option is not enabled, it only checks for incremental keywords (keywords that are newly added between the old and new database instances). If any keyword is found, it is considered a check failure.

-v  
--verbose

Enable detailed internal logging.

-V  
--version

Display version information and exit.

-?  
--help

Display help information and exit.

## Usage

Below is the command to perform a check by invoking `lt_upgrade_check` on the new database instance:

```
new-bindir/lt_upgrade_check -d old-datadir -D new-datadir -b old-  
bindir -B new-bindir -v -r 50
```

This command indicates that during the upgrade from the specified old library database instance to the new library database instance, keyword checking is performed with non-strict enforcement. It requires the remaining disk space to be greater than 150% of the original directory size and prints detailed checking logs.

- **Running `lt_upgrade_check`**

Prior to running `lt_upgrade_check`, ensure that both the new and old database instances are on the same server and are in a stopped state. During the check, no one should have access to these instances. By default, the check will run a service on port 50432 to prevent unintended client connections. You can use the same port number for both instances during the check, as the new and old instances will not be running simultaneously.

The checking process is as follows: After obtaining the keyword information from the new and old database instances, the keyword check is performed first. Then, the storage space check is conducted. Finally, the `lt_upgrade --check` command is invoked on the new database for further verification.



---

# lt\_waldump

`lt_waldump` — display a human-readable rendering of the write-ahead log of a LightDB database cluster

## Synopsis

```
lt_waldump [option...] [startseg [endseg]]
```

## Description

`lt_waldump` displays the write-ahead log (WAL) and is mainly useful for debugging or educational purposes.

This utility can only be run by the user who installed the server, because it requires read-only access to the data directory.

## Options

The following command-line options control the location and format of the output:

*startseg*

Start reading at the specified log segment file. This implicitly determines the path in which files will be searched for, and the timeline to use.

*endseg*

Stop after reading the specified log segment file.

`-b`

`--bkp-details`

Output detailed information about backup blocks.

`-e end`

`--end=end`

Stop reading at the specified WAL location, instead of reading to the end of the log stream.

`-f`

`--follow`

After reaching the end of valid WAL, keep polling once per second for new WAL to appear.

`-n limit`

`--limit=limit`

Display the specified number of records, then stop.

`-p path`

`--path=path`

Specifies a directory to search for log segment files or a directory with a `lt_wal` subdirectory that contains such files. The default is to search in the current directory, the `lt_wal` subdirectory of the current directory, and the `lt_wal` subdirectory of `LTDATA`.

`-q`  
`--quiet`

Do not print any output, except for errors. This option can be useful when you want to know whether a range of WAL records can be successfully parsed but don't care about the record contents.

`-r rmgr`  
`--rmgr=rmgr`

Only display records generated by the specified resource manager. If `list` is passed as name, print a list of valid resource manager names, and exit.

`-s start`  
`--start=start`

WAL location at which to start reading. The default is to start reading the first valid log record found in the earliest file found.

`-t timeline`  
`--timeline=timeline`

Timeline from which to read log records. The default is to use the value in `startseg`, if that is specified; otherwise, the default is 1.

`-V`  
`--version`

Print the `lt_waldump` version and exit.

`-x xid`  
`--xid=xid`

Only display records marked with the given transaction ID.

`-z`  
`--stats[=record]`

Display summary statistics (number and size of records and full-page images) instead of individual records. Optionally generate statistics per-record instead of per-`rmgr`.

`-?`  
`--help`

Show help about `lt_waldump` command line arguments, and exit.

## Environment

`LTDATA`

Data directory; see also the `-p` option.

`LT_COLOR`

Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

Can give wrong results when the server is running.

Only the specified timeline is displayed (or the default, if none is specified). Records in other timelines are ignored.

lt\_waldump cannot read WAL files with suffix `.partial`. If those files need to be read, `.partial` suffix needs to be removed from the file name.

## See Also

Section 27.5

---

# lightdb

lightdb — LightDB database server

## Synopsis

```
lightdb [option...]
```

## Description

`lightdb` is the LightDB database server. In order for a client application to access a database it connects (over a network or locally) to a running `lightdb` instance. The `lightdb` instance then starts a separate server process to handle the connection.

One `lightdb` instance always manages the data of exactly one database cluster. A database cluster is a collection of databases that is stored at a common file system location (the “data area”). More than one `lightdb` instance can run on a system at one time, so long as they use different data areas and different communication ports (see below). When `lightdb` starts it needs to know the location of the data area. The location must be specified by the `-D` option or the `LTDATA` environment variable; there is no default. Typically, `-D` or `LTDATA` points directly to the data area directory created by `initdb`. Other possible file layouts are discussed in Section 17.2.

By default `lightdb` starts in the foreground and prints log messages to the standard error stream. In practical applications `lightdb` should be started as a background process, perhaps at boot time.

The `lightdb` command can also be called in single-user mode. The primary use for this mode is during bootstrapping by `initdb`. Sometimes it is used for debugging or disaster recovery; note that running a single-user server is not truly suitable for debugging the server, since no realistic interprocess communication and locking will happen. When invoked in single-user mode from the shell, the user can enter queries and the results will be printed to the screen, but in a form that is more useful for developers than end users. In the single-user mode, the session user will be set to the user with ID 1, and implicit superuser powers are granted to this user. This user does not actually have to exist, so the single-user mode can be used to manually recover from certain kinds of accidental damage to the system catalogs.

## Options

`lightdb` accepts the following command-line arguments. For a detailed discussion of the options consult Chapter 17. You can save typing most of these options by setting up a configuration file. Some (safe) options can also be set from the connecting client in an application-dependent way to apply only for that session. For example, if the environment variable `LTOPTIONS` is set, then libpq-based clients will pass that string to the server, which will interpret it as `lightdb` command-line options.

## General Purpose

`-B nbuffers`

Sets the number of shared buffers for use by the server processes. The default value of this parameter is chosen automatically by `initdb`. Specifying this option is equivalent to setting the `shared_buffers` configuration parameter.

`-c name=value`

Sets a named run-time parameter. The configuration parameters supported by LightDB are described in Chapter 17. Most of the other command line options are in fact short forms of such a parameter assignment. `-c` can appear multiple times to set multiple parameters.

-C *name*

Prints the value of the named run-time parameter, and exits. (See the `-c` option above for details.) This can be used on a running server, and returns values from `lightdb.conf`, modified by any parameters supplied in this invocation. It does not reflect parameters supplied when the cluster was started.

This option is meant for other programs that interact with a server instance, such as `lt_ctl`, to query configuration parameter values. User-facing applications should instead use `SHOW` or the `pg_settings` view.

-d *debug-level*

Sets the debug level. The higher this value is set, the more debugging output is written to the server log. Values are from 1 to 5. It is also possible to pass `-d 0` for a specific session, which will prevent the server log level of the parent `lightdb` process from being propagated to this session.

-D *datadir*

Specifies the file system location of the database configuration files. See Section 17.2 for details.

-e

Sets the default date style to “European”, that is `DMY` ordering of input date fields. This also causes the day to be printed before the month in certain date output formats. See Section 8.5 for more information.

-F

Disables `fsync` calls for improved performance, at the risk of data corruption in the event of a system crash. Specifying this option is equivalent to disabling the `fsync` configuration parameter. Read the detailed documentation before using this!

-h *hostname*

Specifies the IP host name or address on which `lightdb` is to listen for TCP/IP connections from client applications. The value can also be a comma-separated list of addresses, or `*` to specify listening on all available interfaces. An empty value specifies not listening on any IP addresses, in which case only Unix-domain sockets can be used to connect to the server. Defaults to listening only on localhost. Specifying this option is equivalent to setting the `listen_addresses` configuration parameter.

-i

Allows remote clients to connect via TCP/IP (Internet domain) connections. Without this option, only local connections are accepted. This option is equivalent to setting `listen_addresses` to `*` in `lightdb.conf` or via `-h`.

This option is deprecated since it does not allow access to the full functionality of `listen_addresses`. It's usually better to set `listen_addresses` directly.

-k *directory*

Specifies the directory of the Unix-domain socket on which `lightdb` is to listen for connections from client applications. The value can also be a comma-separated list of directories. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. Specifying this option is equivalent to setting the `unix_socket_directories` configuration parameter.

-l

Enables secure connections using SSL. LightDB must have been compiled with support for SSL for this option to be available. For more information on using SSL, refer to Section 16.9.

-N *max-connections*

Sets the maximum number of client connections that this server will accept. The default value of this parameter is chosen automatically by initdb. Specifying this option is equivalent to setting the `max_connections` configuration parameter.

-o *extra-options*

The command-line-style arguments specified in *extra-options* are passed to all server processes started by this `lightdb` process.

Spaces within *extra-options* are considered to separate arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash. Multiple arguments can also be specified via multiple uses of `-o`.

The use of this option is obsolete; all command-line options for server processes can be specified directly on the `lightdb` command line.

-p *port*

Specifies the TCP/IP port or local Unix domain socket file extension on which `lightdb` is to listen for connections from client applications. Defaults to the value of the `LTPORT` environment variable, or if `LTPORT` is not set, then defaults to the value established during compilation (normally 5432). If you specify a port other than the default port, then all client applications must specify the same port using either command-line options or `LTPORT`.

-s

Print time information and other statistics at the end of each command. This is useful for benchmarking or for use in tuning the number of buffers.

-S *work-mem*

Specifies the base amount of memory to be used by sorts and hash tables before resorting to temporary disk files. See the description of the `work_mem` configuration parameter in Section 17.4.1.

-V

--version

Print the `lightdb` version and exit.

--name=*value*

Sets a named run-time parameter; a shorter form of `-c`.

--describe-config

This option dumps out the server's internal configuration variables, descriptions, and defaults in tab-delimited `COPY` format. It is designed primarily for use by administration tools.

-?

--help

Show help about `lightdb` command line arguments, and exit.

## Semi-Internal Options

The options described here are used mainly for debugging purposes, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them in a production database setup. They are listed here only for use by LightDB system developers. Furthermore, these options might change or be removed in a future release without notice.

`-f { s | i | o | b | t | n | m | h }`

Forbids the use of particular scan and join methods: `s` and `i` disable sequential and index scans respectively, `o`, `b` and `t` disable index-only scans, bitmap index scans, and TID scans respectively, while `n`, `m`, and `h` disable nested-loop, merge and hash joins respectively.

Neither sequential scans nor nested-loop joins can be disabled completely; the `-fs` and `-fn` options simply discourage the optimizer from using those plan types if it has any other alternative.

`-n`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `lightdb` will not reinitialize shared data structures. A knowledgeable system programmer can then use a debugger to examine shared memory and semaphore state.

`-O`

Allows the structure of system tables to be modified. This is used by `initdb`.

`-P`

Ignore system indexes when reading system tables, but still update the indexes when modifying the tables. This is useful when recovering from damaged system indexes.

`-t pa[rser] | pl[anner] | e[xecutor]`

Print timing statistics for each query relating to each of the major system modules. This option cannot be used together with the `-s` option.

`-T`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `lightdb` will stop all other server processes by sending the signal `SIGSTOP`, but will not cause them to terminate. This permits system programmers to collect core dumps from all server processes by hand.

`-v protocol`

Specifies the version number of the frontend/backend protocol to be used for a particular session. This option is for internal use only.

`-W seconds`

A delay of this many seconds occurs when a new server process is started, after it conducts the authentication procedure. This is intended to give an opportunity to attach to the server process with a debugger.

## Options for Single-User Mode

The following options only apply to the single-user mode (see Single-User Mode below).

`--single`

Selects the single-user mode. This must be the first argument on the command line.

*database*

Specifies the name of the database to be accessed. This must be the last argument on the command line. If it is omitted it defaults to the user name.

`-E`

Echo all commands to standard output before executing them.

`-j`

Use semicolon followed by two newlines, rather than just newline, as the command entry terminator.

`-r filename`

Send all server log output to *filename*. This option is only honored when supplied as a command-line option.

## Environment

LTCLIENTENCODING

Default character encoding used by clients. (The clients can override this individually.) This value can also be set in the configuration file.

LTDATA

Default data directory location

LTDATESTYLE

Default value of the DateStyle run-time parameter. (The use of this environment variable is deprecated.)

LTSPORT

Default port number (preferably set in the configuration file)

## Diagnostics

A failure message mentioning `semget` or `shmget` probably indicates you need to configure your kernel to provide adequate shared memory and semaphores. For more discussion see Section 16.4. You might be able to postpone reconfiguring your kernel by decreasing `shared_buffers` to reduce the shared memory consumption of LightDB, and/or by reducing `max_connections` to reduce the semaphore consumption.

A failure message suggesting that another server is already running should be checked carefully, for example by using the command

```
$ ps ax | grep lightdb
```

or



```
$ ps -ef | grep lightdb
```

depending on your system. If you are certain that no conflicting server is running, you can remove the lock file mentioned in the message and try again.

A failure message indicating inability to bind to a port might indicate that that port is already in use by some non-LightDB process. You might also get this error if you terminate `lightdb` and immediately restart it using the same port; in this case, you must simply wait a few seconds until the operating system closes the port before trying again. Finally, you might get this error if you specify a port number that your operating system considers to be reserved. For example, many versions of Unix consider port numbers under 1024 to be “trusted” and only permit the Unix superuser to access them.

## Notes

The utility command `lt_ctl` can be used to start and shut down the `lightdb` server safely and comfortably.

If at all possible, *do not* use `SIGKILL` to kill the main `lightdb` server. Doing so will prevent `lightdb` from freeing the system resources (e.g., shared memory and semaphores) that it holds before terminating. This might cause problems for starting a fresh `lightdb` run.

To terminate the `lightdb` server normally, the signals `SIGTERM`, `SIGINT`, or `SIGQUIT` can be used. The first will wait for all clients to terminate before quitting, the second will forcefully disconnect all clients, and the third will quit immediately without proper shutdown, resulting in a recovery run during restart.

The `SIGHUP` signal will reload the server configuration files. It is also possible to send `SIGHUP` to an individual server process, but that is usually not sensible.

To cancel a running query, send the `SIGINT` signal to the process running that command. To terminate a backend process cleanly, send `SIGTERM` to that process. See also `pg_cancel_backend` and `pg_terminate_backend` in Section 9.27.2 for the SQL-callable equivalents of these two actions.

The `lightdb` server uses `SIGQUIT` to tell subordinate server processes to terminate without normal cleanup. This signal *should not* be used by users. It is also unwise to send `SIGKILL` to a server process — the main `lightdb` process will interpret this as a crash and will force all the sibling processes to quit as part of its standard crash-recovery procedure.

## Bugs

The `--` options will not work on FreeBSD or OpenBSD. Use `-c` instead. This is a bug in the affected operating systems; a future release of LightDB will provide a workaround if this is not fixed.

## Single-User Mode

To start a single-user mode server, use a command like

```
lightdb --single -D /usr/local/lightdb-x/data other-options  
my_database
```

Provide the correct path to the database directory with `-D`, or make sure that the environment variable `LTDATA` is set. Also specify the name of the particular database you want to work in.

Normally, the single-user mode server treats newline as the command entry terminator; there is no intelligence about semicolons, as there is in `ltsql`. To continue a command across multiple lines, you must type backslash just before each newline except the last one. The backslash and adjacent newline

are both dropped from the input command. Note that this will happen even when within a string literal or comment.

But if you use the `-j` command line switch, a single newline does not terminate command entry; instead, the sequence semicolon-newline-newline does. That is, type a semicolon immediately followed by a completely empty line. Backslash-newline is not treated specially in this mode. Again, there is no intelligence about such a sequence appearing within a string literal or comment.

In either input mode, if you type a semicolon that is not just before or part of a command entry terminator, it is considered a command separator. When you do type a command entry terminator, the multiple statements you've entered will be executed as a single transaction.

To quit the session, type EOF (**Control+D**, usually). If you've entered any text since the last command entry terminator, then EOF will be taken as a command entry terminator, and another EOF will be needed to exit.

Note that the single-user mode server does not provide sophisticated line-editing features (no command history, for example). Single-user mode also does not do any background processing, such as automatic checkpoints or replication.

## Examples

To start `lightdb` in the background using default values, type:

```
$ nohup lightdb >logfile 2>&1 </dev/null &
```

To start `lightdb` with a specific port, e.g., 1234:

```
$ lightdb -p 1234
```

To connect to this server using `ltsql`, specify this port with the `-p` option:

```
$ ltsql -p 1234
```

or set the environment variable `LTPORT`:

```
$ export LTPORT=1234
$ ltsql
```

Named run-time parameters can be set in either of these styles:

```
$ lightdb -c work_mem=1234
$ lightdb --work-mem=1234
```

Either form overrides whatever setting might exist for `work_mem` in `lightdb.conf`. Notice that underscores in parameter names can be written as either underscore or dash on the command line. Except for short-term experiments, it's probably better practice to edit the setting in `lightdb.conf` than to rely on a command-line switch to set a parameter.

## See Also

`initdb`, `lt_ctl`

---

# postmaster

postmaster — LightDB database server

## Synopsis

```
postmaster [option...]
```

## Description

postmaster is a deprecated alias of lightdb.

## See Also

lightdb

---

# LightDB Tool Applications

LightDB installation comes with a number of third-party tools that are available after LightDB is installed in the `$LTHOME/tools` directory.

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# check\_list

check\_list — Check the LightDB runtime environment status tool.

## Synopsis

```
python3 check_list/lightdb_maa_checklist.py [-d FILENAME] [-p PORT] [-t TAG] [-m LTHOME] [-n DBNAME]
```

## Description

check\_list is used to check the possible causes of instability of the operating system, configuration, network, etc. and to check the availability, correctness, stability, easy troubleshooting, and data consistency of the LightDB.

## Options

-d/--output\_dir

output file in this directory name, default current directory.

-p/--port

Lightdb database server port (default: "5432")

-t/--tag

A string for create output html filename. (default: None)

--m/--lthome

Specifies the file system location of the LightDB software. If this option is omitted, the environment variable \$LTHOME is used.

--n/--dbname

Lightdb database name to connect to (default: "postgres")

-?

--help

Show help about check\_list command line arguments, and exit.

## Usage

Use all default arguments. If execute successful, print the file name.

```
$ python3 check_list/lightdb_maa_checklist.py
```

Specify parameter execution. If execute successful, print the file name.

```
$ python3 check_list/lightdb_maa_checklist.py --port 5432  
--tag "master_node" --dbname postgres --lthome /usr/local/lightdb
```

---

# iftop

iftop — Display bandwidth usage on an interface

## Description

For details, see iftop<sup>1</sup>.

---

<sup>1</sup> <http://www.ex-parrot.com/pdw/iftop/>

---

# iotop

iotop — How much I/O was going on.

## Description

For details, see [iotop](http://guichaz.free.fr/iotop/)<sup>1</sup>.

---

<sup>1</sup> <http://guichaz.free.fr/iotop/>

---

# keepalived

keepalived — Provide simple and robust facilities for loadbalancing and high-availability.

## Description

For details, see [keepalived](https://www.keepalived.org/)<sup>1</sup>.

---

<sup>1</sup> <https://www.keepalived.org/>



---

# linux-ftools

linux-ftools — Linux command line tools for fallocate, fincore, fadvise, etc

## Description

For details, see [linux-ftools](https://code.google.com/archive/p/linux-ftools/)<sup>1</sup>.

---

<sup>1</sup> <https://code.google.com/archive/p/linux-ftools/>

---

# Itloader

Itloader — Itloader loads data into LightDB.

## Description

For details, see [pgloader](https://pgloader.io/)<sup>1</sup>.

---

<sup>1</sup> <https://pgloader.io/>

---

# lvs

lvs — A highly scalable and highly available server built on a cluster of real servers, with the load balancer running on the Linux operating system.

## Description

For details, see [lvs](#)<sup>1</sup>.

---

<sup>1</sup> <http://www.linuxvirtualserver.org/>

---

# ntp

ntp — NTP is widely used to synchronize a computer to Internet time servers or other sources, such as a radio or satellite receiver or telephone modem service.

## Description

For details, see [ntp](#)<sup>1</sup>.

---

<sup>1</sup> <http://www.ntp.org/index.html>

---

# ora2pg

ora2pg — Moves Oracle and MySQL database to LightDB.

## Description

For details, see ora2pg<sup>1</sup>.

---

<sup>1</sup> <https://ora2pg.darold.net/>

---

# PostgREST

PostgREST — serves a fully RESTful API from any existing LightDB database.

## Description

For details, see PostgREST<sup>1</sup>.

---

<sup>1</sup> <https://postgrest.org/en/stable/>

---

# tshark

tshark — Dump and analyze network traffic

## Description

For details, see [tshark](#)<sup>1</sup>.

---

<sup>1</sup> <https://www.wireshark.org/docs/man-pages/tshark.html>

---

# vmtouch

vmtouch — A tool for learning about and controlling the file system cache.

## Description

For details, see [vmtouch](https://hoytech.com/vmtouch/)<sup>1</sup>.

---

<sup>1</sup> <https://hoytech.com/vmtouch/>



---

# Part VII. Internals

This part contains assorted information that might be of use to LightDB developers.

---

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# Chapter 47. Overview of LightDB Internals

## Author

This chapter originated as part of [sim98], Stefan Simkovics' Master's Thesis prepared at Vienna University of Technology under the direction of O.Univ.Prof.Dr. Georg Gottlob and Univ.Ass. Mag. Katrin Seyr.

This chapter gives an overview of the internal structure of the backend of LightDB. After having read the following sections you should have an idea of how a query is processed. This chapter does not aim to provide a detailed description of the internal operation of LightDB, as such a document would be very extensive. Rather, this chapter is intended to help the reader understand the general sequence of operations that occur within the backend from the point at which a query is received, to the point at which the results are returned to the client.

## 47.1. The Path of a Query

Here we give a short overview of the stages a query has to pass in order to obtain a result.

1. A connection from an application program to the LightDB server has to be established. The application program transmits a query to the server and waits to receive the results sent back by the server.
2. The *parser stage* checks the query transmitted by the application program for correct syntax and creates a *query tree*.
3. The *rewrite system* takes the query tree created by the parser stage and looks for any *rules* (stored in the *system catalogs*) to apply to the query tree. It performs the transformations given in the *rule bodies*.

One application of the rewrite system is in the realization of *views*. Whenever a query against a view (i.e., a *virtual table*) is made, the rewrite system rewrites the user's query to a query that accesses the *base tables* given in the *view definition* instead.

4. The *planner/optimizer* takes the (rewritten) query tree and creates a *query plan* that will be the input to the *executor*.

It does so by first creating all possible *paths* leading to the same result. For example if there is an index on a relation to be scanned, there are two paths for the scan. One possibility is a simple sequential scan and the other possibility is to use the index. Next the cost for the execution of each path is estimated and the cheapest path is chosen. The cheapest path is expanded into a complete plan that the executor can use.

5. The executor recursively steps through the *plan tree* and retrieves rows in the way represented by the plan. The executor makes use of the *storage system* while scanning relations, performs *sorts* and *joins*, evaluates *qualifications* and finally hands back the rows derived.

In the following sections we will cover each of the above listed items in more detail to give a better understanding of LightDB's internal control and data structures.

## 47.2. How Connections Are Established

LightDB is implemented using a simple “process per user” client/server model. In this model there is one *client process* connected to exactly one *server process*. As we do not know ahead of time how

many connections will be made, we have to use a *master process* that spawns a new server process every time a connection is requested. This master process is called `lightdb` and listens at a specified TCP/IP port for incoming connections. Whenever a request for a connection is detected the `lightdb` process spawns a new server process. The server tasks communicate with each other using *semaphores* and *shared memory* to ensure data integrity throughout concurrent data access.

The client process can be any program that understands the LightDB protocol described in Chapter 49. Many clients are based on the C-language library `libpq`, but several independent implementations of the protocol exist, such as the Java JDBC driver.

Once a connection is established the client process can send a query to the *backend* (server). The query is transmitted using plain text, i.e., there is no parsing done in the *frontend* (client). The server parses the query, creates an *execution plan*, executes the plan and returns the retrieved rows to the client by transmitting them over the established connection.

## 47.3. The Parser Stage

The *parser stage* consists of two parts:

- The *parser* defined in `gram.y` and `scan.l` is built using the Unix tools `bison` and `flex`.
- The *transformation process* does modifications and augmentations to the data structures returned by the parser.

### 47.3.1. Parser

The parser has to check the query string (which arrives as plain text) for valid syntax. If the syntax is correct a *parse tree* is built up and handed back; otherwise an error is returned. The parser and lexer are implemented using the well-known Unix tools `bison` and `flex`.

The *lexer* is defined in the file `scan.l` and is responsible for recognizing *identifiers*, the *SQL key words* etc. For every key word or identifier that is found, a *token* is generated and handed to the parser.

The parser is defined in the file `gram.y` and consists of a set of *grammar rules* and *actions* that are executed whenever a rule is fired. The code of the actions (which is actually C code) is used to build up the parse tree.

The file `scan.l` is transformed to the C source file `scan.c` using the program `flex` and `gram.y` is transformed to `gram.c` using `bison`. After these transformations have taken place a normal C compiler can be used to create the parser. Never make any changes to the generated C files as they will be overwritten the next time `flex` or `bison` is called.

#### Note

The mentioned transformations and compilations are normally done automatically using the *makefiles* shipped with the LightDB source distribution.

A detailed description of `bison` or the grammar rules given in `gram.y` would be beyond the scope of this paper. There are many books and documents dealing with `flex` and `bison`. You should be familiar with `bison` before you start to study the grammar given in `gram.y` otherwise you won't understand what happens there.

### 47.3.2. Transformation Process

The parser stage creates a parse tree using only fixed rules about the syntactic structure of SQL. It does not make any lookups in the system catalogs, so there is no possibility to understand the detailed



semantics of the requested operations. After the parser completes, the *transformation process* takes the tree handed back by the parser as input and does the semantic interpretation needed to understand which tables, functions, and operators are referenced by the query. The data structure that is built to represent this information is called the *query tree*.

The reason for separating raw parsing from semantic analysis is that system catalog lookups can only be done within a transaction, and we do not wish to start a transaction immediately upon receiving a query string. The raw parsing stage is sufficient to identify the transaction control commands (BEGIN, ROLLBACK, etc), and these can then be correctly executed without any further analysis. Once we know that we are dealing with an actual query (such as SELECT or UPDATE), it is okay to start a transaction if we're not already in one. Only then can the transformation process be invoked.

The query tree created by the transformation process is structurally similar to the raw parse tree in most places, but it has many differences in detail. For example, a FuncCall node in the parse tree represents something that looks syntactically like a function call. This might be transformed to either a FuncExpr or Aggref node depending on whether the referenced name turns out to be an ordinary function or an aggregate function. Also, information about the actual data types of columns and expression results is added to the query tree.

## 47.4. The LightDB Rule System

LightDB supports a powerful *rule system* for the specification of *views* and ambiguous *view updates*. Originally the LightDB rule system consisted of two implementations:

- The first one worked using *row level* processing and was implemented deep in the *executor*. The rule system was called whenever an individual row had been accessed. This implementation was removed in 1995 when the last official release of the Berkeley Postgres project was transformed into Postgres95.
- The second implementation of the rule system is a technique called *query rewriting*. The *rewrite system* is a module that exists between the *parser stage* and the *planner/optimizer*. This technique is still implemented.

The query rewriter is discussed in some detail in Chapter 39, so there is no need to cover it here. We will only point out that both the input and the output of the rewriter are query trees, that is, there is no change in the representation or level of semantic detail in the trees. Rewriting can be thought of as a form of macro expansion.

## 47.5. Planner/Optimizer

The task of the *planner/optimizer* is to create an optimal execution plan. A given SQL query (and hence, a query tree) can be actually executed in a wide variety of different ways, each of which will produce the same set of results. If it is computationally feasible, the query optimizer will examine each of these possible execution plans, ultimately selecting the execution plan that is expected to run the fastest.

### Note

In some situations, examining each possible way in which a query can be executed would take an excessive amount of time and memory space. In particular, this occurs when executing queries involving large numbers of join operations. In order to determine a reasonable (not necessarily optimal) query plan in a reasonable amount of time, LightDB uses a *Genetic Query Optimizer* (see Chapter 56) when the number of joins exceeds a threshold (see `geqo_threshold`).

The planner's search procedure actually works with data structures called *paths*, which are simply cut-down representations of plans containing only as much information as the planner needs to make its decisions. After the cheapest path is determined, a full-fledged *plan tree* is built to pass to the executor. This represents the desired execution plan in sufficient detail for the executor to run it. In the rest of this section we'll ignore the distinction between paths and plans.

## 47.5.1. Generating Possible Plans

The planner/optimizer starts by generating plans for scanning each individual relation (table) used in the query. The possible plans are determined by the available indexes on each relation. There is always the possibility of performing a sequential scan on a relation, so a sequential scan plan is always created. Assume an index is defined on a relation (for example a B-tree index) and a query contains the restriction `relation.attribute OPR constant`. If `relation.attribute` happens to match the key of the B-tree index and `OPR` is one of the operators listed in the index's *operator class*, another plan is created using the B-tree index to scan the relation. If there are further indexes present and the restrictions in the query happen to match a key of an index, further plans will be considered. Index scan plans are also generated for indexes that have a sort ordering that can match the query's `ORDER BY` clause (if any), or a sort ordering that might be useful for merge joining (see below).

If the query requires joining two or more relations, plans for joining relations are considered after all feasible plans have been found for scanning single relations. The three available join strategies are:

- *nested loop join*: The right relation is scanned once for every row found in the left relation. This strategy is easy to implement but can be very time consuming. (However, if the right relation can be scanned with an index scan, this can be a good strategy. It is possible to use values from the current row of the left relation as keys for the index scan of the right.)
- *merge join*: Each relation is sorted on the join attributes before the join starts. Then the two relations are scanned in parallel, and matching rows are combined to form join rows. This kind of join is more attractive because each relation has to be scanned only once. The required sorting might be achieved either by an explicit sort step, or by scanning the relation in the proper order using an index on the join key.
- *hash join*: the right relation is first scanned and loaded into a hash table, using its join attributes as hash keys. Next the left relation is scanned and the appropriate values of every row found are used as hash keys to locate the matching rows in the table.

When the query involves more than two relations, the final result must be built up by a tree of join steps, each with two inputs. The planner examines different possible join sequences to find the cheapest one.

If the query uses fewer than `geqo_threshold` relations, a near-exhaustive search is conducted to find the best join sequence. The planner preferentially considers joins between any two relations for which there exist a corresponding join clause in the `WHERE` qualification (i.e., for which a restriction like `where rel1.attr1=rel2.attr2` exists). Join pairs with no join clause are considered only when there is no other choice, that is, a particular relation has no available join clauses to any other relation. All possible plans are generated for every join pair considered by the planner, and the one that is (estimated to be) the cheapest is chosen.

When `geqo_threshold` is exceeded, the join sequences considered are determined by heuristics, as described in Chapter 56. Otherwise the process is the same.

The finished plan tree consists of sequential or index scans of the base relations, plus nested-loop, merge, or hash join nodes as needed, plus any auxiliary steps needed, such as sort nodes or aggregate-function calculation nodes. Most of these plan node types have the additional ability to do *selection* (discarding rows that do not meet a specified Boolean condition) and *projection* (computation of a derived column set based on given column values, that is, evaluation of scalar expressions where needed). One of the responsibilities of the planner is to attach selection conditions from the `WHERE` clause and computation of required output expressions to the most appropriate nodes of the plan tree.

## 47.6. Executor

The *executor* takes the plan created by the planner/optimizer and recursively processes it to extract the required set of rows. This is essentially a demand-pull pipeline mechanism. Each time a plan node is called, it must deliver one more row, or report that it is done delivering rows.

To provide a concrete example, assume that the top node is a `MergeJoin` node. Before any merge can be done two rows have to be fetched (one from each subplan). So the executor recursively calls itself to process the subplans (it starts with the subplan attached to `lefttree`). The new top node (the top node of the left subplan) is, let's say, a `Sort` node and again recursion is needed to obtain an input row. The child node of the `Sort` might be a `SeqScan` node, representing actual reading of a table. Execution of this node causes the executor to fetch a row from the table and return it up to the calling node. The `Sort` node will repeatedly call its child to obtain all the rows to be sorted. When the input is exhausted (as indicated by the child node returning a `NULL` instead of a row), the `Sort` code performs the sort, and finally is able to return its first output row, namely the first one in sorted order. It keeps the remaining rows stored so that it can deliver them in sorted order in response to later demands.

The `MergeJoin` node similarly demands the first row from its right subplan. Then it compares the two rows to see if they can be joined; if so, it returns a join row to its caller. On the next call, or immediately if it cannot join the current pair of inputs, it advances to the next row of one table or the other (depending on how the comparison came out), and again checks for a match. Eventually, one subplan or the other is exhausted, and the `MergeJoin` node returns `NULL` to indicate that no more join rows can be formed.

Complex queries can involve many levels of plan nodes, but the general approach is the same: each node computes and returns its next output row each time it is called. Each node is also responsible for applying any selection or projection expressions that were assigned to it by the planner.

The executor mechanism is used to evaluate all four basic SQL query types: `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. For `SELECT`, the top-level executor code only needs to send each row returned by the query plan tree off to the client. `INSERT . . . SELECT`, `UPDATE`, and `DELETE` are effectively `SELECT`s under a special top-level plan node called `ModifyTable`.

`INSERT . . . SELECT` feeds the rows up to `ModifyTable` for insertion. For `UPDATE`, the planner arranges that each computed row includes all the updated column values, plus the *TID* (tuple ID, or row ID) of the original target row; this data is fed up to the `ModifyTable` node, which uses the information to create a new updated row and mark the old row deleted. For `DELETE`, the only column that is actually returned by the plan is the *TID*, and the `ModifyTable` node simply uses the *TID* to visit each target row and mark it deleted.

A simple `INSERT . . . VALUES` command creates a trivial plan tree consisting of a single `Result` node, which computes just one result row, feeding that up to `ModifyTable` to perform the insertion.

---

# Chapter 48. System Catalogs

The system catalogs are the place where a relational database management system stores schema metadata, such as information about tables and columns, and internal bookkeeping information. LightDB's system catalogs are regular tables. You can drop and recreate the tables, add columns, insert and update values, and severely mess up your system that way. Normally, one should not change the system catalogs by hand, there are normally SQL commands to do that. (For example, CREATE DATABASE inserts a row into the pg\_database catalog — and actually creates the database on disk.) There are some exceptions for particularly esoteric operations, but many of those have been made available as SQL commands over time, and so the need for direct manipulation of the system catalogs is ever decreasing.

## 48.1. Overview

Table 48.1 lists the system catalogs. More detailed documentation of each catalog follows below.

Most system catalogs are copied from the template database during database creation and are thereafter database-specific. A few catalogs are physically shared across all databases in a cluster; these are noted in the descriptions of the individual catalogs.

**Table 48.1. System Catalogs**

Catalog Name	Purpose
lt_attr_ext	table columns extend attributes
lt_database_ext	database extra properties
lt_global_temp_table_ext	global temporary table
lt_package	plorasql package definition
lt_partition_ext	partition table extra properties
lt_proc_ext	function information in the package
lt_type_ext	type priority
lt_variable	variable information in the package
pg_aggregate	aggregate functions
pg_am	relation access methods
pg_amop	access method operators
pg_amproc	access method support functions
pg_attrdef	column default values
pg_attribute	table columns (“attributes”)
pg_authid	authorization identifiers (roles)
pg_auth_members	authorization identifier membership relationships
pg_cast	casts (data type conversions)
pg_class	tables, indexes, sequences, views (“relations”)
pg_collation	collations (locale information)
pg_constraint	check constraints, unique constraints, primary key constraints, foreign key constraints
pg_conversion	encoding conversion information
pg_database	databases within this database cluster
pg_db_role_setting	per-role and per-database settings

<b>Catalog Name</b>	<b>Purpose</b>
pg_default_acl	default privileges for object types
pg_depend	dependencies between database objects
pg_description	descriptions or comments on database objects
pg_enum	enum label and value definitions
pg_event_trigger	event triggers
pg_extension	installed extensions
pg_foreign_data_wrapper	foreign-data wrapper definitions
pg_foreign_server	foreign server definitions
pg_foreign_table	additional foreign table information
pg_index	additional index information
pg_inherits	table inheritance hierarchy
pg_init_privs	object initial privileges
pg_language	languages for writing functions
pg_largeobject	data pages for large objects
pg_largeobject_metadata	metadata for large objects
pg_namespace	schemas
pg_opclass	access method operator classes
pg_operator	operators
pg_opfamily	access method operator families
pg_partitioned_table	information about partition key of tables
pg_policy	row-security policies
pg_proc	functions and procedures
pg_publication	publications for logical replication
pg_publication_rel	relation to publication mapping
pg_range	information about range types
pg_replication_origin	registered replication origins
pg_rewrite	query rewrite rules
pg_seclabel	security labels on database objects
pg_sequence	information about sequences
pg_shdepend	dependencies on shared objects
pg_shdescription	comments on shared objects
pg_shseclabel	security labels on shared database objects
pg_statistic	planner statistics
pg_statistic_ext	extended planner statistics (definition)
pg_statistic_ext_data	extended planner statistics (built statistics)
pg_subscription	logical replication subscriptions
pg_subscription_rel	relation state for subscriptions
pg_tablespace	tablespaces within this database cluster
pg_transform	transforms (data type to procedural language conversions)
pg_trigger	triggers

Catalog Name	Purpose
pg_ts_config	text search configurations
pg_ts_config_map	text search configurations' token mappings
pg_ts_dict	text search dictionaries
pg_ts_parser	text search parsers
pg_ts_template	text search templates
pg_type	data types
pg_user_mapping	mappings of users to foreign servers

## 48.2. lt\_attri\_ext

The catalog `lt_attri_ext` stores update timestamp information about table columns.

**Table 48.2. `lt_attri_ext` Columns**

Column Type	Description
relid oid	The table this column belongs to
colname name	The column name
updatetimestamp int16	Auto update timestamp flag.

## 48.3. lt\_database\_ext

The catalog `lt_database_ext` stores extra information about database. like `pg_database` catalogs, `lt_database_ext` is shared across all databases of a cluster: there is only one copy of `lt_database_ext` per cluster, not one per database.

**Table 48.3. `lt_database_ext` Columns**

Column Type	Description
datoid oid (references <code>pg_database.oid</code> )	database oid
compa_type int4	Compatibility Mode Type
ascii_zero_store_value int4	Lightdb 23.3 introduced a new database level GUC parameter <code>lightdb_ascii_zero_store_value</code> , We store the value here, and it must be within the valid range of 0 to 32, inclusive of both 0 and 32. This value only make means if the database compatible type is set to Oracle or Mysql. For more information about GUC <code>lightdb_ascii_zero_store_value</code> , See <code>lightdb_ascii_zero_store_value</code>

## 48.4. lt\_global\_temp\_table\_ext

The catalog `lt_global_temp_table_ext` stores information about global temporary table.

**Table 48.4. lt\_global\_temp\_table\_ext Columns**

Column Type	Description
relid oid	Row identifier.
nspname name	The OID of the namespace that contains this relation.
relname name	Name of the table.
preserved boolean	True if the session-level global temporary table, False if the transaction-level global temporary table.
code text	Additional information, temporarily as a reserved field.

## 48.5. lt\_package

The catalog `lt_package` stores package information about plorasql procedure language.

**Table 48.5. lt\_package Columns**

Column Type	Description
oid oid	The oid of package.
pkgname name	The package name.
pkgnamespace oid	The namespace oid of package.
pkgowner oid	The owner oid of package.
pkgsecdef bool	Package security clause.
pkgspec text	Text string of package specification.
pkgbody text	Text string of package body.
pkgaccessor anyarray	Package accessor's list.
pkgacl aclitem[ ]	Package access permissions.

## 48.6. lt\_partition\_ext

The catalog `lt_partition_ext` stores information about partition table extra properties.

**Table 48.6. lt\_partition\_ext Columns**

Column Type	Description
oid oid	

Column Type	Description
	Row identifier.
auto_partition_type int32	Automatic partition type. Currently only type 3 is supported. Type 3 is automatic partitioning of time range. Subsequent versions will support other types of automatic partition.
interval_type int32	Time type in automatic partitioning of time range. 6 types in total, 1-6 corresponding to year/month/day/hour/minute/second respectively.
interval_value int32	Interval value.
interval_start_time text	Start time of automatic partition of time range.

## 48.7. lt\_proc\_ext

The catalog `lt_proc_ext` stores information about package function.

**Table 48.7. lt\_proc\_ext Columns**

Column Type	Description
oid oid	Row identifier.
procoid oid (references pg_proc.oid)	OID of the function.
proname name	Name of the function.
pronamespace oid	Package of function.
proaccess char	Package function's access.
procspec text	Package constructor anonymous block.

## 48.8. lt\_type\_ext

The catalog `lt_type_ext` stores information about type priority. For detail see section Section 10.7.

**Table 48.8. lt\_type\_ext Columns**

Column Type	Description
oid oid	Row identifier.
typeid oid (references pg_type.oid)	OID of type.
priority int8	Priority of type.
typnamespace oid	



Column Type	Description
	Namespace of type.
typaccess char	Package type's access.
typtype integer	Type attribute defined in the package.
typename name	Package type's name.

## 48.9. `lt_variable`

The catalog `lt_variable` stores information about package variable.

**Table 48.9. `lt_variable` Columns**

Column Type	Description
oid oid	Row identifier.
varname name	Name of variable.
varnamespace oid	Package of variable.
vartype oid	Type of variable.
vartypmod integer	Domains use <code>vartypmod</code> to record the <code>typmod</code> to be applied to their base type (-1 if base type does not use a <code>typmod</code> ). -1 if this type is not a domain.
varowner oid	Owner of the variable.
varcollation oid (references <code>pg_collation.oid</code> )	<code>varcollation</code> specifies the collation of the type. If the type does not support collations, this will be zero. A base type that supports collations will have a nonzero value here, typically <code>DEFAULT_COLLATION_OID</code> . A domain over a collatable type can have a collation OID different from its base type's, if one was specified for the domain.
varisnotnull boolean	<code>varisnotnull</code> represents a not-null constraint on a type. Used for domains only.
varisimmutable boolean	Is it a table type data.
vareoxaction char	EOX action of the variable.
vardefexpr <code>pg_node_tree</code>	If <code>vardefexpr</code> is not null, it is the <code>nodeToString()</code> representation of a default expression for the type. This is only used for domains.
varacl <code>aclitem[]</code>	Access privileges; see Section 5.7 for details.
varaccess char	Package variable's access.
cursorquery text	

Column Type	Description
	Cursor definition statement.

## 48.10. pg\_aggregate

The catalog `pg_aggregate` stores information about aggregate functions. An aggregate function is a function that operates on a set of values (typically one column from each row that matches a query condition) and returns a single value computed from all these values. Typical aggregate functions are `sum`, `count`, and `max`. Each entry in `pg_aggregate` is an extension of an entry in `pg_proc`. The `pg_proc` entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

**Table 48.10. pg\_aggregate Columns**

Column Type	Description
<code>aggfnoid regproc</code> (references <code>pg_proc.oid</code> )	<code>pg_proc</code> OID of the aggregate function
<code>aggkind char</code>	Aggregate kind: <code>n</code> for “normal” aggregates, <code>o</code> for “ordered-set” aggregates, or <code>h</code> for “hypothetical-set” aggregates
<code>aggnumdirectargs int2</code>	Number of direct (non-aggregated) arguments of an ordered-set or hypothetical-set aggregate, counting a variadic array as one argument. If equal to <code>pronargs</code> , the aggregate must be variadic and the variadic array describes the aggregated arguments as well as the final direct arguments. Always zero for normal aggregates.
<code>aggtransfn regproc</code> (references <code>pg_proc.oid</code> )	Transition function
<code>aggfinalfn regproc</code> (references <code>pg_proc.oid</code> )	Final function (zero if none)
<code>aggcombinefn regproc</code> (references <code>pg_proc.oid</code> )	Combine function (zero if none)
<code>aggserialfn regproc</code> (references <code>pg_proc.oid</code> )	Serialization function (zero if none)
<code>aggdeserialfn regproc</code> (references <code>pg_proc.oid</code> )	Deserialization function (zero if none)
<code>aggmtransfn regproc</code> (references <code>pg_proc.oid</code> )	Forward transition function for moving-aggregate mode (zero if none)
<code>aggminvtransfn regproc</code> (references <code>pg_proc.oid</code> )	Inverse transition function for moving-aggregate mode (zero if none)
<code>aggmfinalfn regproc</code> (references <code>pg_proc.oid</code> )	Final function for moving-aggregate mode (zero if none)
<code>aggfinalextra bool</code>	True to pass extra dummy arguments to <code>aggfinalfn</code>
<code>aggmfinalextra bool</code>	True to pass extra dummy arguments to <code>aggmfinalfn</code>
<code>aggfinalmodify char</code>	Whether <code>aggfinalfn</code> modifies the transition state value: <code>r</code> if it is read-only, <code>s</code> if the <code>aggtransfn</code> cannot be applied after the <code>aggfinalfn</code> , or <code>w</code> if it writes on the value
<code>aggmfinalmodify char</code>	

<b>Column Type</b>	<b>Description</b>
	Like <code>aggfinalmodify</code> , but for the <code>aggmfinalfn</code>
<code>aggsortop oid</code> (references <code>pg_operator.oid</code> )	Associated sort operator (zero if none)
<code>aggtranstype oid</code> (references <code>pg_type.oid</code> )	Data type of the aggregate function's internal transition (state) data
<code>aggtransspace int4</code>	Approximate average size (in bytes) of the transition state data, or zero to use a default estimate
<code>aggmtranstype oid</code> (references <code>pg_type.oid</code> )	Data type of the aggregate function's internal transition (state) data for moving-aggregate mode (zero if none)
<code>aggmtransspace int4</code>	Approximate average size (in bytes) of the transition state data for moving-aggregate mode, or zero to use a default estimate
<code>agginitval text</code>	The initial value of the transition state. This is a text field containing the initial value in its external string representation. If this field is null, the transition state value starts out null.
<code>aggminitval text</code>	The initial value of the transition state for moving-aggregate mode. This is a text field containing the initial value in its external string representation. If this field is null, the transition state value starts out null.

New aggregate functions are registered with the `CREATE AGGREGATE` command. See Section 36.12 for more information about writing aggregate functions and the meaning of the transition functions, etc.

## 48.11. `pg_am`

The catalog `pg_am` stores information about relation access methods. There is one row for each access method supported by the system. Currently, only tables and indexes have access methods. The requirements for table and index access methods are discussed in detail in Chapter 57 and Chapter 58 respectively.

**Table 48.11. `pg_am` Columns**

<b>Column Type</b>	<b>Description</b>
<code>oid oid</code>	Row identifier
<code>amname name</code>	Name of the access method
<code>amhandler regproc</code> (references <code>pg_proc.oid</code> )	OID of a handler function that is responsible for supplying information about the access method
<code>amtype char</code>	t = table (including materialized views), i = index.

**Note**

Before LightDB 9.6, `pg_am` contained many additional columns representing properties of index access methods. That data is now only directly visible at the C code level. However, `pg_index_column_has_property()` and related functions have been added to allow SQL queries to inspect index access method properties; see Table 9.69.

## 48.12. `pg_amop`

The catalog `pg_amop` stores information about operators associated with access method operator families. There is one row for each operator that is a member of an operator family. A family member can be either a *search* operator or an *ordering* operator. An operator can appear in more than one family, but cannot appear in more than one search position nor more than one ordering position within a family. (It is allowed, though unlikely, for an operator to be used for both search and ordering purposes.)

**Table 48.12. `pg_amop` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>amopfamily oid (references pg_opfamily.oid)</code>	The operator family this entry is for
<code>amoplefttype oid (references pg_type.oid)</code>	Left-hand input data type of operator
<code>amoprightrighttype oid (references pg_type.oid)</code>	Right-hand input data type of operator
<code>amopstrategy int2</code>	Operator strategy number
<code>amoppurpose char</code>	Operator purpose, either <code>s</code> for search or <code>o</code> for ordering
<code>amopopr oid (references pg_operator.oid)</code>	OID of the operator
<code>amopmethod oid (references pg_am.oid)</code>	Index access method operator family is for
<code>amopsortfamily oid (references pg_opfamily.oid)</code>	The B-tree operator family this entry sorts according to, if an ordering operator; zero if a search operator

A “search” operator entry indicates that an index of this operator family can be searched to find all rows satisfying `WHERE indexed_column operator constant`. Obviously, such an operator must return `boolean`, and its left-hand input type must match the index's column data type.

An “ordering” operator entry indicates that an index of this operator family can be scanned to return rows in the order represented by `ORDER BY indexed_column operator constant`. Such an operator could return any sortable data type, though again its left-hand input type must match the index's column data type. The exact semantics of the `ORDER BY` are specified by the `amopsortfamily` column, which must reference a B-tree operator family for the operator's result type.

**Note**

At present, it's assumed that the sort order for an ordering operator is the default for the referenced operator family, i.e., `ASC NULLS LAST`. This might someday be relaxed by adding additional columns to specify sort options explicitly.

An entry's `amopmethod` must match the `opfmethod` of its containing operator family (including `amopmethod` here is an intentional denormalization of the catalog structure for performance reasons). Also, `amoplefttype` and `amoprightrighttype` must match the `oprleft` and `oprright` fields of the referenced `pg_operator` entry.

## 48.13. `pg_amproc`

The catalog `pg_amproc` stores information about support functions associated with access method operator families. There is one row for each support function belonging to an operator family.

**Table 48.13. `pg_amproc` Columns**

Column	Type	Description
<code>oid</code>	<code>oid</code>	Row identifier
<code>amprocfamily</code>	<code>oid</code> (references <code>pg_opfamily.oid</code> )	The operator family this entry is for
<code>amprocleftrighttype</code>	<code>oid</code> (references <code>pg_type.oid</code> )	Left-hand input data type of associated operator
<code>amprocrightrighttype</code>	<code>oid</code> (references <code>pg_type.oid</code> )	Right-hand input data type of associated operator
<code>amprocnum</code>	<code>int2</code>	Support function number
<code>amproc</code>	<code>regproc</code> (references <code>pg_proc.oid</code> )	OID of the function

The usual interpretation of the `amprocleftrighttype` and `amprocrightrighttype` fields is that they identify the left and right input types of the operator(s) that a particular support function supports. For some access methods these match the input data type(s) of the support function itself, for others not. There is a notion of “default” support functions for an index, which are those with `amprocleftrighttype` and `amprocrightrighttype` both equal to the index operator class's `opcintype`.

## 48.14. `pg_attrdef`

The catalog `pg_attrdef` stores column default values. The main information about columns is stored in `pg_attribute`. Only columns for which a default value has been explicitly set will have an entry here.

**Table 48.14. `pg_attrdef` Columns**

Column	Type	Description
<code>oid</code>	<code>oid</code>	Row identifier

Column Type	Description
adrelid oid (references pg_class.oid)	The table this column belongs to
adnum int2 (references pg_attribute.attnum)	The number of the column
adbin pg_node_tree	The column default value, in nodeToString() representation. Use pg_get_expr(adbin, adrelid) to convert it to an SQL expression.

## 48.15. pg\_attribute

The catalog `pg_attribute` stores information about table columns. There will be exactly one `pg_attribute` row for every column in every table in the database. (There will also be attribute entries for indexes, and indeed all objects that have `pg_class` entries.)

The term attribute is equivalent to column and is used for historical reasons.

**Table 48.15. pg\_attribute Columns**

Column Type	Description
attrelid oid (references pg_class.oid)	The table this column belongs to
attname name	The column name
atttypid oid (references pg_type.oid)	The data type of this column
attstattarget int4	<code>attstattarget</code> controls the level of detail of statistics accumulated for this column by <code>ANALYZE</code> . A zero value indicates that no statistics should be collected. A negative value says to use the system default statistics target. The exact meaning of positive values is data type-dependent. For scalar data types, <code>attstattarget</code> is both the target number of “most common values” to collect, and the target number of histogram bins to create.
attlen int2	A copy of <code>pg_type.typelen</code> of this column's type
attnum int2	The number of the column. Ordinary columns are numbered from 1 up. System columns, such as <code>ctid</code> , have (arbitrary) negative numbers.
attn_dims int4	Number of dimensions, if the column is an array type; otherwise 0. (Presently, the number of dimensions of an array is not enforced, so any nonzero value effectively means “it's an array”.)
attcacheoff int4	Always -1 in storage, but when loaded into a row descriptor in memory this might be updated to cache the offset of the attribute within the row
atttypmod int4	<code>atttypmod</code> records type-specific data supplied at table creation time (for example, the maximum length of a <code>varchar</code> column). It is passed to type-specific input functions and length coercion functions. The value will generally be -1 for types that do not need <code>atttypmod</code> .

<b>Column Type</b>	<b>Description</b>
<code>attbyval</code> bool	A copy of <code>pg_type.typbyval</code> of this column's type
<code>attstorage</code> char	Normally a copy of <code>pg_type.typstorage</code> of this column's type. For TOAST-able data types, this can be altered after column creation to control storage policy.
<code>attalign</code> char	A copy of <code>pg_type.typalign</code> of this column's type
<code>attnotnull</code> bool	This represents a not-null constraint.
<code>atthasdef</code> bool	This column has a default expression or generation expression, in which case there will be a corresponding entry in the <code>pg_attrdef</code> catalog that actually defines the expression. (Check <code>attgenerated</code> to determine whether this is a default or a generation expression.)
<code>atthasmissing</code> bool	This column has a value which is used where the column is entirely missing from the row, as happens when a column is added with a non-volatile <code>DEFAULT</code> value after the row is created. The actual value used is stored in the <code>attmissingval</code> column.
<code>attidentity</code> char	If a zero byte ( ' ' ), then not an identity column. Otherwise, a = generated always, d = generated by default.
<code>attgenerated</code> char	If a zero byte ( ' ' ), then not a generated column. Otherwise, s = stored. (Other values might be added in the future.)
<code>attisdropped</code> bool	This column has been dropped and is no longer valid. A dropped column is still physically present in the table, but is ignored by the parser and so cannot be accessed via SQL.
<code>attislocal</code> bool	This column is defined locally in the relation. Note that a column can be locally defined and inherited simultaneously.
<code>attinhcount</code> int4	The number of direct ancestors this column has. A column with a nonzero number of ancestors cannot be dropped nor renamed.
<code>attcollation</code> oid (references <code>pg_collation.oid</code> )	The defined collation of the column, or zero if the column is not of a collatable data type.
<code>attacl</code> aclitem[ ]	Column-level access privileges, if any have been granted specifically on this column
<code>attoptions</code> text[ ]	Attribute-level options, as “keyword=value” strings
<code>attfdwoptions</code> text[ ]	Attribute-level foreign data wrapper options, as “keyword=value” strings
<code>attmissingval</code> anyarray	This column has a one element array containing the value used when the column is entirely missing from the row, as happens when the column is added with a non-volatile <code>DEFAULT</code> value after the row is created. The value is only used when <code>atthasmissing</code> is true. If there is no value the column is null.

In a dropped column's `pg_attribute` entry, `atttypid` is reset to zero, but `attlen` and the other fields copied from `pg_type` are still valid. This arrangement is needed to cope with the situation

where the dropped column's data type was later dropped, and so there is no `pg_type` row anymore. `attlen` and the other fields can be used to interpret the contents of a row of the table.

## 48.16. `pg_authid`

The catalog `pg_authid` contains information about database authorization identifiers (roles). A role subsumes the concepts of “users” and “groups”. A user is essentially just a role with the `rolcanlogin` flag set. Any role (with or without `rolcanlogin`) can have other roles as members; see `pg_auth_members`.

Since this catalog contains passwords, it must not be publicly readable. `pg_roles` is a publicly readable view on `pg_authid` that blanks out the password field.

Chapter 19 contains detailed information about user and privilege management.

Because user identities are cluster-wide, `pg_authid` is shared across all databases of a cluster: there is only one copy of `pg_authid` per cluster, not one per database.

**Table 48.16. `pg_authid` Columns**

Column	Type	Description
<code>oid</code>	<code>oid</code>	Row identifier
<code>rolname</code>	<code>name</code>	Role name
<code>rolsuper</code>	<code>bool</code>	Role has superuser privileges
<code>rolinherit</code>	<code>bool</code>	Role automatically inherits privileges of roles it is a member of
<code>rolcreaterole</code>	<code>bool</code>	Role can create more roles
<code>rolcreatedb</code>	<code>bool</code>	Role can create databases
<code>rolcanlogin</code>	<code>bool</code>	Role can log in. That is, this role can be given as the initial session authorization identifier.
<code>rolreplication</code>	<code>bool</code>	Role is a replication role. A replication role can initiate replication connections and create and drop replication slots.
<code>rolbypassrsls</code>	<code>bool</code>	Role bypasses every row level security policy, see Section 5.8 for more information.
<code>rolconlimit</code>	<code>int4</code>	For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
<code>rolpassword</code>	<code>text</code>	Password (possibly encrypted); null if none. The format depends on the form of encryption used.
<code>rolvaliduntil</code>	<code>timestampz</code>	Password expiry time (only used for password authentication); null if no expiration

For an MD5 encrypted password, `rolpassword` column will begin with the string `md5` followed by a 32-character hexadecimal MD5 hash. The MD5 hash will be of the user's password concatenated



to their user name. For example, if user `joe` has password `xyzyzy`, LightDB will store the md5 hash of `xyzyzyjoe`.

If the password is encrypted with SCRAM-SHA-256, it has the format:

```
SCRAM-SHA-256$<iteration count>:<salt>$<StoredKey>:<ServerKey>
```

where `salt`, `StoredKey` and `ServerKey` are in Base64 encoded format. This format is the same as that specified by RFC 5803.

A password that does not follow either of those formats is assumed to be unencrypted.

## 48.17. pg\_auth\_members

The catalog `pg_auth_members` shows the membership relations between roles. Any non-circular set of relationships is allowed.

Because user identities are cluster-wide, `pg_auth_members` is shared across all databases of a cluster: there is only one copy of `pg_auth_members` per cluster, not one per database.

**Table 48.17. pg\_auth\_members Columns**

Column Type	Description
<code>roleid oid</code> (references <code>pg_authid.oid</code> )	ID of a role that has a member
<code>member oid</code> (references <code>pg_authid.oid</code> )	ID of a role that is a member of <code>roleid</code>
<code>grantor oid</code> (references <code>pg_authid.oid</code> )	ID of the role that granted this membership
<code>admin_option bool</code>	True if member can grant membership in <code>roleid</code> to others

## 48.18. pg\_cast

The catalog `pg_cast` stores data type conversion paths, both built-in and user-defined.

It should be noted that `pg_cast` does not represent every type conversion that the system knows how to perform; only those that cannot be deduced from some generic rule. For example, casting between a domain and its base type is not explicitly represented in `pg_cast`. Another important exception is that “automatic I/O conversion casts”, those performed using a data type's own I/O functions to convert to or from `text` or other string types, are not explicitly represented in `pg_cast`.

**Table 48.18. pg\_cast Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>castsource oid</code> (references <code>pg_type.oid</code> )	OID of the source data type
<code>casttarget oid</code> (references <code>pg_type.oid</code> )	OID of the target data type
<code>castfunc oid</code> (references <code>pg_proc.oid</code> )	

Column Type	Description
	The OID of the function to use to perform this cast. Zero is stored if the cast method doesn't require a function.
castcontext char	Indicates what contexts the cast can be invoked in. e means only as an explicit cast (using CAST or :: syntax). a means implicitly in assignment to a target column, as well as explicitly. i means implicitly in expressions, as well as the other cases.
castmethod char	Indicates how the cast is performed. f means that the function specified in the castfunc field is used. i means that the input/output functions are used. b means that the types are binary-coercible, thus no conversion is required.

The cast functions listed in `pg_cast` must always take the cast source type as their first argument type, and return the cast destination type as their result type. A cast function can have up to three arguments. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or -1 if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise.

It is legitimate to create a `pg_cast` entry in which the source and target types are the same, if the associated function takes more than one argument. Such entries represent “length coercion functions” that coerce values of the type to be legal for a particular type modifier value.

When a `pg_cast` entry has different source and target types and a function that takes more than one argument, it represents converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

## 48.19. pg\_class

The catalog `pg_class` catalogs tables and most everything else that has columns or is otherwise similar to a table. This includes indexes (but see also `pg_index`), sequences (but see also `pg_sequence`), views, materialized views, composite types, and TOAST tables; see `relkind`. Below, when we mean all of these kinds of objects we speak of “relations”. Not all columns are meaningful for all relation types.

**Table 48.19. pg\_class Columns**

Column Type	Description
oid oid	Row identifier
relname name	Name of the table, index, view, etc.
relnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this relation
reltype oid (references pg_type.oid)	The OID of the data type that corresponds to this table's row type, if any (zero for indexes, which have no <code>pg_type</code> entry)
reloftype oid (references pg_type.oid)	For typed tables, the OID of the underlying composite type, zero for all other relations
relowner oid (references pg_authid.oid)	Owner of the relation
relam oid (references pg_am.oid)	If this is a table or an index, the access method used (heap, B-tree, hash, etc.)

<b>Column Type</b>	<b>Description</b>
relfilenode oid	Name of the on-disk file of this relation; zero means this is a “mapped” relation whose disk file name is determined by low-level state
reltablespace oid (references pg_tablespace.oid)	The tablespace in which this relation is stored. If zero, the database's default tablespace is implied. (Not meaningful if the relation has no on-disk file.)
relpages int4	Size of the on-disk representation of this table in pages (of size BLCKSZ). This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
reltuples float4	Number of live rows in the table. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
relallvisible int4	Number of pages that are marked all-visible in the table's visibility map. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
reltoastrelid oid (references pg_class.oid)	OID of the TOAST table associated with this table, 0 if none. The TOAST table stores large attributes “out of line” in a secondary table.
relhasindex bool	True if this is a table and it has (or recently had) any indexes
relisshared bool	True if this table is shared across all databases in the cluster. Only certain system catalogs (such as pg_database) are shared.
relpersistence char	p = permanent table, u = unlogged table, t = temporary table
relkind char	r = ordinary table, i = index, S = sequence, t = TOAST table, v = view, m = materialized view, c = composite type, f = foreign table, p = partitioned table, I = partitioned index
relnatts int2	Number of user columns in the relation (system columns not counted). There must be this many corresponding entries in pg_attribute. See also pg_attribute.attnum.
relchecks int2	Number of CHECK constraints on the table; see pg_constraint catalog
relhasrules bool	True if table has (or once had) rules; see pg_rewrite catalog
relhastriggers bool	True if table has (or once had) triggers; see pg_trigger catalog
relhassubclass bool	True if table or index has (or once had) any inheritance children
relrowsecurity bool	True if table has row level security enabled; see pg_policy catalog
relforcerowsecurity bool	True if row level security (when enabled) will also apply to table owner; see pg_policy catalog
relispopulated bool	

Column Type	Description
	True if relation is populated (this is true for all relations other than some materialized views)
relreplident char	Columns used to form “replica identity” for rows: d = default (primary key, if any), n = nothing, f = all columns, i = index with indisreplident set (same as nothing if the index used has been dropped)
relispartition bool	True if table or index is a partition
relrewrite oid (references pg_class.oid)	For new relations being written during a DDL operation that requires a table rewrite, this contains the OID of the original relation; otherwise 0. That state is only visible internally; this field should never contain anything other than 0 for a user-visible relation.
relfrozenxid xid	All transaction IDs before this one have been replaced with a permanent (“frozen”) transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound or to allow <code>lt_xact</code> to be shrunk. Zero ( <code>InvalidTransactionId</code> ) if the relation is not a table.
relminmxid xid	All multixact IDs before this one have been replaced by a transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent multixact ID wraparound or to allow <code>lt_multixact</code> to be shrunk. Zero ( <code>InvalidMultiXactId</code> ) if the relation is not a table.
relacl aclitem[ ]	Access privileges; see Section 5.7 for details
reloptions text[ ]	Access-method-specific options, as “keyword=value” strings
relpartbound pg_node_tree	If table is a partition (see <code>relispartition</code> ), internal representation of the partition bound

Several of the Boolean flags in `pg_class` are maintained lazily: they are guaranteed to be true if that's the correct state, but may not be reset to false immediately when the condition is no longer true. For example, `relhasindex` is set by `CREATE INDEX`, but it is never cleared by `DROP INDEX`. Instead, `VACUUM` clears `relhasindex` if it finds the table has no indexes. This arrangement avoids race conditions and improves concurrency.

## 48.20. pg\_collation

The catalog `pg_collation` describes the available collations, which are essentially mappings from an SQL name to operating system locale categories. See Section 21.2 for more information.

**Table 48.20. pg\_collation Columns**

Column Type	Description
oid oid	Row identifier
collname name	Collation name (unique per namespace and encoding)
collnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this collation

Column Type	Description
<code>collowner oid</code> (references <code>pg_authid.oid</code> )	Owner of the collation
<code>collprovider char</code>	Provider of the collation: <code>d</code> = database default, <code>c</code> = libc, <code>i</code> = icu
<code>collisdeterministic bool</code>	Is the collation deterministic?
<code>collencoding int4</code>	Encoding in which the collation is applicable, or -1 if it works for any encoding
<code>collcollate name</code>	LC_COLLATE for this collation object
<code>collctype name</code>	LC_CTYPE for this collation object
<code>collversion text</code>	Provider-specific version of the collation. This is recorded when the collation is created and then checked when it is used, to detect changes in the collation definition that could lead to data corruption.

Note that the unique key on this catalog is (`collname`, `collencoding`, `collnamespace`) not just (`collname`, `collnamespace`). LightDB generally ignores all collations that do not have `collencoding` equal to either the current database's encoding or -1, and creation of new entries with the same name as an entry with `collencoding` = -1 is forbidden. Therefore it is sufficient to use a qualified SQL name (*schema.name*) to identify a collation, even though this is not unique according to the catalog definition. The reason for defining the catalog this way is that `initdb` fills it in at cluster initialization time with entries for all locales available on the system, so it must be able to hold entries for all encodings that might ever be used in the cluster.

In the `template0` database, it could be useful to create collations whose encoding does not match the database encoding, since they could match the encodings of databases later cloned from `template0`. This would currently have to be done manually.

## 48.21. `pg_constraint`

The catalog `pg_constraint` stores check, primary key, unique, foreign key, and exclusion constraints on tables. (Column constraints are not treated specially. Every column constraint is equivalent to some table constraint.) Not-null constraints are represented in the `pg_attribute` catalog, not here.

User-defined constraint triggers (created with `CREATE CONSTRAINT TRIGGER`) also give rise to an entry in this table.

Check constraints on domains are stored here, too.

**Table 48.21. `pg_constraint` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>conname name</code>	Constraint name (not necessarily unique!)
<code>connamespace oid</code> (references <code>pg_namespace.oid</code> )	The OID of the namespace that contains this constraint

<b>Column Type</b>	<b>Description</b>
contype char	c = check constraint, f = foreign key constraint, p = primary key constraint, u = unique constraint, t = constraint trigger, x = exclusion constraint
condeferrable bool	Is the constraint deferrable?
condeferred bool	Is the constraint deferred by default?
convalidated bool	Has the constraint been validated? Currently, can only be false for foreign keys and CHECK constraints
conrelid oid (references pg_class.oid)	The table this constraint is on; 0 if not a table constraint
contypid oid (references pg_type.oid)	The domain this constraint is on; 0 if not a domain constraint
conindid oid (references pg_class.oid)	The index supporting this constraint, if it's a unique, primary key, foreign key, or exclusion constraint; else 0
conparentid oid (references pg_constraint.oid)	The corresponding constraint in the parent partitioned table, if this is a constraint in a partition; else 0
confrelid oid (references pg_class.oid)	If a foreign key, the referenced table; else 0
confupdtype char	Foreign key update action code: a = no action, r = restrict, c = cascade, n = set null, d = set default
confdeltype char	Foreign key deletion action code: a = no action, r = restrict, c = cascade, n = set null, d = set default
confmatchtype char	Foreign key match type: f = full, p = partial, s = simple
conislocal bool	This constraint is defined locally for the relation. Note that a constraint can be locally defined and inherited simultaneously.
coninhcount int4	The number of direct inheritance ancestors this constraint has. A constraint with a nonzero number of ancestors cannot be dropped nor renamed.
connoinherit bool	This constraint is defined locally for the relation. It is a non-inheritable constraint.
conkey int2[] (references pg_attribute.attnum)	If a table constraint (including foreign keys, but not constraint triggers), list of the constrained columns
confkey int2[] (references pg_attribute.attnum)	If a foreign key, list of the referenced columns
conpeqop oid[] (references pg_operator.oid)	If a foreign key, list of the equality operators for PK = FK comparisons
conppeqop oid[] (references pg_operator.oid)	If a foreign key, list of the equality operators for PK = PK comparisons
conffeqop oid[] (references pg_operator.oid)	

Column Type	Description
	If a foreign key, list of the equality operators for FK = FK comparisons
conexcl op oid[] (references pg_operator.oid)	If an exclusion constraint, list of the per-column exclusion operators
conbin pg_node_tree	If a check constraint, an internal representation of the expression. (It's recommended to use pg_get_constraintdef() to extract the definition of a check constraint.)

In the case of an exclusion constraint, `conkey` is only useful for constraint elements that are simple column references. For other cases, a zero appears in `conkey` and the associated index must be consulted to discover the expression that is constrained. (`conkey` thus has the same contents as `pg_index.indkey` for the index.)

### Note

`pg_class.relchecks` needs to agree with the number of check-constraint entries found in this table for each relation.

## 48.22. pg\_conversion

The catalog `pg_conversion` describes encoding conversion functions. See `CREATE CONVERSION` for more information.

**Table 48.22. pg\_conversion Columns**

Column Type	Description
oid oid	Row identifier
conname name	Conversion name (unique within a namespace)
connamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this conversion
conowner oid (references pg_authid.oid)	Owner of the conversion
conforencoding int4	Source encoding ID
contoencoding int4	Destination encoding ID
conproc regproc (references pg_proc.oid)	Conversion function
condefault bool	True if this is the default conversion

## 48.23. pg\_database

The catalog `pg_database` stores information about the available databases. Databases are created with the `CREATE DATABASE` command. Consult Chapter 20 for details about the meaning of some of the parameters.

Unlike most system catalogs, `pg_database` is shared across all databases of a cluster: there is only one copy of `pg_database` per cluster, not one per database.

**Table 48.23. `pg_database` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>datname name</code>	Database name
<code>datdba oid (references pg_authid.oid)</code>	Owner of the database, usually the user who created it
<code>encoding int4</code>	Character encoding for this database ( <code>pg_encoding_to_char()</code> can translate this number to the encoding name)
<code>datcollate name</code>	LC_COLLATE for this database
<code>datctype name</code>	LC_CTYPE for this database
<code>datistemplate bool</code>	If true, then this database can be cloned by any user with <code>CREATEDB</code> privileges; if false, then only superusers or the owner of the database can clone it.
<code>dataallowconn bool</code>	If false then no one can connect to this database. This is used to protect the <code>template0</code> database from being altered.
<code>datconnlimit int4</code>	Sets maximum number of concurrent connections that can be made to this database. -1 means no limit.
<code>datlastsysoid oid</code>	Last system OID in the database; useful particularly to <code>lt_dump</code>
<code>datfrozenxid xid</code>	All transaction IDs before this one have been replaced with a permanent (“frozen”) transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow <code>lt_xact</code> to be shrunk. It is the minimum of the per-table <code>pg_class.relfrozenxid</code> values.
<code>datminmxid xid</code>	All multixact IDs before this one have been replaced with a transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent multixact ID wraparound or to allow <code>lt_multixact</code> to be shrunk. It is the minimum of the per-table <code>pg_class.relminmxid</code> values.
<code>dattablespace oid (references pg_tablespace.oid)</code>	The default tablespace for the database. Within this database, all tables for which <code>pg_class.reltablespace</code> is zero will be stored in this tablespace; in particular, all the non-shared system catalogs will be there.
<code>datacl aclitem[]</code>	Access privileges; see Section 5.7 for details

## 48.24. `pg_db_role_setting`

The catalog `pg_db_role_setting` records the default values that have been set for run-time configuration variables, for each role and database combination.



Unlike most system catalogs, `pg_db_role_setting` is shared across all databases of a cluster: there is only one copy of `pg_db_role_setting` per cluster, not one per database.

**Table 48.24. `pg_db_role_setting` Columns**

Column Type	Description
<code>setdatabase oid</code> (references <code>pg_database.oid</code> )	The OID of the database the setting is applicable to, or zero if not database-specific
<code>setrole oid</code> (references <code>pg_authid.oid</code> )	The OID of the role the setting is applicable to, or zero if not role-specific
<code>setconfig text[ ]</code>	Defaults for run-time configuration variables

## 48.25. `pg_default_acl`

The catalog `pg_default_acl` stores initial privileges to be assigned to newly created objects.

**Table 48.25. `pg_default_acl` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>defaclrole oid</code> (references <code>pg_authid.oid</code> )	The OID of the role associated with this entry
<code>defaclnamespace oid</code> (references <code>pg_namespace.oid</code> )	The OID of the namespace associated with this entry, or 0 if none
<code>defaclobjtype char</code>	Type of object this entry is for: <code>r</code> = relation (table, view), <code>S</code> = sequence, <code>f</code> = function, <code>T</code> = type, <code>n</code> = schema
<code>defaclacl aclitem[ ]</code>	Access privileges that this type of object should have on creation

A `pg_default_acl` entry shows the initial privileges to be assigned to an object belonging to the indicated user. There are currently two types of entry: “global” entries with `defaclnamespace` = 0, and “per-schema” entries that reference a particular schema. If a global entry is present then it *overrides* the normal hard-wired default privileges for the object type. A per-schema entry, if present, represents privileges to be *added* to the global or hard-wired default privileges.

Note that when an ACL entry in another catalog is null, it is taken to represent the hard-wired default privileges for its object, *not* whatever might be in `pg_default_acl` at the moment. `pg_default_acl` is only consulted during object creation.

## 48.26. `pg_depend`

The catalog `pg_depend` records the dependency relationships between database objects. This information allows `DROP` commands to find which other objects must be dropped by `DROP CASCADE` or prevent dropping in the `DROP RESTRICT` case.

See also `pg_shdepend`, which performs a similar function for dependencies involving objects that are shared across a database cluster.

**Table 48.26. pg\_depend Columns**

Column Type	Description
classid oid (references pg_class.oid)	The OID of the system catalog the dependent object is in
objid oid (references any OID column)	The OID of the specific dependent object
objsubid int4	For a table column, this is the column number (the objid and classid refer to the table itself). For all other object types, this column is zero.
refclassid oid (references pg_class.oid)	The OID of the system catalog the referenced object is in
refobjid oid (references any OID column)	The OID of the specific referenced object
refobjsubid int4	For a table column, this is the column number (the refobjid and refclassid refer to the table itself). For all other object types, this column is zero.
deptype char	A code defining the specific semantics of this dependency relationship; see text

In all cases, a `pg_depend` entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

`DEPENDENCY_NORMAL` (n)

A normal relationship between separately-created objects. The dependent object can be dropped without affecting the referenced object. The referenced object can only be dropped by specifying `CASCADE`, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.

`DEPENDENCY_AUTO` (a)

The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of `RESTRICT` or `CASCADE` mode) if the referenced object is dropped. Example: a named constraint on a table is made auto-dependent on the table, so that it will go away if the table is dropped.

`DEPENDENCY_INTERNAL` (i)

The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation. A direct `DROP` of the dependent object will be disallowed outright (we'll tell the user to issue a `DROP` against the referenced object, instead). A `DROP` of the referenced object will result in automatically dropping the dependent object whether `CASCADE` is specified or not. If the dependent object has to be dropped due to a dependency on some other object being removed, its drop is converted to a drop of the referenced object, so that `NORMAL` and `AUTO` dependencies of the dependent object behave much like they were dependencies of the referenced object. Example: a view's `ON SELECT` rule is made internally dependent on the view, preventing it from being dropped while the view remains. Dependencies of the rule (such as tables it refers to) act as if they were dependencies of the view.

`DEPENDENCY_PARTITION_PRI` (P)

`DEPENDENCY_PARTITION_SEC` (S)

The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation; however, unlike `INTERNAL`, there is more than one

such referenced object. The dependent object must not be dropped unless at least one of these referenced objects is dropped; if any one is, the dependent object should be dropped whether or not `CASCADE` is specified. Also unlike `INTERNAL`, a drop of some other object that the dependent object depends on does not result in automatic deletion of any partition-referenced object. Hence, if the drop does not cascade to at least one of these objects via some other path, it will be refused. (In most cases, the dependent object shares all its non-partition dependencies with at least one partition-referenced object, so that this restriction does not result in blocking any cascaded delete.) Primary and secondary partition dependencies behave identically except that the primary dependency is preferred for use in error messages; hence, a partition-dependent object should have one primary partition dependency and one or more secondary partition dependencies. Note that partition dependencies are made in addition to, not instead of, any dependencies the object would normally have. This simplifies `ATTACH/DETACH PARTITION` operations: the partition dependencies need only be added or removed. Example: a child partitioned index is made partition-dependent on both the partition table it is on and the parent partitioned index, so that it goes away if either of those is dropped, but not otherwise. The dependency on the parent index is primary, so that if the user tries to drop the child partitioned index, the error message will suggest dropping the parent index instead (not the table).

#### `DEPENDENCY_EXTENSION (e)`

The dependent object is a member of the *extension* that is the referenced object (see `pg_extension`). The dependent object can be dropped only via `DROP EXTENSION` on the referenced object. Functionally this dependency type acts the same as an `INTERNAL` dependency, but it's kept separate for clarity and to simplify `lt_dump`.

#### `DEPENDENCY_AUTO_EXTENSION (x)`

The dependent object is not a member of the extension that is the referenced object (and so it should not be ignored by `lt_dump`), but it cannot function without the extension and should be auto-dropped if the extension is. The dependent object may be dropped on its own as well. Functionally this dependency type acts the same as an `AUTO` dependency, but it's kept separate for clarity and to simplify `lt_dump`.

#### `DEPENDENCY_PIN (p)`

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by `initdb`. The columns for the dependent object contain zeroes.

Other dependency flavors might be needed in future.

Note that it's quite possible for two objects to be linked by more than one `pg_depend` entry. For example, a child partitioned index would have both a partition-type dependency on its associated partition table, and an auto dependency on each column of that table that it indexes. This sort of situation expresses the union of multiple dependency semantics. A dependent object can be dropped without `CASCADE` if any of its dependencies satisfies its condition for automatic dropping. Conversely, all the dependencies' restrictions about which objects must be dropped together must be satisfied.

## 48.27. `pg_description`

The catalog `pg_description` stores optional descriptions (comments) for each database object. Descriptions can be manipulated with the `COMMENT` command and viewed with `ltsql`'s `\d` commands. Descriptions of many built-in system objects are provided in the initial contents of `pg_description`.

See also `pg_shdescription`, which performs a similar function for descriptions involving objects that are shared across a database cluster.

**Table 48.27. pg\_description Columns**

Column Type	Description
objoid oid	(references any OID column) The OID of the object this description pertains to
classoid oid	(references pg_class.oid) The OID of the system catalog this object appears in
objsubid int4	For a comment on a table column, this is the column number (the objoid and classoid refer to the table itself). For all other object types, this column is zero.
description text	Arbitrary text that serves as the description of this object

## 48.28. pg\_enum

The `pg_enum` catalog contains entries showing the values and labels for each enum type. The internal representation of a given enum value is actually the OID of its associated row in `pg_enum`.

**Table 48.28. pg\_enum Columns**

Column Type	Description
oid oid	Row identifier
enumtypeid oid	(references pg_type.oid) The OID of the <code>pg_type</code> entry owning this enum value
enumsortorder float4	The sort position of this enum value within its enum type
enumlabel name	The textual label for this enum value

The OIDs for `pg_enum` rows follow a special rule: even-numbered OIDs are guaranteed to be ordered in the same way as the sort ordering of their enum type. That is, if two even OIDs belong to the same enum type, the smaller OID must have the smaller `enumsortorder` value. Odd-numbered OID values need bear no relationship to the sort order. This rule allows the enum comparison routines to avoid catalog lookups in many common cases. The routines that create and alter enum types attempt to assign even OIDs to enum values whenever possible.

When an enum type is created, its members are assigned sort-order positions 1..n. But members added later might be given negative or fractional values of `enumsortorder`. The only requirement on these values is that they be correctly ordered and unique within each enum type.

## 48.29. pg\_event\_trigger

The catalog `pg_event_trigger` stores event triggers. See Chapter 38 for more information.

**Table 48.29. pg\_event\_trigger Columns**

Column Type	Description
oid oid	Row identifier
evtname name	

Column Type	Description
	Trigger name (must be unique)
evtevent name	Identifies the event for which this trigger fires
evtowner oid (references pg_authid.oid)	Owner of the event trigger
evtfoid oid (references pg_proc.oid)	The function to be called
evtenabled char	Controls in which session_replication_role modes the event trigger fires. O = trigger fires in “origin” and “local” modes, D = trigger is disabled, R = trigger fires in “replica” mode, A = trigger fires always.
evttags text[ ]	Command tags for which this trigger will fire. If NULL, the firing of this trigger is not restricted on the basis of the command tag.

## 48.30. pg\_extension

The catalog `pg_extension` stores information about the installed extensions. See Section 36.17 for details about extensions.

**Table 48.30. pg\_extension Columns**

Column Type	Description
oid oid	Row identifier
extname name	Name of the extension
extowner oid (references pg_authid.oid)	Owner of the extension
extnamespace oid (references pg_namespace.oid)	Schema containing the extension's exported objects
extrelocatable bool	True if extension can be relocated to another schema
extversion text	Version name for the extension
extconfig oid[ ] (references pg_class.oid)	Array of <code>regclass</code> OIDs for the extension's configuration table(s), or NULL if none
extcondition text[ ]	Array of WHERE-clause filter conditions for the extension's configuration table(s), or NULL if none

Note that unlike most catalogs with a “namespace” column, `extnamespace` is not meant to imply that the extension belongs to that schema. Extension names are never schema-qualified. Rather, `extnamespace` indicates the schema that contains most or all of the extension's objects. If `extrelocatable` is true, then this schema must in fact contain all schema-qualifiable objects belonging to the extension.

## 48.31. pg\_foreign\_data\_wrapper

The catalog `pg_foreign_data_wrapper` stores foreign-data wrapper definitions. A foreign-data wrapper is the mechanism by which external data, residing on foreign servers, is accessed.

**Table 48.31. `pg_foreign_data_wrapper` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>fdwname name</code>	Name of the foreign-data wrapper
<code>fdwowner oid (references pg_authid.oid)</code>	Owner of the foreign-data wrapper
<code>fdwhandler oid (references pg_proc.oid)</code>	References a handler function that is responsible for supplying execution routines for the foreign-data wrapper. Zero if no handler is provided
<code>fdwvalidator oid (references pg_proc.oid)</code>	References a validator function that is responsible for checking the validity of the options given to the foreign-data wrapper, as well as options for foreign servers and user mappings using the foreign-data wrapper. Zero if no validator is provided
<code>fdwacl aclitem[ ]</code>	Access privileges; see Section 5.7 for details
<code>fdwoptions text[ ]</code>	Foreign-data wrapper specific options, as “keyword=value” strings

## 48.32. `pg_foreign_server`

The catalog `pg_foreign_server` stores foreign server definitions. A foreign server describes a source of external data, such as a remote server. Foreign servers are accessed via foreign-data wrappers.

**Table 48.32. `pg_foreign_server` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>srvname name</code>	Name of the foreign server
<code>srvowner oid (references pg_authid.oid)</code>	Owner of the foreign server
<code>srvfdw oid (references pg_foreign_data_wrapper.oid)</code>	OID of the foreign-data wrapper of this foreign server
<code>srvtype text</code>	Type of the server (optional)
<code>srvversion text</code>	Version of the server (optional)
<code>srvacl aclitem[ ]</code>	Access privileges; see Section 5.7 for details
<code>srvoptions text[ ]</code>	Foreign server specific options, as “keyword=value” strings

## 48.33. pg\_foreign\_table

The catalog `pg_foreign_table` contains auxiliary information about foreign tables. A foreign table is primarily represented by a `pg_class` entry, just like a regular table. Its `pg_foreign_table` entry contains the information that is pertinent only to foreign tables and not any other kind of relation.

**Table 48.33. pg\_foreign\_table Columns**

Column Type	Description
<code>ftrelid oid</code> (references <code>pg_class.oid</code> )	OID of the <code>pg_class</code> entry for this foreign table
<code>ftserver oid</code> (references <code>pg_foreign_server.oid</code> )	OID of the foreign server for this foreign table
<code>ftoptions text[]</code>	Foreign table options, as “keyword=value” strings

## 48.34. pg\_index

The catalog `pg_index` contains part of the information about indexes. The rest is mostly in `pg_class`.

**Table 48.34. pg\_index Columns**

Column Type	Description
<code>indexrelid oid</code> (references <code>pg_class.oid</code> )	The OID of the <code>pg_class</code> entry for this index
<code>indrelid oid</code> (references <code>pg_class.oid</code> )	The OID of the <code>pg_class</code> entry for the table this index is for
<code>indnatts int2</code>	The total number of columns in the index (duplicates <code>pg_class.relnatts</code> ); this number includes both key and included attributes
<code>indnkeyatts int2</code>	The number of <i>key columns</i> in the index, not counting any <i>included columns</i> , which are merely stored and do not participate in the index semantics
<code>indisunique bool</code>	If true, this is a unique index
<code>indisprimary bool</code>	If true, this index represents the primary key of the table ( <code>indisunique</code> should always be true when this is true)
<code>indisexclusion bool</code>	If true, this index supports an exclusion constraint
<code>indimmediate bool</code>	If true, the uniqueness check is enforced immediately on insertion (irrelevant if <code>indisunique</code> is not true)
<code>indisclustered bool</code>	If true, the table was last clustered on this index
<code>indisvalid bool</code>	If true, the index is currently valid for queries. False means the index is possibly incomplete: it must still be modified by <code>INSERT/UPDATE</code> operations, but it cannot

Column Type	Description
	safely be used for queries. If it is unique, the uniqueness property is not guaranteed true either.
<code>indcheckxmin</code> bool	If true, queries must not use the index until the <code>xmin</code> of this <code>pg_index</code> row is below their <code>TransactionXmin</code> event horizon, because the table may contain broken HOT chains with incompatible rows that they can see
<code>indisready</code> bool	If true, the index is currently ready for inserts. False means the index must be ignored by INSERT/UPDATE operations.
<code>indislive</code> bool	If false, the index is in process of being dropped, and should be ignored for all purposes (including HOT-safety decisions)
<code>indisreplident</code> bool	If true this index has been chosen as “replica identity” using <code>ALTER TABLE ... REPLICA IDENTITY USING INDEX ...</code>
<code>indkey</code> int2vector (references <code>pg_attribute.attnum</code> )	This is an array of <code>indnatts</code> values that indicate which table columns this index indexes. For example a value of <code>1 3</code> would mean that the first and the third table columns make up the index entries. Key columns come before non-key (included) columns. A zero in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference.
<code>indcollation</code> oidvector (references <code>pg_collation.oid</code> )	For each column in the index key ( <code>indnkeyatts</code> values), this contains the OID of the collation to use for the index, or zero if the column is not of a collatable data type.
<code>indclass</code> oidvector (references <code>pg_opclass.oid</code> )	For each column in the index key ( <code>indnkeyatts</code> values), this contains the OID of the operator class to use. See <code>pg_opclass</code> for details.
<code>indoption</code> int2vector	This is an array of <code>indnkeyatts</code> values that store per-column flag bits. The meaning of the bits is defined by the index's access method.
<code>indexprs</code> <code>pg_node_tree</code>	Expression trees (in <code>nodeToString()</code> representation) for index attributes that are not simple column references. This is a list with one element for each zero entry in <code>indkey</code> . Null if all index attributes are simple references.
<code>indpred</code> <code>pg_node_tree</code>	Expression tree (in <code>nodeToString()</code> representation) for partial index predicate. Null if not a partial index.

## 48.35. `pg_inherits`

The catalog `pg_inherits` records information about table and index inheritance hierarchies. There is one entry for each direct parent-child table or index relationship in the database. (Indirect inheritance can be determined by following chains of entries.)

**Table 48.35. `pg_inherits` Columns**

Column Type	Description
<code>inhrelid</code> oid (references <code>pg_class.oid</code> )	The OID of the child table or index
<code>inhparent</code> oid (references <code>pg_class.oid</code> )	



Column Type	Description
	The OID of the parent table or index
inhseqno int4	If there is more than one direct parent for a child table (multiple inheritance), this number tells the order in which the inherited columns are to be arranged. The count starts at 1. Indexes cannot have multiple inheritance, since they can only inherit when using declarative partitioning.

## 48.36. pg\_init\_privs

The catalog `pg_init_privs` records information about the initial privileges of objects in the system. There is one entry for each object in the database which has a non-default (non-NULL) initial set of privileges.

Objects can have initial privileges either by having those privileges set when the system is initialized (by `initdb`) or when the object is created during a `CREATE EXTENSION` and the extension script sets initial privileges using the `GRANT` system. Note that the system will automatically handle recording of the privileges during the extension script and that extension authors need only use the `GRANT` and `REVOKE` statements in their script to have the privileges recorded. The `privtype` column indicates if the initial privilege was set by `initdb` or during a `CREATE EXTENSION` command.

Objects which have initial privileges set by `initdb` will have entries where `privtype` is 'i', while objects which have initial privileges set by `CREATE EXTENSION` will have entries where `privtype` is 'e'.

**Table 48.36. pg\_init\_privs Columns**

Column Type	Description
objoid oid (references any OID column)	The OID of the specific object
classoid oid (references pg_class.oid)	The OID of the system catalog the object is in
objsubid int4	For a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other object types, this column is zero.
privtype char	A code defining the type of initial privilege of this object; see text
initprivs aclitem[ ]	The initial access privileges; see Section 5.7 for details

## 48.37. pg\_language

The catalog `pg_language` registers languages in which you can write functions or stored procedures. See `CREATE LANGUAGE` and Chapter 40 for more information about language handlers.

**Table 48.37. pg\_language Columns**

Column Type	Description
oid oid	Row identifier
lanname name	

Column Type	Description
	Name of the language
lanowner oid (references pg_authid.oid)	Owner of the language
lanispl bool	This is false for internal languages (such as SQL) and true for user-defined languages. Currently, <code>lt_dump</code> still uses this to determine which languages need to be dumped, but this might be replaced by a different mechanism in the future.
lanpltrusted bool	True if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only superusers can create functions in untrusted languages.
lanplcallfoid oid (references pg_proc.oid)	For noninternal languages this references the language handler, which is a special function that is responsible for executing all functions that are written in the particular language
laninline oid (references pg_proc.oid)	This references a function that is responsible for executing “inline” anonymous code blocks (DO blocks). Zero if inline blocks are not supported.
lanvalidator oid (references pg_proc.oid)	This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. Zero if no validator is provided.
lanacl aclitem[ ]	Access privileges; see Section 5.7 for details

## 48.38. pg\_largeobject

The catalog `pg_largeobject` holds the data making up “large objects”. A large object is identified by an OID assigned when it is created. Each large object is broken into segments or “pages” small enough to be conveniently stored as rows in `pg_largeobject`. The amount of data per page is defined to be `LOBLKSIZE` (which is currently `BLCKSZ/4`, or typically 2 kB).

Prior to LightDB 9.0, there was no permission structure associated with large objects. As a result, `pg_largeobject` was publicly readable and could be used to obtain the OIDs (and contents) of all large objects in the system. This is no longer the case; use `pg_largeobject_metadata` to obtain a list of large object OIDs.

**Table 48.38. pg\_largeobject Columns**

Column Type	Description
loid oid (references pg_largeobject_metadata.oid)	Identifier of the large object that includes this page
pageno int4	Page number of this page within its large object (counting from zero)
data bytea	Actual data stored in the large object. This will never be more than <code>LOBLKSIZE</code> bytes and might be less.

Each row of `pg_largeobject` holds data for one page of a large object, beginning at byte offset (`pageno * LOBLKSIZE`) within the object. The implementation allows sparse storage: pages might be missing, and might be shorter than `LOBLKSIZE` bytes even if they are not the last page of the object. Missing regions within a large object read as zeroes.

## 48.39. pg\_largeobject\_metadata

The catalog `pg_largeobject_metadata` holds metadata associated with large objects. The actual large object data is stored in `pg_largeobject`.

**Table 48.39. pg\_largeobject\_metadata Columns**

Column Type	Description
oid oid	Row identifier
lomowner oid (references pg_authid.oid)	Owner of the large object
lomacl aclitem[ ]	Access privileges; see Section 5.7 for details

## 48.40. pg\_namespace

The catalog `pg_namespace` stores namespaces. A namespace is the structure underlying SQL schemas: each namespace can have a separate collection of relations, types, etc. without name conflicts.

**Table 48.40. pg\_namespace Columns**

Column Type	Description
oid oid	Row identifier
nspname name	Name of the namespace
nspowner oid (references pg_authid.oid)	Owner of the namespace
nspacl aclitem[ ]	Access privileges; see Section 5.7 for details

## 48.41. pg\_opclass

The catalog `pg_opclass` defines index access method operator classes. Each operator class defines semantics for index columns of a particular data type and a particular index access method. An operator class essentially specifies that a particular operator family is applicable to a particular indexable column data type. The set of operators from the family that are actually usable with the indexed column are whichever ones accept the column's data type as their left-hand input.

Operator classes are described at length in Section 36.16.

**Table 48.41. pg\_opclass Columns**

Column Type	Description
oid oid	Row identifier
opcmeth oid (references pg_am.oid)	Index access method operator class is for

Column Type	Description
opcname name	Name of this operator class
opcnamespace oid (references pg_namespace.oid)	Namespace of this operator class
opcowner oid (references pg_authid.oid)	Owner of the operator class
opcfamily oid (references pg_opfamily.oid)	Operator family containing the operator class
opcintype oid (references pg_type.oid)	Data type that the operator class indexes
opcdefault bool	True if this operator class is the default for opcintype
opckeytype oid (references pg_type.oid)	Type of data stored in index, or zero if same as opcintype

An operator class's `opcmethod` must match the `opfmethod` of its containing operator family. Also, there must be no more than one `pg_opclass` row having `opcdefault` true for any given combination of `opcmethod` and `opcintype`.

## 48.42. pg\_operator

The catalog `pg_operator` stores information about operators. See `CREATE OPERATOR` and Section 36.14 for more information.

**Table 48.42. pg\_operator Columns**

Column Type	Description
oid oid	Row identifier
oprname name	Name of the operator
oprnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this operator
oprowner oid (references pg_authid.oid)	Owner of the operator
oprkind char	b = infix (“both”), l = prefix (“left”), r = postfix (“right”)
oprcanmerge bool	This operator supports merge joins
oprcanhash bool	This operator supports hash joins
oprleft oid (references pg_type.oid)	Type of the left operand
oprright oid (references pg_type.oid)	Type of the right operand
oprresult oid (references pg_type.oid)	Type of the result
oprcom oid (references pg_operator.oid)	

Column Type	Description
	Commutator of this operator, if any
oprnegate oid (references pg_operator.oid)	Negator of this operator, if any
oprcode regproc (references pg_proc.oid)	Function that implements this operator
oprrest regproc (references pg_proc.oid)	Restriction selectivity estimation function for this operator
oprjoin regproc (references pg_proc.oid)	Join selectivity estimation function for this operator

Unused columns contain zeroes. For example, `oprleft` is zero for a prefix operator.

## 48.43. pg\_opfamily

The catalog `pg_opfamily` defines operator families. Each operator family is a collection of operators and associated support routines that implement the semantics specified for a particular index access method. Furthermore, the operators in a family are all “compatible”, in a way that is specified by the access method. The operator family concept allows cross-data-type operators to be used with indexes and to be reasoned about using knowledge of access method semantics.

Operator families are described at length in Section 36.16.

**Table 48.43. pg\_opfamily Columns**

Column Type	Description
oid oid	Row identifier
opfmeth oid (references pg_am.oid)	Index access method operator family is for
opfname name	Name of this operator family
opfnamespace oid (references pg_namespace.oid)	Namespace of this operator family
opfowner oid (references pg_authid.oid)	Owner of the operator family

The majority of the information defining an operator family is not in its `pg_opfamily` row, but in the associated rows in `pg_amop`, `pg_amproc`, and `pg_opclass`.

## 48.44. pg\_partitioned\_table

The catalog `pg_partitioned_table` stores information about how tables are partitioned.

**Table 48.44. pg\_partitioned\_table Columns**

Column Type	Description
partrelid oid (references pg_class.oid)	The OID of the <code>pg_class</code> entry for this partitioned table
partstrat char	

Column Type	Description
	Partitioning strategy; h = hash partitioned table, l = list partitioned table, r = range partitioned table
partnatts int2	The number of columns in partition key
partdefid oid (references pg_class.oid)	The OID of the pg_class entry for the default partition of this partitioned table, or zero if this partitioned table does not have a default partition.
partattrs int2vector (references pg_attribute.attnum)	This is an array of partnatts values that indicate which table columns are part of the partition key. For example, a value of 1 3 would mean that the first and the third table columns make up the partition key. A zero in this array indicates that the corresponding partition key column is an expression, rather than a simple column reference.
partclass oidvector (references pg_opclass.oid)	For each column in the partition key, this contains the OID of the operator class to use. See pg_opclass for details.
partcollation oidvector (references pg_collation.oid)	For each column in the partition key, this contains the OID of the collation to use for partitioning, or zero if the column is not of a collatable data type.
partexprs pg_node_tree	Expression trees (in nodeToString() representation) for partition key columns that are not simple column references. This is a list with one element for each zero entry in partattrs. Null if all partition key columns are simple references.

## 48.45. pg\_policy

The catalog pg\_policy stores row level security policies for tables. A policy includes the kind of command that it applies to (possibly all commands), the roles that it applies to, the expression to be added as a security-barrier qualification to queries that include the table, and the expression to be added as a WITH CHECK option for queries that attempt to add new records to the table.

**Table 48.45. pg\_policy Columns**

Column Type	Description
oid oid	Row identifier
polname name	The name of the policy
polrelid oid (references pg_class.oid)	The table to which the policy applies
polcmd char	The command type to which the policy is applied: r for SELECT, a for INSERT, w for UPDATE, d for DELETE, or * for all
polpermissive bool	Is the policy permissive or restrictive?
polroles oid[] (references pg_authid.oid)	The roles to which the policy is applied
polqual pg_node_tree	The expression tree to be added to the security barrier qualifications for queries that use the table

Column Type	Description
<code>polwithcheck</code> <code>pg_node_tree</code>	The expression tree to be added to the WITH CHECK qualifications for queries that attempt to add rows to the table

### Note

Policies stored in `pg_policy` are applied only when `pg_class.relrowsecurity` is set for their table.

## 48.46. `pg_proc`

The catalog `pg_proc` stores information about functions, procedures, aggregate functions, and window functions (collectively also known as routines). See `CREATE FUNCTION`, `CREATE PROCEDURE`, and Section 36.3 for more information.

If `prokind` indicates that the entry is for an aggregate function, there should be a matching row in `pg_aggregate`.

**Table 48.46. `pg_proc` Columns**

Column Type	Description
<code>oid</code> <code>oid</code>	Row identifier
<code>proname</code> <code>name</code>	Name of the function
<code>pronamespace</code> <code>oid</code> (references <code>pg_namespace.oid</code> )	The OID of the namespace that contains this function
<code>proowner</code> <code>oid</code> (references <code>pg_authid.oid</code> )	Owner of the function
<code>prolang</code> <code>oid</code> (references <code>pg_language.oid</code> )	Implementation language or call interface of this function
<code>procost</code> <code>float4</code>	Estimated execution cost (in units of <code>cpu_operator_cost</code> ); if <code>proretset</code> , this is cost per row returned
<code>prorows</code> <code>float4</code>	Estimated number of result rows (zero if not <code>proretset</code> )
<code>provariadic</code> <code>oid</code> (references <code>pg_type.oid</code> )	Data type of the variadic array parameter's elements, or zero if the function does not have a variadic parameter
<code>prosupport</code> <code>regproc</code> (references <code>pg_proc.oid</code> )	Optional planner support function for this function (see Section 36.11)
<code>prokind</code> <code>char</code>	<code>f</code> for a normal function, <code>p</code> for a procedure, <code>a</code> for an aggregate function, or <code>w</code> for a window function
<code>prosecdef</code> <code>bool</code>	Function is a security definer (i.e., a "setuid" function)
<code>proleakproof</code> <code>bool</code>	

<b>Column Type</b>	<b>Description</b>
	The function has no side effects. No information about the arguments is conveyed except via the return value. Any function that might throw an error depending on the values of its arguments is not leak-proof.
<code>proisstrict bool</code>	Function returns null if any call argument is null. In that case the function won't actually be called at all. Functions that are not "strict" must be prepared to handle null inputs.
<code>proretset bool</code>	Function returns a set (i.e., multiple values of the specified data type)
<code>provolatile char</code>	<code>provolatile</code> tells whether the function's result depends only on its input arguments, or is affected by outside factors. It is <code>i</code> for "immutable" functions, which always deliver the same result for the same inputs. It is <code>s</code> for "stable" functions, whose results (for fixed inputs) do not change within a scan. It is <code>v</code> for "volatile" functions, whose results might change at any time. (Use <code>v</code> also for functions with side-effects, so that calls to them cannot get optimized away.)
<code>proparallel char</code>	<code>proparallel</code> tells whether the function can be safely run in parallel mode. It is <code>s</code> for functions which are safe to run in parallel mode without restriction. It is <code>r</code> for functions which can be run in parallel mode, but their execution is restricted to the parallel group leader; parallel worker processes cannot invoke these functions. It is <code>u</code> for functions which are unsafe in parallel mode; the presence of such a function forces a serial execution plan.
<code>pronargs int2</code>	Number of input arguments
<code>pronargdefaults int2</code>	Number of arguments that have defaults
<code>prorettype oid (references pg_type.oid)</code>	Data type of the return value
<code>proargtypes oidvector (references pg_type.oid)</code>	An array of the data types of the function arguments. This includes only input arguments (including INOUT and VARIADIC arguments), and thus represents the call signature of the function.
<code>proallargtypes oid[ ] (references pg_type.oid)</code>	An array of the data types of the function arguments. This includes all arguments (including OUT and INOUT arguments); however, if all the arguments are IN arguments, this field will be null. Note that subscripting is 1-based, whereas for historical reasons <code>proargtypes</code> is subscripted from 0.
<code>proargmodes char[ ]</code>	An array of the modes of the function arguments, encoded as <code>i</code> for IN arguments, <code>o</code> for OUT arguments, <code>b</code> for INOUT arguments, <code>v</code> for VARIADIC arguments, <code>t</code> for TABLE arguments. If all the arguments are IN arguments, this field will be null. Note that subscripts correspond to positions of <code>proallargtypes</code> not <code>proargtypes</code> .
<code>proargnames text[ ]</code>	An array of the names of the function arguments. Arguments without a name are set to empty strings in the array. If none of the arguments have a name, this field will be null. Note that subscripts correspond to positions of <code>proallargtypes</code> not <code>proargtypes</code> .
<code>proargdefaults pg_node_tree</code>	Expression trees (in <code>nodeToString( )</code> representation) for default values. This is a list with <code>pronargdefaults</code> elements, corresponding to the last <i>N</i> input arguments (i.e.,



Column Type	Description
	the last <code>N</code> <code>proargtypes</code> positions). If none of the arguments have defaults, this field will be null.
<code>protrfotypes oid[]</code> (references <code>pg_type.oid</code> )	An array of the argument/result data type(s) for which to apply transforms (from the function's <code>TRANSFORM</code> clause). Null if none.
<code>prosrc text</code>	This tells the function handler how to invoke the function. It might be the actual source code of the function for interpreted languages, a link symbol, a file name, or just about anything else, depending on the implementation language/call convention.
<code>probin text</code>	Additional information about how to invoke the function. Again, the interpretation is language-specific.
<code>proconfig text[]</code>	Function's local settings for run-time configuration variables
<code>proacl aclitem[]</code>	Access privileges; see Section 5.7 for details

For compiled functions, both built-in and dynamically loaded, `prosrc` contains the function's C-language name (link symbol). For all other currently-known language types, `prosrc` contains the function's source text. `probin` is unused except for dynamically-loaded C functions, for which it gives the name of the shared library file containing the function.

## 48.47. `pg_publication`

The catalog `pg_publication` contains all publications created in the database. For more on publications see Section 28.1.

**Table 48.47. `pg_publication` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>pubname name</code>	Name of the publication
<code>pubowner oid</code> (references <code>pg_authid.oid</code> )	Owner of the publication
<code>puballtables bool</code>	If true, this publication automatically includes all tables in the database, including any that will be created in the future.
<code>pubinsert bool</code>	If true, <code>INSERT</code> operations are replicated for tables in the publication.
<code>pubupdate bool</code>	If true, <code>UPDATE</code> operations are replicated for tables in the publication.
<code>pubdelete bool</code>	If true, <code>DELETE</code> operations are replicated for tables in the publication.
<code>pubtruncate bool</code>	If true, <code>TRUNCATE</code> operations are replicated for tables in the publication.
<code>pubviaroot bool</code>	

Column Type	Description
	If true, operations on a leaf partition are replicated using the identity and schema of its topmost partitioned ancestor mentioned in the publication instead of its own.

## 48.48. `pg_publication_rel`

The catalog `pg_publication_rel` contains the mapping between relations and publications in the database. This is a many-to-many mapping. See also Section 48.86 for a more user-friendly view of this information.

**Table 48.48. `pg_publication_rel` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>prpubid oid (references pg_publication.oid)</code>	Reference to publication
<code>prrelid oid (references pg_class.oid)</code>	Reference to relation

## 48.49. `pg_range`

The catalog `pg_range` stores information about range types. This is in addition to the types' entries in `pg_type`.

**Table 48.49. `pg_range` Columns**

Column Type	Description
<code>rngtypeid oid (references pg_type.oid)</code>	OID of the range type
<code>rngsubtype oid (references pg_type.oid)</code>	OID of the element type (subtype) of this range type
<code>rngcollation oid (references pg_collation.oid)</code>	OID of the collation used for range comparisons, or 0 if none
<code>rngsubopc oid (references pg_opclass.oid)</code>	OID of the subtype's operator class used for range comparisons
<code>rngcanonical regproc (references pg_proc.oid)</code>	OID of the function to convert a range value into canonical form, or 0 if none
<code>rngsubdiff regproc (references pg_proc.oid)</code>	OID of the function to return the difference between two element values as double precision, or 0 if none

`rngsubopc` (plus `rngcollation`, if the element type is collatable) determines the sort ordering used by the range type. `rngcanonical` is used when the element type is discrete. `rngsubdiff` is optional but should be supplied to improve performance of GiST indexes on the range type.

## 48.50. `pg_replication_origin`

The `pg_replication_origin` catalog contains all replication origins created. For more on replication origins see Chapter 46.

Unlike most system catalogs, `pg_replication_origin` is shared across all databases of a cluster: there is only one copy of `pg_replication_origin` per cluster, not one per database.

**Table 48.50. `pg_replication_origin` Columns**

Column	Type	Description
<code>roident</code>	<code>oid</code>	A unique, cluster-wide identifier for the replication origin. Should never leave the system.
<code>roname</code>	<code>text</code>	The external, user defined, name of a replication origin.

## 48.51. `pg_rewrite`

The catalog `pg_rewrite` stores rewrite rules for tables and views.

**Table 48.51. `pg_rewrite` Columns**

Column	Type	Description
<code>oid</code>	<code>oid</code>	Row identifier
<code>rulename</code>	<code>name</code>	Rule name
<code>ev_class</code>	<code>oid</code> (references <code>pg_class.oid</code> )	The table this rule is for
<code>ev_type</code>	<code>char</code>	Event type that the rule is for: 1 = SELECT, 2 = UPDATE, 3 = INSERT, 4 = DELETE
<code>ev_enabled</code>	<code>char</code>	Controls in which <code>session_replication_role</code> modes the rule fires. O = rule fires in “origin” and “local” modes, D = rule is disabled, R = rule fires in “replica” mode, A = rule fires always.
<code>is_instead</code>	<code>bool</code>	True if the rule is an INSTEAD rule
<code>ev_qual</code>	<code>pg_node_tree</code>	Expression tree (in the form of a <code>nodeToString()</code> representation) for the rule's qualifying condition
<code>ev_action</code>	<code>pg_node_tree</code>	Query tree (in the form of a <code>nodeToString()</code> representation) for the rule's action

### Note

`pg_class.relhasrules` must be true if a table has any rules in this catalog.

## 48.52. `pg_seclabel`

The catalog `pg_seclabel` stores security labels on database objects. Security labels can be manipulated with the `SECURITY LABEL` command. For an easier way to view security labels, see Section 48.91.

See also `pg_shseclabel`, which performs a similar function for security labels of database objects that are shared across a database cluster.

**Table 48.52. `pg_seclabel` Columns**

Column Type	Description
<code>objoid oid</code> (references any OID column)	The OID of the object this security label pertains to
<code>classoid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog this object appears in
<code>objsubid int4</code>	For a security label on a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other object types, this column is zero.
<code>provider text</code>	The label provider associated with this label.
<code>label text</code>	The security label applied to this object.

## 48.53. `pg_sequence`

The catalog `pg_sequence` contains information about sequences. Some of the information about sequences, such as the name and the schema, is in `pg_class`.

**Table 48.53. `pg_sequence` Columns**

Column Type	Description
<code>seqrelid oid</code> (references <code>pg_class.oid</code> )	The OID of the <code>pg_class</code> entry for this sequence
<code>seqtypeid oid</code> (references <code>pg_type.oid</code> )	Data type of the sequence
<code>seqstart int8</code>	Start value of the sequence
<code>seqincrement int8</code>	Increment value of the sequence
<code>seqmax int8</code>	Maximum value of the sequence
<code>seqmin int8</code>	Minimum value of the sequence
<code>seqcache int8</code>	Cache size of the sequence
<code>seqcycle bool</code>	Whether the sequence cycles

## 48.54. `pg_shdepend`

The catalog `pg_shdepend` records the dependency relationships between database objects and shared objects, such as roles. This information allows LightDB to ensure that those objects are unreferenced before attempting to delete them.

See also `pg_depend`, which performs a similar function for dependencies involving objects within a single database.

Unlike most system catalogs, `pg_shdepend` is shared across all databases of a cluster: there is only one copy of `pg_shdepend` per cluster, not one per database.

**Table 48.54. `pg_shdepend` Columns**

Column Type	Description
<code>dbid oid</code> (references <code>pg_database.oid</code> )	The OID of the database the dependent object is in, or zero for a shared object
<code>classid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog the dependent object is in
<code>objid oid</code> (references any OID column)	The OID of the specific dependent object
<code>objsubid int4</code>	For a table column, this is the column number (the <code>objid</code> and <code>classid</code> refer to the table itself). For all other object types, this column is zero.
<code>refclassid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog the referenced object is in (must be a shared catalog)
<code>refobjid oid</code> (references any OID column)	The OID of the specific referenced object
<code>deptype char</code>	A code defining the specific semantics of this dependency relationship; see text

In all cases, a `pg_shdepend` entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

`SHARED_DEPENDENCY_OWNER` (o)

The referenced object (which must be a role) is the owner of the dependent object.

`SHARED_DEPENDENCY_ACL` (a)

The referenced object (which must be a role) is mentioned in the ACL (access control list, i.e., privileges list) of the dependent object. (A `SHARED_DEPENDENCY_ACL` entry is not made for the owner of the object, since the owner will have a `SHARED_DEPENDENCY_OWNER` entry anyway.)

`SHARED_DEPENDENCY_POLICY` (r)

The referenced object (which must be a role) is mentioned as the target of a dependent policy object.

`SHARED_DEPENDENCY_PIN` (p)

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by `initdb`. The columns for the dependent object contain zeroes.

`SHARED_DEPENDENCY_TABLESPACE` (t)

The referenced object (which must be a tablespace) is mentioned as the tablespace for a relation that doesn't have storage.

Other dependency flavors might be needed in future. Note in particular that the current definition only supports roles and tablespaces as referenced objects.

## 48.55. `pg_shdescription`

The catalog `pg_shdescription` stores optional descriptions (comments) for shared database objects. Descriptions can be manipulated with the `COMMENT` command and viewed with `lsc`'s `\d` commands.

See also `pg_description`, which performs a similar function for descriptions involving objects within a single database.

Unlike most system catalogs, `pg_shdescription` is shared across all databases of a cluster: there is only one copy of `pg_shdescription` per cluster, not one per database.

**Table 48.55. `pg_shdescription` Columns**

Column Type	Description
<code>objoid oid</code> (references any OID column)	The OID of the object this description pertains to
<code>classoid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog this object appears in
<code>description text</code>	Arbitrary text that serves as the description of this object

## 48.56. `pg_shseclabel`

The catalog `pg_shseclabel` stores security labels on shared database objects. Security labels can be manipulated with the `SECURITY LABEL` command. For an easier way to view security labels, see Section 48.91.

See also `pg_seclabel`, which performs a similar function for security labels involving objects within a single database.

Unlike most system catalogs, `pg_shseclabel` is shared across all databases of a cluster: there is only one copy of `pg_shseclabel` per cluster, not one per database.

**Table 48.56. `pg_shseclabel` Columns**

Column Type	Description
<code>objoid oid</code> (references any OID column)	The OID of the object this security label pertains to
<code>classoid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog this object appears in
<code>provider text</code>	The label provider associated with this label.
<code>label text</code>	The security label applied to this object.

## 48.57. `pg_statistic`

The catalog `pg_statistic` stores statistical data about the contents of the database. Entries are created by `ANALYZE` and subsequently used by the query planner. Note that all the statistical data is inherently approximate, even assuming that it is up-to-date.

Normally there is one entry, with `stainherit = false`, for each table column that has been analyzed. If the table has inheritance children, a second entry with `stainherit = true` is also created. This row represents the column's statistics over the inheritance tree, i.e., statistics for the data you'd see with `SELECT column FROM table*`, whereas the `stainherit = false` row represents the results of `SELECT column FROM ONLY table`.

`pg_statistic` also stores statistical data about the values of index expressions. These are described as if they were actual data columns; in particular, `starelid` references the index. No entry is made for an ordinary non-expression index column, however, since it would be redundant with the entry for the underlying table column. Currently, entries for index expressions always have `stainherit = false`.

Since different kinds of statistics might be appropriate for different kinds of data, `pg_statistic` is designed not to assume very much about what sort of statistics it stores. Only extremely general statistics (such as nullness) are given dedicated columns in `pg_statistic`. Everything else is stored in “slots”, which are groups of associated columns whose content is identified by a code number in one of the slot's columns. For more information see `src/include/catalog/pg_statistic.h`.

`pg_statistic` should not be readable by the public, since even statistical information about a table's contents might be considered sensitive. (Example: minimum and maximum values of a salary column might be quite interesting.) `pg_stats` is a publicly readable view on `pg_statistic` that only exposes information about those tables that are readable by the current user.

**Table 48.57. `pg_statistic` Columns**

Column Type	Description
<code>starelid oid</code> (references <code>pg_class.oid</code> )	The table or index that the described column belongs to
<code>staattnum int2</code> (references <code>pg_attribute.attnum</code> )	The number of the described column
<code>stainherit bool</code>	If true, the stats include inheritance child columns, not just the values in the specified relation
<code>stanullfrac float4</code>	The fraction of the column's entries that are null
<code>stawidth int4</code>	The average stored width, in bytes, of nonnull entries
<code>stadistinct float4</code>	The number of distinct nonnull data values in the column. A value greater than zero is the actual number of distinct values. A value less than zero is the negative of a multiplier for the number of rows in the table; for example, a column in which about 80% of the values are nonnull and each nonnull value appears about twice on average could be represented by <code>stadistinct = -0.4</code> . A zero value means the number of distinct values is unknown.
<code>stakindN int2</code>	A code number indicating the kind of statistics stored in the <i>N</i> th “slot” of the <code>pg_statistic</code> row.
<code>staopN oid</code> (references <code>pg_operator.oid</code> )	An operator used to derive the statistics stored in the <i>N</i> th “slot”. For example, a histogram slot would show the <code>&lt;</code> operator that defines the sort order of the data.
<code>stacollN oid</code> (references <code>pg_collation.oid</code> )	

Column Type	Description
	The collation used to derive the statistics stored in the <i>N</i> th “slot”. For example, a histogram slot for a collatable column would show the collation that defines the sort order of the data. Zero for noncollatable data.
<code>stanumbers</code> <i>N</i> float4[ ]	Numerical statistics of the appropriate kind for the <i>N</i> th “slot”, or null if the slot kind does not involve numerical values
<code>stavalues</code> <i>N</i> anyarray	Column data values of the appropriate kind for the <i>N</i> th “slot”, or null if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, or a related type such as an array's element type, so there is no way to define these columns' type more specifically than <code>anyarray</code> .

## 48.58. `pg_statistic_ext`

The catalog `pg_statistic_ext` holds definitions of extended planner statistics. Each row in this catalog corresponds to a *statistics object* created with `CREATE STATISTICS`.

**Table 48.58. `pg_statistic_ext` Columns**

Column Type	Description
<code>oid</code> oid	Row identifier
<code>stxrelid</code> oid (references <code>pg_class.oid</code> )	Table containing the columns described by this object
<code>stxname</code> name	Name of the statistics object
<code>stxnamespace</code> oid (references <code>pg_namespace.oid</code> )	The OID of the namespace that contains this statistics object
<code>stxowner</code> oid (references <code>pg_authid.oid</code> )	Owner of the statistics object
<code>stxstattarget</code> int4	<code>stxstattarget</code> controls the level of detail of statistics accumulated for this statistics object by <code>ANALYZE</code> . A zero value indicates that no statistics should be collected. A negative value says to use the maximum of the statistics targets of the referenced columns, if set, or the system default statistics target. Positive values of <code>stxstattarget</code> determine the target number of “most common values” to collect.
<code>stxkeys</code> int2vector (references <code>pg_attribute.attnum</code> )	An array of attribute numbers, indicating which table columns are covered by this statistics object; for example a value of 1 3 would mean that the first and the third table columns are covered
<code>stxkind</code> char[ ]	An array containing codes for the enabled statistics kinds; valid values are: <code>d</code> for <code>n</code> -distinct statistics, <code>f</code> for functional dependency statistics, and <code>m</code> for most common values (MCV) list statistics

The `pg_statistic_ext` entry is filled in completely during `CREATE STATISTICS`, but the actual statistical values are not computed then. Subsequent `ANALYZE` commands compute the desired values and populate an entry in the `pg_statistic_ext_data` catalog.

## 48.59. `pg_statistic_ext_data`



The catalog `pg_statistic_ext_data` holds data for extended planner statistics defined in `pg_statistic_ext`. Each row in this catalog corresponds to a *statistics object* created with `CREATE STATISTICS`.

Like `pg_statistic`, `pg_statistic_ext_data` should not be readable by the public, since the contents might be considered sensitive. (Example: most common combinations of values in columns might be quite interesting.) `pg_stats_ext` is a publicly readable view on `pg_statistic_ext_data` (after joining with `pg_statistic_ext`) that only exposes information about those tables and columns that are readable by the current user.

**Table 48.59. `pg_statistic_ext_data` Columns**

Column Type	Description
<code>stxoid oid</code> (references <code>pg_statistic_ext.oid</code> )	Extended statistic object containing the definition for this data
<code>stxdndistinct pg_ndistinct</code>	N-distinct counts, serialized as <code>pg_ndistinct</code> type
<code>stxddependencies pg_dependencies</code>	Functional dependency statistics, serialized as <code>pg_dependencies</code> type
<code>stxdmcv pg_mcv_list</code>	MCV (most-common values) list statistics, serialized as <code>pg_mcv_list</code> type

## 48.60. `pg_subscription`

The catalog `pg_subscription` contains all existing logical replication subscriptions. For more information about logical replication see Chapter 28.

Unlike most system catalogs, `pg_subscription` is shared across all databases of a cluster: there is only one copy of `pg_subscription` per cluster, not one per database.

Access to the column `subconninfo` is revoked from normal users, because it could contain plain-text passwords.

**Table 48.60. `pg_subscription` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>subdbid oid</code> (references <code>pg_database.oid</code> )	OID of the database which the subscription resides in
<code>subname name</code>	Name of the subscription
<code>subowner oid</code> (references <code>pg_authid.oid</code> )	Owner of the subscription
<code>subenabled bool</code>	If true, the subscription is enabled and should be replicating.
<code>subconninfo text</code>	Connection string to the upstream database
<code>subslotname name</code>	Name of the replication slot in the upstream database (also used for the local replication origin name); null represents NONE
<code>subsynccommit text</code>	

Column Type	Description
	Contains the value of the <code>synchronous_commit</code> setting for the subscription workers.
<code>subpublications text[]</code>	Array of subscribed publication names. These reference the publications on the publisher server. For more on publications see Section 28.1.

## 48.61. `pg_subscription_rel`

The catalog `pg_subscription_rel` contains the state for each replicated relation in each subscription. This is a many-to-many mapping.

This catalog only contains tables known to the subscription after running either `CREATE SUBSCRIPTION` or `ALTER SUBSCRIPTION ... REFRESH PUBLICATION`.

**Table 48.61. `pg_subscription_rel` Columns**

Column Type	Description
<code>srsubid oid</code> (references <code>pg_subscription.oid</code> )	Reference to subscription
<code>srrelid oid</code> (references <code>pg_class.oid</code> )	Reference to relation
<code>srsubstate char</code>	State code: <code>i</code> = initialize, <code>d</code> = data is being copied, <code>s</code> = synchronized, <code>r</code> = ready (normal replication)
<code>srsublsn pg_lsn</code>	Remote LSN of the state change used for synchronization coordination when in <code>s</code> or <code>r</code> states, otherwise null

## 48.62. `pg_tablespace`

The catalog `pg_tablespace` stores information about the available tablespaces. Tables can be placed in particular tablespaces to aid administration of disk layout.

Unlike most system catalogs, `pg_tablespace` is shared across all databases of a cluster: there is only one copy of `pg_tablespace` per cluster, not one per database.

**Table 48.62. `pg_tablespace` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>spcname name</code>	Tablespace name
<code>spcowner oid</code> (references <code>pg_authid.oid</code> )	Owner of the tablespace, usually the user who created it
<code>spcacl aclitem[]</code>	Access privileges; see Section 5.7 for details
<code>spcoptions text[]</code>	Tablespace-level options, as “keyword=value” strings

## 48.63. pg\_transform

The catalog `pg_transform` stores information about transforms, which are a mechanism to adapt data types to procedural languages. See `CREATE TRANSFORM` for more information.

**Table 48.63. pg\_transform Columns**

Column Type	Description
oid oid	Row identifier
trftype oid (references pg_type.oid)	OID of the data type this transform is for
trflang oid (references pg_language.oid)	OID of the language this transform is for
trffromsql regproc (references pg_proc.oid)	The OID of the function to use when converting the data type for input to the procedural language (e.g., function parameters). Zero is stored if this operation is not supported.
trftosql regproc (references pg_proc.oid)	The OID of the function to use when converting output from the procedural language (e.g., return values) to the data type. Zero is stored if this operation is not supported.

## 48.64. pg\_trigger

The catalog `pg_trigger` stores triggers on tables and views. See `CREATE TRIGGER` for more information.

**Table 48.64. pg\_trigger Columns**

Column Type	Description
oid oid	Row identifier
tgrelid oid (references pg_class.oid)	The table this trigger is on
tgparentid oid (references pg_trigger.oid)	Parent trigger that this trigger is cloned from, zero if not a clone; this happens when partitions are created or attached to a partitioned table.
tgname name	Trigger name (must be unique among triggers of same table)
tgfoid oid (references pg_proc.oid)	The function to be called
tgtype int2	Bit mask identifying trigger firing conditions
tgenabled char	Controls in which session_replication_role modes the trigger fires. O = trigger fires in “origin” and “local” modes, D = trigger is disabled, R = trigger fires in “replica” mode, A = trigger fires always.
tgisinternal bool	True if trigger is internally generated (usually, to enforce the constraint identified by tgconstraint)
tgconstrrelid oid (references pg_class.oid)	

Column Type	Description
	The table referenced by a referential integrity constraint
tgconstrindid oid (references pg_class.oid)	The index supporting a unique, primary key, referential integrity, or exclusion constraint
tgconstraint oid (references pg_constraint.oid)	The pg_constraint entry associated with the trigger, if any
tgdeferrable bool	True if constraint trigger is deferrable
tginitdeferred bool	True if constraint trigger is initially deferred
tgargs int2	Number of argument strings passed to trigger function
tgattr int2vector (references pg_attribute.attnum)	Column numbers, if trigger is column-specific; otherwise an empty array
tgargs bytea	Argument strings to pass to trigger, each NULL-terminated
tgqual pg_node_tree	Expression tree (in nodeToString( ) representation) for the trigger's WHEN condition, or null if none
tgoldtable name	REFERENCING clause name for OLD TABLE, or null if none
tgnewtable name	REFERENCING clause name for NEW TABLE, or null if none

Currently, column-specific triggering is supported only for UPDATE events, and so tgattr is relevant only for that event type. tgtype might contain bits for other event types as well, but those are presumed to be table-wide regardless of what is in tgattr.

### Note

When tgconstraint is nonzero, tgconstrrelid, tgconstrindid, tgdeferrable, and tginitdeferred are largely redundant with the referenced pg\_constraint entry. However, it is possible for a non-deferrable trigger to be associated with a deferrable constraint: foreign key constraints can have some deferrable and some non-deferrable triggers.

### Note

pg\_class.relhastriggers must be true if a relation has any triggers in this catalog.

## 48.65. pg\_ts\_config

The pg\_ts\_config catalog contains entries representing text search configurations. A configuration specifies a particular text search parser and a list of dictionaries to use for each of the parser's output token types. The parser is shown in the pg\_ts\_config entry, but the token-to-dictionary mapping is defined by subsidiary entries in pg\_ts\_config\_map.

LightDB's text search features are described at length in Chapter 12.

**Table 48.65. pg\_ts\_config Columns**

Column Type	Description
oid oid	Row identifier
cfgname name	Text search configuration name
cfgnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this configuration
cfgowner oid (references pg_authid.oid)	Owner of the configuration
cfgparser oid (references pg_ts_parser.oid)	The OID of the text search parser for this configuration

## 48.66. pg\_ts\_config\_map

The `pg_ts_config_map` catalog contains entries showing which text search dictionaries should be consulted, and in what order, for each output token type of each text search configuration's parser.

LightDB's text search features are described at length in Chapter 12.

**Table 48.66. pg\_ts\_config\_map Columns**

Column Type	Description
mapcfg oid (references pg_ts_config.oid)	The OID of the <code>pg_ts_config</code> entry owning this map entry
maptokentype int4	A token type emitted by the configuration's parser
mapseqno int4	Order in which to consult this entry (lower <code>mapseqnos</code> first)
mapdict oid (references pg_ts_dict.oid)	The OID of the text search dictionary to consult

## 48.67. pg\_ts\_dict

The `pg_ts_dict` catalog contains entries defining text search dictionaries. A dictionary depends on a text search template, which specifies all the implementation functions needed; the dictionary itself provides values for the user-settable parameters supported by the template. This division of labor allows dictionaries to be created by unprivileged users. The parameters are specified by a text string `dictinitoption`, whose format and meaning vary depending on the template.

LightDB's text search features are described at length in Chapter 12.

**Table 48.67. pg\_ts\_dict Columns**

Column Type	Description
oid oid	Row identifier
dictname name	Text search dictionary name
dictnamespace oid (references pg_namespace.oid)	

Column Type	Description
	The OID of the namespace that contains this dictionary
dictowner oid (references pg_authid.oid)	Owner of the dictionary
dicttemplate oid (references pg_ts_template.oid)	The OID of the text search template for this dictionary
dictinitoption text	Initialization option string for the template

## 48.68. pg\_ts\_parser

The `pg_ts_parser` catalog contains entries defining text search parsers. A parser is responsible for splitting input text into lexemes and assigning a token type to each lexeme. Since a parser must be implemented by C-language-level functions, creation of new parsers is restricted to database superusers.

LightDB's text search features are described at length in Chapter 12.

**Table 48.68. pg\_ts\_parser Columns**

Column Type	Description
oid oid	Row identifier
prsname name	Text search parser name
prsnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this parser
prsstart regproc (references pg_proc.oid)	OID of the parser's startup function
prstoken regproc (references pg_proc.oid)	OID of the parser's next-token function
prsend regproc (references pg_proc.oid)	OID of the parser's shutdown function
prsheadline regproc (references pg_proc.oid)	OID of the parser's headline function
prsllexype regproc (references pg_proc.oid)	OID of the parser's lexype function

## 48.69. pg\_ts\_template

The `pg_ts_template` catalog contains entries defining text search templates. A template is the implementation skeleton for a class of text search dictionaries. Since a template must be implemented by C-language-level functions, creation of new templates is restricted to database superusers.

LightDB's text search features are described at length in Chapter 12.

**Table 48.69. pg\_ts\_template Columns**

Column Type	Description
oid oid	

Column Type	Description
	Row identifier
tmplname name	Text search template name
tmplnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this template
tmplinit regproc (references pg_proc.oid)	OID of the template's initialization function
tmpllexize regproc (references pg_proc.oid)	OID of the template's lexize function

## 48.70. pg\_type

The catalog `pg_type` stores information about data types. Base types and enum types (scalar types) are created with `CREATE TYPE`, and domains with `CREATE DOMAIN`. A composite type is automatically created for each table in the database, to represent the row structure of the table. It is also possible to create composite types with `CREATE TYPE AS`.

**Table 48.70. pg\_type Columns**

Column Type	Description
oid oid	Row identifier
typname name	Data type name
typnamespace oid (references pg_namespace.oid)	The OID of the namespace that contains this type
typowner oid (references pg_authid.oid)	Owner of the type
typlen int2	For a fixed-size type, <code>typlen</code> is the number of bytes in the internal representation of the type. But for a variable-length type, <code>typlen</code> is negative. -1 indicates a “varlena” type (one that has a length word), -2 indicates a null-terminated C string.
typbyval bool	<code>typbyval</code> determines whether internal routines pass a value of this type by value or by reference. <code>typbyval</code> had better be false if <code>typlen</code> is not 1, 2, or 4 (or 8 on machines where Datum is 8 bytes). Variable-length types are always passed by reference. Note that <code>typbyval</code> can be false even if the length would allow pass-by-value.
typtype char	<code>typtype</code> is <code>b</code> for a base type, <code>c</code> for a composite type (e.g., a table's row type), <code>d</code> for a domain, <code>e</code> for an enum type, <code>p</code> for a pseudo-type, or <code>r</code> for a range type. See also <code>typrelid</code> and <code>typbasetype</code> .
typcategory char	<code>typcategory</code> is an arbitrary classification of data types that is used by the parser to determine which implicit casts should be “preferred”. See Table 48.71.
typispreferred bool	True if the type is a preferred cast target within its <code>typcategory</code>
typisdefined bool	

<b>Column Type</b>	<b>Description</b>
	True if the type is defined, false if this is a placeholder entry for a not-yet-defined type. When <code>typisdefined</code> is false, nothing except the type name, namespace, and OID can be relied on.
<code>typdelim char</code>	Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type.
<code>typrelid oid</code> (references <code>pg_class.oid</code> )	If this is a composite type (see <code>typtype</code> ), then this column points to the <code>pg_class</code> entry that defines the corresponding table. (For a free-standing composite type, the <code>pg_class</code> entry doesn't really represent a table, but it is needed anyway for the type's <code>pg_attribute</code> entries to link to.) Zero for non-composite types.
<code>typelem oid</code> (references <code>pg_type.oid</code> )	If <code>typelem</code> is not 0 then it identifies another row in <code>pg_type</code> . The current type can then be subscripted like an array yielding values of type <code>typelem</code> . A “true” array type is variable length ( <code>typlen = -1</code> ), but some fixed-length ( <code>typlen &gt; 0</code> ) types also have nonzero <code>typelem</code> , for example <code>name</code> and <code>point</code> . If a fixed-length type has a <code>typelem</code> then its internal representation must be some number of values of the <code>typelem</code> data type with no other data. Variable-length array types have a header defined by the array subroutines.
<code>typarray oid</code> (references <code>pg_type.oid</code> )	If <code>typarray</code> is not 0 then it identifies another row in <code>pg_type</code> , which is the “true” array type having this type as element
<code>typinput regproc</code> (references <code>pg_proc.oid</code> )	Input conversion function (text format)
<code>typoutput regproc</code> (references <code>pg_proc.oid</code> )	Output conversion function (text format)
<code>typreceive regproc</code> (references <code>pg_proc.oid</code> )	Input conversion function (binary format), or 0 if none
<code>typsend regproc</code> (references <code>pg_proc.oid</code> )	Output conversion function (binary format), or 0 if none
<code>typmodin regproc</code> (references <code>pg_proc.oid</code> )	Type modifier input function, or 0 if type does not support modifiers
<code>typmodout regproc</code> (references <code>pg_proc.oid</code> )	Type modifier output function, or 0 to use the standard format
<code>typanalyze regproc</code> (references <code>pg_proc.oid</code> )	Custom ANALYZE function, or 0 to use the standard function
<code>typalign char</code>	<p><code>typalign</code> is the alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside LightDB. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a datum of this type so that it begins on the specified boundary. The alignment reference is the beginning of the first datum in the sequence. Possible values are:</p> <ul style="list-style-type: none"> <li>• <code>c</code> = char alignment, i.e., no alignment needed.</li> <li>• <code>s</code> = short alignment (2 bytes on most machines).</li> <li>• <code>i</code> = int alignment (4 bytes on most machines).</li> <li>• <code>d</code> = double alignment (8 bytes on many machines, but by no means all).</li> </ul>



<b>Column Type</b>	<b>Description</b>
<code>typstorage</code> char	<p><code>typstorage</code> tells for varlena types (those with <code>typplen = -1</code>) if the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are:</p> <ul style="list-style-type: none"> <li>• <code>p</code> (plain): Values must always be stored plain (non-varlena types always use this value).</li> <li>• <code>e</code> (external): Values can be stored in a secondary “TOAST” relation (if relation has one, see <code>pg_class.reltoastrelid</code>).</li> <li>• <code>m</code> (main): Values can be compressed and stored inline.</li> <li>• <code>x</code> (extended): Values can be compressed and/or moved to a secondary relation.</li> </ul> <p><code>x</code> is the usual choice for toast-able types. Note that <code>m</code> values can also be moved out to secondary storage, but only as a last resort (<code>e</code> and <code>x</code> values are moved first).</p>
<code>typnotnull</code> bool	<code>typnotnull</code> represents a not-null constraint on a type. Used for domains only.
<code>typbasetype</code> oid (references <code>pg_type.oid</code> )	If this is a domain (see <code>typtype</code> ), then <code>typbasetype</code> identifies the type that this one is based on. Zero if this type is not a domain.
<code>typtypmod</code> int4	Domains use <code>typtypmod</code> to record the <code>typmod</code> to be applied to their base type (-1 if base type does not use a <code>typmod</code> ). -1 if this type is not a domain.
<code>typndims</code> int4	<code>typndims</code> is the number of array dimensions for a domain over an array (that is, <code>typbasetype</code> is an array type). Zero for types other than domains over array types.
<code>typcollation</code> oid (references <code>pg_collation.oid</code> )	<code>typcollation</code> specifies the collation of the type. If the type does not support collations, this will be zero. A base type that supports collations will have a nonzero value here, typically <code>DEFAULT_COLLATION_OID</code> . A domain over a collatable type can have a collation OID different from its base type's, if one was specified for the domain.
<code>typdefaultbin</code> <code>pg_node_tree</code>	If <code>typdefaultbin</code> is not null, it is the <code>nodeToString()</code> representation of a default expression for the type. This is only used for domains.
<code>typdefault</code> text	<code>typdefault</code> is null if the type has no associated default value. If <code>typdefaultbin</code> is not null, <code>typdefault</code> must contain a human-readable version of the default expression represented by <code>typdefaultbin</code> . If <code>typdefaultbin</code> is null and <code>typdefault</code> is not, then <code>typdefault</code> is the external representation of the type's default value, which can be fed to the type's input converter to produce a constant.
<code>typacl</code> aclitem[]	Access privileges; see Section 5.7 for details

### Note

For fixed-width types used in system tables, it is critical that the size and alignment defined in `pg_type` agree with the way that the compiler will lay out the column in a structure representing a table row.

Table 48.71 lists the system-defined values of `typcategory`. Any future additions to this list will also be upper-case ASCII letters. All other ASCII characters are reserved for user-defined categories.

**Table 48.71. `typcategory` Codes**

Code	Category
A	Array types
B	Boolean types
C	Composite types
D	Date/time types
E	Enum types
G	Geometric types
I	Network address types
N	Numeric types
P	Pseudo-types
R	Range types
S	String types
T	Timespan types
U	User-defined types
V	Bit-string types
X	unknown type

## 48.71. `pg_user_mapping`

The catalog `pg_user_mapping` stores the mappings from local user to remote. Access to this catalog is restricted from normal users, use the view `pg_user_mappings` instead.

**Table 48.72. `pg_user_mapping` Columns**

Column Type	Description
<code>oid oid</code>	Row identifier
<code>umuser oid (references pg_authid.oid)</code>	OID of the local role being mapped, 0 if the user mapping is public
<code>umserver oid (references pg_foreign_server.oid)</code>	The OID of the foreign server that contains this mapping
<code>umoptions text[]</code>	User mapping specific options, as “keyword=value” strings

## 48.72. System Views

In addition to the system catalogs, LightDB provides a number of built-in views. Some system views provide convenient access to some commonly used queries on the system catalogs. Other views provide access to internal server state.

The information schema (Chapter 35) provides an alternative set of views which overlap the functionality of the system views. Since the information schema is SQL-standard whereas the views described here are LightDB-specific, it's usually better to use the information schema if it provides all the information you need.

Table 48.73 lists the system views described here. More detailed documentation of each view follows below. There are some additional views that provide access to the results of the statistics collector; they are described in Table 25.2.

Except where noted, all the views described here are read-only.

**Table 48.73. System Views**

View Name	Purpose
pg_available_extensions	available extensions
pg_available_extension_versions	available versions of extensions
pg_config	compile-time configuration parameters
pg_cursors	open cursors
pg_file_settings	summary of configuration file contents
pg_group	groups of database users
pg_hba_file_rules	summary of client authentication configuration file contents
pg_indexes	indexes
pg_locks	locks currently held or awaited
pg_matviews	materialized views
pg_policies	policies
pg_prepared_statements	prepared statements
pg_prepared_xacts	prepared transactions
pg_publication_tables	publications and their associated tables
pg_replication_origin_status	information about replication origins, including replication progress
pg_replication_slots	replication slot information
pg_roles	database roles
pg_rules	rules
pg_seclabels	security labels
pg_sequences	sequences
pg_settings	parameter settings
pg_shadow	database users
pg_shmem_allocations	shared memory allocations
pg_stats	planner statistics
pg_stats_ext	extended planner statistics
pg_tables	tables
pg_timezone_abbrevs	time zone abbreviations
pg_timezone_names	time zone names
pg_user	database users
pg_user_mappings	user mappings
pg_views	views

## 48.73. pg\_available\_extensions

The `pg_available_extensions` view lists the extensions that are available for installation. See also the `pg_extension` catalog, which shows the extensions currently installed.

**Table 48.74. `pg_available_extensions` Columns**

Column Type	Description
name name	Extension name
default_version text	Name of default version, or NULL if none is specified
installed_version text	Currently installed version of the extension, or NULL if not installed
comment text	Comment string from the extension's control file

The `pg_available_extensions` view is read only.

## 48.74. `pg_available_extension_versions`

The `pg_available_extension_versions` view lists the specific extension versions that are available for installation. See also the `pg_extension` catalog, which shows the extensions currently installed.

**Table 48.75. `pg_available_extension_versions` Columns**

Column Type	Description
name name	Extension name
version text	Version name
installed bool	True if this version of this extension is currently installed
superuser bool	True if only superusers are allowed to install this extension (but see <code>trusted</code> )
trusted bool	True if the extension can be installed by non-superusers with appropriate privileges
relocatable bool	True if extension can be relocated to another schema
schema name	Name of the schema that the extension must be installed into, or NULL if partially or fully relocatable
requires name[ ]	Names of prerequisite extensions, or NULL if none
comment text	Comment string from the extension's control file

The `pg_available_extension_versions` view is read only.

## 48.75. `pg_config`

The view `pg_config` describes the compile-time configuration parameters of the currently installed version of LightDB. It is intended, for example, to be used by software packages that want to interface to LightDB to facilitate finding the required header files and libraries. It provides the same basic information as the `lt_config` LightDB client application.

By default, the `pg_config` view can be read only by superusers.

**Table 48.76. `pg_config` Columns**

Column Type	Description
<code>name text</code>	The parameter name
<code>setting text</code>	The parameter value

## 48.76. `pg_cursors`

The `pg_cursors` view lists the cursors that are currently available. Cursors can be defined in several ways:

- via the `DECLARE` statement in SQL
- via the `Bind` message in the frontend/backend protocol, as described in Section 49.2.3
- via the Server Programming Interface (SPI), as described in Section 43.1

The `pg_cursors` view displays cursors created by any of these means. Cursors only exist for the duration of the transaction that defines them, unless they have been declared `WITH HOLD`. Therefore non-holdable cursors are only present in the view until the end of their creating transaction.

### Note

Cursors are used internally to implement some of the components of LightDB, such as procedural languages. Therefore, the `pg_cursors` view might include cursors that have not been explicitly created by the user.

**Table 48.77. `pg_cursors` Columns**

Column Type	Description
<code>name text</code>	The name of the cursor
<code>statement text</code>	The verbatim query string submitted to declare this cursor
<code>is_holdable bool</code>	<code>true</code> if the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed); <code>false</code> otherwise
<code>is_binary bool</code>	<code>true</code> if the cursor was declared <code>BINARY</code> ; <code>false</code> otherwise
<code>is_scrollable bool</code>	<code>true</code> if the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner); <code>false</code> otherwise
<code>creation_time timestampz</code>	

Column Type	Description
	The time at which the cursor was declared

The `pg_cursors` view is read only.

## 48.77. `pg_file_settings`

The view `pg_file_settings` provides a summary of the contents of the server's configuration file(s). A row appears in this view for each “name = value” entry appearing in the files, with annotations indicating whether the value could be applied successfully. Additional row(s) may appear for problems not linked to a “name = value” entry, such as syntax errors in the files.

This view is helpful for checking whether planned changes in the configuration files will work, or for diagnosing a previous failure. Note that this view reports on the *current* contents of the files, not on what was last applied by the server. (The `pg_settings` view is usually sufficient to determine that.)

By default, the `pg_file_settings` view can be read only by superusers.

**Table 48.78. `pg_file_settings` Columns**

Column Type	Description
<code>sourcefile</code> text	Full path name of the configuration file
<code>sourceline</code> int4	Line number within the configuration file where the entry appears
<code>seqno</code> int4	Order in which the entries are processed (1..n)
<code>name</code> text	Configuration parameter name
<code>setting</code> text	Value to be assigned to the parameter
<code>applied</code> bool	True if the value can be applied successfully
<code>error</code> text	If not null, an error message indicating why this entry could not be applied

If the configuration file contains syntax errors or invalid parameter names, the server will not attempt to apply any settings from it, and therefore all the `applied` fields will read as false. In such a case there will be one or more rows with non-null `error` fields indicating the problem(s). Otherwise, individual settings will be applied if possible. If an individual setting cannot be applied (e.g., invalid value, or the setting cannot be changed after server start) it will have an appropriate message in the `error` field. Another way that an entry might have `applied = false` is that it is overridden by a later entry for the same parameter name; this case is not considered an error so nothing appears in the `error` field.

See Section 17.1 for more information about the various ways to change run-time parameters.

## 48.78. `pg_group`

The view `pg_group` exists for backwards compatibility: it emulates a catalog that existed in LightDB before version 8.1. It shows the names and members of all roles that are marked as `not rolcanlogin`, which is an approximation to the set of roles that are being used as groups.

**Table 48.79. pg\_group Columns**

Column Type	Description
groname name (references pg_authid.rolname)	Name of the group
grosysid oid (references pg_authid.oid)	ID of this group
grolist oid[] (references pg_authid.oid)	An array containing the IDs of the roles in this group

## 48.79. pg\_hba\_file\_rules

The view `pg_hba_file_rules` provides a summary of the contents of the client authentication configuration file, `lt_hba.conf`. A row appears in this view for each non-empty, non-comment line in the file, with annotations indicating whether the rule could be applied successfully.

This view can be helpful for checking whether planned changes in the authentication configuration file will work, or for diagnosing a previous failure. Note that this view reports on the *current* contents of the file, not on what was last loaded by the server.

By default, the `pg_hba_file_rules` view can be read only by superusers.

**Table 48.80. pg\_hba\_file\_rules Columns**

Column Type	Description
line_number int4	Line number of this rule in <code>lt_hba.conf</code>
type text	Type of connection
database text[]	List of database name(s) to which this rule applies
user_name text[]	List of user and group name(s) to which this rule applies
address text	Host name or IP address, or one of <code>all</code> , <code>samehost</code> , or <code>samenet</code> , or null for local connections
netmask text	IP address mask, or null if not applicable
auth_method text	Authentication method
options text[]	Options specified for authentication method, if any
error text	If not null, an error message indicating why this line could not be processed

Usually, a row reflecting an incorrect entry will have values for only the `line_number` and `error` fields.

See Chapter 18 for more information about client authentication configuration.

## 48.80. pg\_indexes

The view `pg_indexes` provides access to useful information about each index in the database.

**Table 48.81. `pg_indexes` Columns**

Column Type	Description
<code>schemaname name</code> (references <code>pg_namespace.nspname</code> )	Name of schema containing table and index
<code>tablename name</code> (references <code>pg_class.relname</code> )	Name of table the index is for
<code>indexname name</code> (references <code>pg_class.relname</code> )	Name of index
<code>tablespace name</code> (references <code>pg_tablespace.spcname</code> )	Name of tablespace containing index (null if default for database)
<code>indexdef text</code>	Index definition (a reconstructed <code>CREATE INDEX</code> command)

## 48.81. `pg_locks`

The view `pg_locks` provides access to information about the locks held by active processes within the database server. See Chapter 13 for more discussion of locking.

`pg_locks` contains one row per active lockable object, requested lock mode, and relevant process. Thus, the same lockable object might appear many times, if multiple processes are holding or waiting for locks on it. However, an object that currently has no locks on it will not appear at all.

There are several distinct types of lockable objects: whole relations (e.g., tables), individual pages of relations, individual tuples of relations, transaction IDs (both virtual and permanent IDs), and general database objects (identified by class OID and object OID, in the same way as in `pg_description` or `pg_depend`). Also, the right to extend a relation is represented as a separate lockable object, as is the right to update `pg_database.datfrozenxid`. Also, “advisory” locks can be taken on numbers that have user-defined meanings.

**Table 48.82. `pg_locks` Columns**

Column Type	Description
<code>locktype text</code>	Type of the lockable object: <code>relation</code> , <code>extend</code> , <code>frozenid</code> , <code>page</code> , <code>tuple</code> , <code>transactionid</code> , <code>virtualxid</code> , <code>spectoken</code> , <code>object</code> , <code>userlock</code> , or <code>advisory</code> . (See also Table 25.11.)
<code>database oid</code> (references <code>pg_database.oid</code> )	OID of the database in which the lock target exists, or zero if the target is a shared object, or null if the target is a transaction ID
<code>relation oid</code> (references <code>pg_class.oid</code> )	OID of the relation targeted by the lock, or null if the target is not a relation or part of a relation
<code>page int4</code>	Page number targeted by the lock within the relation, or null if the target is not a relation page or tuple
<code>tuple int2</code>	Tuple number targeted by the lock within the page, or null if the target is not a tuple
<code>virtualxid text</code>	



<b>Column Type</b>	<b>Description</b>
	Virtual ID of the transaction targeted by the lock, or null if the target is not a virtual transaction ID
transactionid xid	ID of the transaction targeted by the lock, or null if the target is not a transaction ID
classid oid (references pg_class.oid)	OID of the system catalog containing the lock target, or null if the target is not a general database object
objid oid (references any OID column)	OID of the lock target within its system catalog, or null if the target is not a general database object
objsubid int2	Column number targeted by the lock (the classid and objid refer to the table itself), or zero if the target is some other general database object, or null if the target is not a general database object
virtualtransaction text	Virtual ID of the transaction that is holding or awaiting this lock
pid int4	Process ID of the server process holding or awaiting this lock, or null if the lock is held by a prepared transaction
mode text	Name of the lock mode held or desired by this process (see Section 13.3.1 and Section 13.2.3)
granted bool	True if lock is held, false if lock is awaited
fastpath bool	True if lock was taken via fast path, false if taken via main lock table

granted is true in a row representing a lock held by the indicated process. False indicates that this process is currently waiting to acquire this lock, which implies that at least one other process is holding or waiting for a conflicting lock mode on the same lockable object. The waiting process will sleep until the other lock is released (or a deadlock situation is detected). A single process can be waiting to acquire at most one lock at a time.

Throughout running a transaction, a server process holds an exclusive lock on the transaction's virtual transaction ID. If a permanent ID is assigned to the transaction (which normally happens only if the transaction changes the state of the database), it also holds an exclusive lock on the transaction's permanent transaction ID until it ends. When a process finds it necessary to wait specifically for another transaction to end, it does so by attempting to acquire share lock on the other transaction's ID (either virtual or permanent ID depending on the situation). That will succeed only when the other transaction terminates and releases its locks.

Although tuples are a lockable type of object, information about row-level locks is stored on disk, not in memory, and therefore row-level locks normally do not appear in this view. If a process is waiting for a row-level lock, it will usually appear in the view as waiting for the permanent transaction ID of the current holder of that row lock.

Advisory locks can be acquired on keys consisting of either a single bigint value or two integer values. A bigint key is displayed with its high-order half in the classid column, its low-order half in the objid column, and objsubid equal to 1. The original bigint value can be reassembled with the expression (classid::bigint << 32) | objid::bigint. Integer keys are displayed with the first key in the classid column, the second key in the objid column, and objsubid equal to 2. The actual meaning of the keys is up to the user. Advisory locks are local to each database, so the database column is meaningful for an advisory lock.

`pg_locks` provides a global view of all locks in the database cluster, not only those relevant to the current database. Although its `relation` column can be joined against `pg_class.oid` to identify locked relations, this will only work correctly for relations in the current database (those for which the database column is either the current database's OID or zero).

The `pid` column can be joined to the `pid` column of the `pg_stat_activity` view to get more information on the session holding or awaiting each lock, for example

```
SELECT * FROM pg_locks pl LEFT JOIN pg_stat_activity psa
    ON pl.pid = psa.pid;
```

Also, if you are using prepared transactions, the `virtualtransaction` column can be joined to the `transaction` column of the `pg_prepared_xacts` view to get more information on prepared transactions that hold locks. (A prepared transaction can never be waiting for a lock, but it continues to hold the locks it acquired while running.) For example:

```
SELECT * FROM pg_locks pl LEFT JOIN pg_prepared_xacts ppx
    ON pl.virtualtransaction = '-1/' || ppx.transaction;
```

While it is possible to obtain information about which processes block which other processes by joining `pg_locks` against itself, this is very difficult to get right in detail. Such a query would have to encode knowledge about which lock modes conflict with which others. Worse, the `pg_locks` view does not expose information about which processes are ahead of which others in lock wait queues, nor information about which processes are parallel workers running on behalf of which other client sessions. It is better to use the `pg_blocking_pids()` function (see Table 9.64) to identify which process(es) a waiting process is blocked behind.

The `pg_locks` view displays data from both the regular lock manager and the predicate lock manager, which are separate systems; in addition, the regular lock manager subdivides its locks into regular and *fast-path* locks. This data is not guaranteed to be entirely consistent. When the view is queried, data on fast-path locks (with `fastpath = true`) is gathered from each backend one at a time, without freezing the state of the entire lock manager, so it is possible for locks to be taken or released while information is gathered. Note, however, that these locks are known not to conflict with any other lock currently in place. After all backends have been queried for fast-path locks, the remainder of the regular lock manager is locked as a unit, and a consistent snapshot of all remaining locks is collected as an atomic action. After unlocking the regular lock manager, the predicate lock manager is similarly locked and all predicate locks are collected as an atomic action. Thus, with the exception of fast-path locks, each lock manager will deliver a consistent set of results, but as we do not lock both lock managers simultaneously, it is possible for locks to be taken or released after we interrogate the regular lock manager and before we interrogate the predicate lock manager.

Locking the regular and/or predicate lock manager could have some impact on database performance if this view is very frequently accessed. The locks are held only for the minimum amount of time necessary to obtain data from the lock managers, but this does not completely eliminate the possibility of a performance impact.

## 48.82. `pg_matviews`

The view `pg_matviews` provides access to useful information about each materialized view in the database.

**Table 48.83. `pg_matviews` Columns**

Column Type	Description
<code>schemaname name</code> (references <code>pg_namespace.nspname</code> )	Name of schema containing materialized view

Column Type	Description
matviewname name (references pg_class.relname)	Name of materialized view
matviewowner name (references pg_authid.rolname)	Name of materialized view's owner
tablespace name (references pg_tablespace.spcname)	Name of tablespace containing materialized view (null if default for database)
hasindexes bool	True if materialized view has (or recently had) any indexes
ispopulated bool	True if materialized view is currently populated
definition text	Materialized view definition (a reconstructed SELECT query)

## 48.83. pg\_policies

The view `pg_policies` provides access to useful information about each row-level security policy in the database.

**Table 48.84. pg\_policies Columns**

Column Type	Description
schemaname name (references pg_namespace.nspname)	Name of schema containing table policy is on
tablename name (references pg_class.relname)	Name of table policy is on
polycname name (references pg_policy.polname)	Name of policy
permissive text	Is the policy permissive or restrictive?
roles name[ ]	The roles to which this policy applies
cmd text	The command type to which the policy is applied
qual text	The expression added to the security barrier qualifications for queries that this policy applies to
with_check text	The expression added to the WITH CHECK qualifications for queries that attempt to add rows to this table

## 48.84. pg\_prepared\_statements

The `pg_prepared_statements` view displays all the prepared statements that are available in the current session. See `PREPARE` for more information about prepared statements.

`pg_prepared_statements` contains one row for each prepared statement. Rows are added to the view when a new prepared statement is created and removed when a prepared statement is released (for example, via the `DEALLOCATE` command).

**Table 48.85. pg\_prepared\_statements Columns**

Column Type	Description
name text	The identifier of the prepared statement
statement text	The query string submitted by the client to create this prepared statement. For prepared statements created via SQL, this is the <code>PREPARE</code> statement submitted by the client. For prepared statements created via the frontend/backend protocol, this is the text of the prepared statement itself.
prepare_time timestamptz	The time at which the prepared statement was created
parameter_types regtype[ ]	The expected parameter types for the prepared statement in the form of an array of <code>regtype</code> . The OID corresponding to an element of this array can be obtained by casting the <code>regtype</code> value to <code>oid</code> .
from_sql bool	<code>true</code> if the prepared statement was created via the <code>PREPARE SQL</code> command; <code>false</code> if the statement was prepared via the frontend/backend protocol

The `pg_prepared_statements` view is read only.

## 48.85. pg\_prepared\_xacts

The view `pg_prepared_xacts` displays information about transactions that are currently prepared for two-phase commit (see `PREPARE TRANSACTION` for details).

`pg_prepared_xacts` contains one row per prepared transaction. An entry is removed when the transaction is committed or rolled back.

**Table 48.86. pg\_prepared\_xacts Columns**

Column Type	Description
transaction xid	Numeric transaction identifier of the prepared transaction
gid text	Global transaction identifier that was assigned to the transaction
prepared timestamptz	Time at which the transaction was prepared for commit
owner name (references pg_authid.rolname)	Name of the user that executed the transaction
database name (references pg_database.datname)	Name of the database in which the transaction was executed

When the `pg_prepared_xacts` view is accessed, the internal transaction manager data structures are momentarily locked, and a copy is made for the view to display. This ensures that the view produces a consistent set of results, while not blocking normal operations longer than necessary. Nonetheless there could be some impact on database performance if this view is frequently accessed.

## 48.86. pg\_publication\_tables

The view `pg_publication_tables` provides information about the mapping between publications and the tables they contain. Unlike the underlying catalog `pg_publication_rel`, this view expands publications defined as `FOR ALL TABLES`, so for such publications there will be a row for each eligible table.

**Table 48.87. `pg_publication_tables` Columns**

Column Type	Description
<code>pubname name</code> (references <code>pg_publication.pubname</code> )	Name of publication
<code>schemaname name</code> (references <code>pg_namespace.nspname</code> )	Name of schema containing table
<code>tablename name</code> (references <code>pg_class.relname</code> )	Name of table

## 48.87. `pg_replication_origin_status`

The `pg_replication_origin_status` view contains information about how far replay for a certain origin has progressed. For more on replication origins see Chapter 46.

**Table 48.88. `pg_replication_origin_status` Columns**

Column Type	Description
<code>local_id oid</code> (references <code>pg_replication_origin.roident</code> )	internal node identifier
<code>external_id text</code> (references <code>pg_replication_origin.roname</code> )	external node identifier
<code>remote_lsn pg_lsn</code>	The origin node's LSN up to which data has been replicated.
<code>local_lsn pg_lsn</code>	This node's LSN at which <code>remote_lsn</code> has been replicated. Used to flush commit records before persisting data to disk when using asynchronous commits.

## 48.88. `pg_replication_slots`

The `pg_replication_slots` view provides a listing of all replication slots that currently exist on the database cluster, along with their current state.

For more on replication slots, see Section 24.2.6 and Chapter 45.

**Table 48.89. `pg_replication_slots` Columns**

Column Type	Description
<code>slot_name name</code>	A unique, cluster-wide identifier for the replication slot
<code>plugin name</code>	The base name of the shared object containing the output plugin this logical slot is using, or null for physical slots.
<code>slot_type text</code>	The slot type: <code>physical</code> or <code>logical</code>

Column Type	Description
<code>datoid oid</code> (references <code>pg_database.oid</code> )	The OID of the database this slot is associated with, or null. Only logical slots have an associated database.
<code>database name</code> (references <code>pg_database.datname</code> )	The name of the database this slot is associated with, or null. Only logical slots have an associated database.
<code>temporary bool</code>	True if this is a temporary replication slot. Temporary slots are not saved to disk and are automatically dropped on error or when the session has finished.
<code>active bool</code>	True if this slot is currently actively being used
<code>active_pid int4</code>	The process ID of the session using this slot if the slot is currently actively being used. NULL if inactive.
<code>xmin xid</code>	The oldest transaction that this slot needs the database to retain. VACUUM cannot remove tuples deleted by any later transaction.
<code>catalog_xmin xid</code>	The oldest transaction affecting the system catalogs that this slot needs the database to retain. VACUUM cannot remove catalog tuples deleted by any later transaction.
<code>restart_lsn pg_lsn</code>	The address (LSN) of oldest WAL which still might be required by the consumer of this slot and thus won't be automatically removed during checkpoints unless this LSN gets behind more than <code>max_slot_wal_keep_size</code> from the current LSN. NULL if the LSN of this slot has never been reserved.
<code>confirmed_flush_lsn pg_lsn</code>	The address (LSN) up to which the logical slot's consumer has confirmed receiving data. Data older than this is not available anymore. NULL for physical slots.
<code>wal_status text</code>	<p>Availability of WAL files claimed by this slot. Possible values are:</p> <ul style="list-style-type: none"> <li><code>reserved</code> means that the claimed files are within <code>max_wal_size</code>.</li> <li><code>extended</code> means that <code>max_wal_size</code> is exceeded but the files are still retained, either by the replication slot or by <code>wal_keep_size</code>.</li> <li><code>unreserved</code> means that the slot no longer retains the required WAL files and some of them are to be removed at the next checkpoint. This state can return to <code>reserved</code> or <code>extended</code>.</li> <li><code>lost</code> means that some required WAL files have been removed and this slot is no longer usable.</li> </ul> <p>The last two states are seen only when <code>max_slot_wal_keep_size</code> is non-negative. If <code>restart_lsn</code> is NULL, this field is null.</p>
<code>safe_wal_size int8</code>	The number of bytes that can be written to WAL such that this slot is not in danger of getting in state "lost". It is NULL for lost slots, as well as if <code>max_slot_wal_keep_size</code> is -1.

## 48.89. pg\_roles

The view `pg_roles` provides access to information about database roles. This is simply a publicly readable view of `pg_authid` that blanks out the password field.

**Table 48.90. `pg_roles` Columns**

Column Type	Description
<code>rolname name</code>	Role name
<code>rolsuper bool</code>	Role has superuser privileges
<code>rolinherit bool</code>	Role automatically inherits privileges of roles it is a member of
<code>rolcreaterole bool</code>	Role can create more roles
<code>rolcreatedb bool</code>	Role can create databases
<code>rolcanlogin bool</code>	Role can log in. That is, this role can be given as the initial session authorization identifier
<code>rolreplication bool</code>	Role is a replication role. A replication role can initiate replication connections and create and drop replication slots.
<code>rolconlimit int4</code>	For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
<code>rolpassword text</code>	Not the password (always reads as <code>*****</code> )
<code>rolvaliduntil timestampz</code>	Password expiry time (only used for password authentication); null if no expiration
<code>rolbypassrls bool</code>	Role bypasses every row level security policy, see Section 5.8 for more information.
<code>rolconfig text[]</code>	Role-specific defaults for run-time configuration variables
<code>oid oid (references pg_authid.oid)</code>	ID of role

## 48.90. `pg_rules`

The view `pg_rules` provides access to useful information about query rewrite rules.

**Table 48.91. `pg_rules` Columns**

Column Type	Description
<code>schemaname name (references pg_namespace.nspname)</code>	Name of schema containing table
<code>tablename name (references pg_class.relname)</code>	Name of table the rule is for
<code>rulename name (references pg_rewrite.rulename)</code>	Name of rule

Column Type	Description
definition text	Rule definition (a reconstructed creation command)

The `pg_rules` view excludes the ON SELECT rules of views and materialized views; those can be seen in `pg_views` and `pg_matviews`.

## 48.91. `pg_seclabels`

The view `pg_seclabels` provides information about security labels. It is an easier-to-query version of the `pg_seclabel` catalog.

**Table 48.92. `pg_seclabels` Columns**

Column Type	Description
<code>objoid oid</code> (references any OID column)	The OID of the object this security label pertains to
<code>classoid oid</code> (references <code>pg_class.oid</code> )	The OID of the system catalog this object appears in
<code>objsubid int4</code>	For a security label on a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other object types, this column is zero.
<code>objtype text</code>	The type of object to which this label applies, as text.
<code>objnamespace oid</code> (references <code>pg_namespace.oid</code> )	The OID of the namespace for this object, if applicable; otherwise NULL.
<code>objname text</code>	The name of the object to which this label applies, as text.
<code>provider text</code> (references <code>pg_seclabel.provider</code> )	The label provider associated with this label.
<code>label text</code> (references <code>pg_seclabel.label</code> )	The security label applied to this object.

## 48.92. `pg_sequences`

The view `pg_sequences` provides access to useful information about each sequence in the database.

**Table 48.93. `pg_sequences` Columns**

Column Type	Description
<code>schemaname name</code> (references <code>pg_namespace.nspname</code> )	Name of schema containing sequence
<code>sequencename name</code> (references <code>pg_class.relname</code> )	Name of sequence
<code>sequenceowner name</code> (references <code>pg_authid.rolname</code> )	Name of sequence's owner
<code>data_type regtype</code> (references <code>pg_type.oid</code> )	Data type of the sequence
<code>start_value int8</code>	



Column Type	Description
	Start value of the sequence
min_value int8	Minimum value of the sequence
max_value int8	Maximum value of the sequence
increment_by int8	Increment value of the sequence
cycle bool	Whether the sequence cycles
cache_size int8	Cache size of the sequence
last_value int8	The last sequence value written to disk. If caching is used, this value can be greater than the last value handed out from the sequence. Null if the sequence has not been read from yet. Also, if the current user does not have USAGE or SELECT privilege on the sequence, the value is null.

## 48.93. pg\_settings

The view `pg_settings` provides access to run-time parameters of the server. It is essentially an alternative interface to the SHOW and SET commands. It also provides access to some facts about each parameter that are not directly available from SHOW, such as minimum and maximum values.

**Table 48.94. pg\_settings Columns**

Column Type	Description
name text	Run-time configuration parameter name
setting text	Current value of the parameter
unit text	Implicit unit of the parameter
category text	Logical group of the parameter
short_desc text	A brief description of the parameter
extra_desc text	Additional, more detailed, description of the parameter
context text	Context required to set the parameter's value (see below)
vartype text	Parameter type (bool, enum, integer, real, or string)
source text	Source of the current parameter value
min_val text	Minimum allowed value of the parameter (null for non-numeric values)
max_val text	

Column Type	Description
	Maximum allowed value of the parameter (null for non-numeric values)
enumvals text[]	Allowed values of an enum parameter (null for non-enum values)
boot_val text	Parameter value assumed at server startup if the parameter is not otherwise set
reset_val text	Value that RESET would reset the parameter to in the current session
sourcefile text	Configuration file the current value was set in (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of <code>pg_read_all_settings</code> ); helpful when using <code>include</code> directives in configuration files
sourceline int4	Line number within the configuration file the current value was set at (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of <code>pg_read_all_settings</code> ).
pending_restart bool	<code>true</code> if the value has been changed in the configuration file but needs a restart; or <code>false</code> otherwise.

There are several possible values of `context`. In order of decreasing difficulty of changing the setting, they are:

#### internal

These settings cannot be changed directly; they reflect internally determined values. Some of them may be adjustable by rebuilding the server with different configuration options, or by changing options supplied to `initdb`.

#### postmaster

These settings can only be applied when the server starts, so any change requires restarting the server. Values for these settings are typically stored in the `lightdb.conf` file, or passed on the command line when starting the server. Of course, settings with any of the lower `context` types can also be set at server start time.

#### sighup

Changes to these settings can be made in `lightdb.conf` without restarting the server. Send a `SIGHUP` signal to the postmaster to cause it to re-read `lightdb.conf` and apply the changes. The postmaster will also forward the `SIGHUP` signal to its child processes so that they all pick up the new value.

#### superuser-backend

Changes to these settings can be made in `lightdb.conf` without restarting the server. They can also be set for a particular session in the connection request packet (for example, via `libpq`'s `PGOPTIONS` environment variable), but only if the connecting user is a superuser. However, these settings never change in a session after it is started. If you change them in `lightdb.conf`, send a `SIGHUP` signal to the postmaster to cause it to re-read `lightdb.conf`. The new values will only affect subsequently-launched sessions.

#### backend

Changes to these settings can be made in `lightdb.conf` without restarting the server. They can also be set for a particular session in the connection request packet (for example, via `libpq`'s

PGOPTIONS environment variable); any user can make such a change for their session. However, these settings never change in a session after it is started. If you change them in `lightdb.conf`, send a `SIGHUP` signal to the postmaster to cause it to re-read `lightdb.conf`. The new values will only affect subsequently-launched sessions.

#### superuser

These settings can be set from `lightdb.conf`, or within a session via the `SET` command; but only superusers can change them via `SET`. Changes in `lightdb.conf` will affect existing sessions only if no session-local value has been established with `SET`.

#### user

These settings can be set from `lightdb.conf`, or within a session via the `SET` command. Any user is allowed to change their session-local value. Changes in `lightdb.conf` will affect existing sessions only if no session-local value has been established with `SET`.

See Section 17.1 for more information about the various ways to change these parameters.

The `pg_settings` view cannot be inserted into or deleted from, but it can be updated. An `UPDATE` applied to a row of `pg_settings` is equivalent to executing the `SET` command on that named parameter. The change only affects the value used by the current session. If an `UPDATE` is issued within a transaction that is later aborted, the effects of the `UPDATE` command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another `UPDATE` or `SET`.

## 48.94. pg\_shadow

The view `pg_shadow` exists for backwards compatibility: it emulates a catalog that existed in LightDB before version 8.1. It shows properties of all roles that are marked as `rolcanlogin` in `pg_authid`.

The name stems from the fact that this table should not be readable by the public since it contains passwords. `pg_user` is a publicly readable view on `pg_shadow` that blanks out the password field.

**Table 48.95. pg\_shadow Columns**

Column	Type	Description
<code>username</code>	<code>name</code>	(references <code>pg_authid.rolname</code> ) User name
<code>usesysid</code>	<code>oid</code>	(references <code>pg_authid.oid</code> ) ID of this user
<code>usecreatedb</code>	<code>bool</code>	User can create databases
<code>usesuper</code>	<code>bool</code>	User is a superuser
<code>userepl</code>	<code>bool</code>	User can initiate streaming replication and put the system in and out of backup mode.
<code>usebypassrls</code>	<code>bool</code>	User bypasses every row level security policy, see Section 5.8 for more information.
<code>passwd</code>	<code>text</code>	Password (possibly encrypted); null if none. See <code>pg_authid</code> for details of how encrypted passwords are stored.
<code>valuntil</code>	<code>timestampz</code>	Password expiry time (only used for password authentication)
<code>useconfig</code>	<code>text[]</code>	

Column Type	Description
	Session defaults for run-time configuration variables

## 48.95. `pg_shmem_allocations`

The `pg_shmem_allocations` view shows allocations made from the server's main shared memory segment. This includes both memory allocated by `lightdb` itself and memory allocated by extensions using the mechanisms detailed in Section 36.10.10.

Note that this view does not include memory allocated using the dynamic shared memory infrastructure.

**Table 48.96. `pg_shmem_allocations` Columns**

Column Type	Description
<code>name</code> text	The name of the shared memory allocation. <code>NULL</code> for unused memory and <code>&lt;anonymous&gt;</code> for anonymous allocations.
<code>off</code> int8	The offset at which the allocation starts. <code>NULL</code> for anonymous allocations, since details related to them are not known.
<code>size</code> int8	Size of the allocation
<code>allocated_size</code> int8	Size of the allocation including padding. For anonymous allocations, no information about padding is available, so the <code>size</code> and <code>allocated_size</code> columns will always be equal. Padding is not meaningful for free memory, so the columns will be equal in that case also.

Anonymous allocations are allocations that have been made with `ShmemAlloc()` directly, rather than via `ShmemInitStruct()` or `ShmemInitHash()`.

By default, the `pg_shmem_allocations` view can be read only by superusers.

## 48.96. `pg_stats`

The view `pg_stats` provides access to the information stored in the `pg_statistic` catalog. This view allows access only to rows of `pg_statistic` that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

`pg_stats` is also designed to present the information in a more readable format than the underlying catalog — at the cost that its schema must be extended whenever new slot types are defined for `pg_statistic`.

**Table 48.97. `pg_stats` Columns**

Column Type	Description
<code>schemaname</code> name (references <code>pg_namespace.nspname</code> )	Name of schema containing table
<code>tablename</code> name (references <code>pg_class.relname</code> )	Name of table
<code>attname</code> name (references <code>pg_attribute.attname</code> )	

<b>Column Type</b>	<b>Description</b>
	Name of the column described by this row
<code>inherited bool</code>	If true, this row includes inheritance child columns, not just the values in the specified table
<code>null_frac float4</code>	Fraction of column entries that are null
<code>avg_width int4</code>	Average width in bytes of column's entries
<code>n_distinct float4</code>	If greater than zero, the estimated number of distinct values in the column. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when <code>ANALYZE</code> believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique column in which the number of distinct values is the same as the number of rows.
<code>most_common_vals anyarray</code>	A list of the most common values in the column. (Null if no values seem to be more common than any others.)
<code>most_common_freqs float4[]</code>	A list of the frequencies of the most common values, i.e., number of occurrences of each divided by total number of rows. (Null when <code>most_common_vals</code> is.)
<code>histogram_bounds anyarray</code>	A list of values that divide the column's values into groups of approximately equal population. The values in <code>most_common_vals</code> , if present, are omitted from this histogram calculation. (This column is null if the column data type does not have a < operator or if the <code>most_common_vals</code> list accounts for the entire population.)
<code>correlation float4</code>	Statistical correlation between physical row ordering and logical ordering of the column values. This ranges from -1 to +1. When the value is near -1 or +1, an index scan on the column will be estimated to be cheaper than when it is near zero, due to reduction of random access to the disk. (This column is null if the column data type does not have a < operator.)
<code>most_common_elems anyarray</code>	A list of non-null element values most often appearing within values of the column. (Null for scalar types.)
<code>most_common_elem_freqs float4[]</code>	A list of the frequencies of the most common element values, i.e., the fraction of rows containing at least one instance of the given value. Two or three additional values follow the per-element frequencies; these are the minimum and maximum of the preceding per-element frequencies, and optionally the frequency of null elements. (Null when <code>most_common_elems</code> is.)
<code>elem_count_histogram float4[]</code>	A histogram of the counts of distinct non-null element values within the values of the column, followed by the average number of distinct non-null elements. (Null for scalar types.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the `default_statistics_target` run-time parameter.

## 48.97. `pg_stats_ext`

The view `pg_stats_ext` provides access to the information stored in the `pg_statistic_ext` and `pg_statistic_ext_data` catalogs. This view allows access only to rows of `pg_statistic_ext` and `pg_statistic_ext_data` that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

`pg_stats_ext` is also designed to present the information in a more readable format than the underlying catalogs — at the cost that its schema must be extended whenever new types of extended statistics are added to `pg_statistic_ext`.

**Table 48.98. `pg_stats_ext` Columns**

Column Type	Description
<code>schemaname</code> name (references <code>pg_namespace.nspname</code> )	Name of schema containing table
<code>tablename</code> name (references <code>pg_class.relname</code> )	Name of table
<code>statistics_schemaname</code> name (references <code>pg_namespace.nspname</code> )	Name of schema containing extended statistic
<code>statistics_name</code> name (references <code>pg_statistic_ext.stxname</code> )	Name of extended statistics
<code>statistics_owner</code> name (references <code>pg_authid.rolname</code> )	Owner of the extended statistics
<code>attnames</code> name[ ] (references <code>pg_attribute.attname</code> )	Names of the columns the extended statistics is defined on
<code>kinds</code> char[ ]	Types of extended statistics enabled for this record
<code>n_distinct</code> <code>pg_ndistinct</code>	N-distinct counts for combinations of column values. If greater than zero, the estimated number of distinct values in the combination. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when <code>ANALYZE</code> believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique combination of columns in which the number of distinct combinations is the same as the number of rows.
<code>dependencies</code> <code>pg_dependencies</code>	Functional dependency statistics
<code>most_common_vals</code> text[ ]	A list of the most common combinations of values in the columns. (Null if no combinations seem to be more common than any others.)
<code>most_common_val_nulls</code> bool[ ]	A list of NULL flags for the most common combinations of values. (Null when <code>most_common_vals</code> is.)
<code>most_common_freqs</code> float8[ ]	A list of the frequencies of the most common combinations, i.e., number of occurrences of each divided by total number of rows. (Null when <code>most_common_vals</code> is.)
<code>most_common_base_freqs</code> float8[ ]	A list of the base frequencies of the most common combinations, i.e., product of per-value frequencies. (Null when <code>most_common_vals</code> is.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the `default_statistics_target` run-time parameter.

## 48.98. pg\_tables

The view `pg_tables` provides access to useful information about each table in the database.

**Table 48.99. pg\_tables Columns**

Column Type	Description
schemaname name (references <code>pg_namespace.nspname</code> )	Name of schema containing table
tablename name (references <code>pg_class.relname</code> )	Name of table
tableowner name (references <code>pg_authid.rolname</code> )	Name of table's owner
tablespace name (references <code>pg_tablespace.spcname</code> )	Name of tablespace containing table (null if default for database)
hasindexes bool (references <code>pg_class.relhasindex</code> )	True if table has (or recently had) any indexes
hasrules bool (references <code>pg_class.relhasrules</code> )	True if table has (or once had) rules
hastriggers bool (references <code>pg_class.relhastriggers</code> )	True if table has (or once had) triggers
rowsecurity bool (references <code>pg_class.relrowsecurity</code> )	True if row security is enabled on the table

## 48.99. pg\_timezone\_abbrevs

The view `pg_timezone_abbrevs` provides a list of time zone abbreviations that are currently recognized by the datetime input routines. The contents of this view change when the `timezone_abbreviations` run-time parameter is modified.

**Table 48.100. pg\_timezone\_abbrevs Columns**

Column Type	Description
abbrev text	Time zone abbreviation
utc_offset interval	Offset from UTC (positive means east of Greenwich)
is_dst bool	True if this is a daylight-savings abbreviation

While most timezone abbreviations represent fixed offsets from UTC, there are some that have historically varied in value (see Section B.4 for more information). In such cases this view presents their current meaning.

## 48.100. pg\_timezone\_names

The view `pg_timezone_names` provides a list of time zone names that are recognized by `SET TIMEZONE`, along with their associated abbreviations, UTC offsets, and daylight-savings status. (Technically, LightDB does not use UTC because leap seconds are not handled.)

Unlike the abbreviations shown in `pg_timezone_abbrevs`, many of these names imply a set of daylight-savings transition date rules. Therefore, the associated information changes across local DST boundaries. The displayed information is computed based on the current value of `CURRENT_TIMESTAMP`.

**Table 48.101. `pg_timezone_names` Columns**

Column Type	Description
name text	Time zone name
abbrev text	Time zone abbreviation
utc_offset interval	Offset from UTC (positive means east of Greenwich)
is_dst bool	True if currently observing daylight savings

## 48.101. `pg_user`

The view `pg_user` provides access to information about database users. This is simply a publicly readable view of `pg_shadow` that blanks out the password field.

**Table 48.102. `pg_user` Columns**

Column Type	Description
username name	User name
usesysid oid	ID of this user
usecreatedb bool	User can create databases
usesuper bool	User is a superuser
userepl bool	User can initiate streaming replication and put the system in and out of backup mode.
usebypassrls bool	User bypasses every row level security policy, see Section 5.8 for more information.
passwd text	Not the password (always reads as <code>*****</code> )
valuntil timestamptz	Password expiry time (only used for password authentication)
useconfig text[]	Session defaults for run-time configuration variables

## 48.102. `pg_user_mappings`

The view `pg_user_mappings` provides access to information about user mappings. This is essentially a publicly readable view of `pg_user_mapping` that leaves out the options field if the user has no rights to use it.



**Table 48.103. pg\_user\_mappings Columns**

Column Type	Description
umid oid (references pg_user_mapping.oid)	OID of the user mapping
srvid oid (references pg_foreign_server.oid)	The OID of the foreign server that contains this mapping
srvname name (references pg_foreign_server.srvname)	Name of the foreign server
umuser oid (references pg_authid.oid)	OID of the local role being mapped, 0 if the user mapping is public
username name	Name of the local user to be mapped
umoptions text[]	User mapping specific options, as “keyword=value” strings

To protect password information stored as a user mapping option, the `umoptions` column will read as null unless one of the following applies:

- current user is the user being mapped, and owns the server or holds `USAGE` privilege on it
- current user is the server owner and mapping is for `PUBLIC`
- current user is a superuser

## 48.103. pg\_views

The view `pg_views` provides access to useful information about each view in the database.

**Table 48.104. pg\_views Columns**

Column Type	Description
schemaname name (references pg_namespace.nspname)	Name of schema containing view
viewname name (references pg_class.relname)	Name of view
viewowner name (references pg_authid.rolname)	Name of view's owner
definition text	View definition (a reconstructed <code>SELECT</code> query)

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# Chapter 49. Frontend/Backend Protocol

LightDB uses a message-based protocol for communication between frontends and backends (clients and servers). The protocol is supported over TCP/IP and also over Unix-domain sockets. Port number 5432 has been registered with IANA as the customary TCP port number for servers supporting this protocol, but in practice any non-privileged port number can be used.

This document describes version 3.0 of the protocol. A single server can support multiple protocol versions. The initial startup-request message tells the server which protocol version the client is attempting to use. If the major version requested by the client is not supported by the server, the connection will be rejected (for example, this would occur if the client requested protocol version 4.0, which does not exist as of this writing). If the minor version requested by the client is not supported by the server (e.g., the client requests version 3.1, but the server supports only 3.0), the server may either reject the connection or may respond with a `NegotiateProtocolVersion` message containing the highest minor protocol version which it supports. The client may then choose either to continue with the connection using the specified protocol version or to abort the connection.

In order to serve multiple clients efficiently, the server launches a new “backend” process for each client. In the current implementation, a new child process is created immediately after an incoming connection is detected. This is transparent to the protocol, however. For purposes of the protocol, the terms “backend” and “server” are interchangeable; likewise “frontend” and “client” are interchangeable.

## 49.1. Overview

The protocol has separate phases for startup and normal operation. In the startup phase, the frontend opens a connection to the server and authenticates itself to the satisfaction of the server. (This might involve a single message, or multiple messages depending on the authentication method being used.) If all goes well, the server then sends status information to the frontend, and finally enters normal operation. Except for the initial startup-request message, this part of the protocol is driven by the server.

During normal operation, the frontend sends queries and other commands to the backend, and the backend sends back query results and other responses. There are a few cases (such as `NOTIFY`) wherein the backend will send unsolicited messages, but for the most part this portion of a session is driven by frontend requests.

Termination of the session is normally by frontend choice, but can be forced by the backend in certain cases. In any case, when the backend closes the connection, it will roll back any open (incomplete) transaction before exiting.

Within normal operation, SQL commands can be executed through either of two sub-protocols. In the “simple query” protocol, the frontend just sends a textual query string, which is parsed and immediately executed by the backend. In the “extended query” protocol, processing of queries is separated into multiple steps: parsing, binding of parameter values, and execution. This offers flexibility and performance benefits, at the cost of extra complexity.

Normal operation has additional sub-protocols for special operations such as `COPY`.

### 49.1.1. Messaging Overview

All communication is through a stream of messages. The first byte of a message identifies the message type, and the next four bytes specify the length of the rest of the message (this length count includes itself, but not the message-type byte). The remaining contents of the message are determined by the message type. For historical reasons, the very first message sent by the client (the startup message) has no initial message-type byte.

To avoid losing synchronization with the message stream, both servers and clients typically read an entire message into a buffer (using the byte count) before attempting to process its contents. This allows easy recovery if an error is detected while processing the contents. In extreme situations (such as not having enough memory to buffer the message), the receiver can use the byte count to determine how much input to skip before it resumes reading messages.

Conversely, both servers and clients must take care never to send an incomplete message. This is commonly done by marshaling the entire message in a buffer before beginning to send it. If a communications failure occurs partway through sending or receiving a message, the only sensible response is to abandon the connection, since there is little hope of recovering message-boundary synchronization.

## 49.1.2. Extended Query Overview

In the extended-query protocol, execution of SQL commands is divided into multiple steps. The state retained between steps is represented by two types of objects: *prepared statements* and *portals*. A prepared statement represents the result of parsing and semantic analysis of a textual query string. A prepared statement is not in itself ready to execute, because it might lack specific values for *parameters*. A portal represents a ready-to-execute or already-partially-executed statement, with any missing parameter values filled in. (For SELECT statements, a portal is equivalent to an open cursor, but we choose to use a different term since cursors don't handle non-SELECT statements.)

The overall execution cycle consists of a *parse* step, which creates a prepared statement from a textual query string; a *bind* step, which creates a portal given a prepared statement and values for any needed parameters; and an *execute* step that runs a portal's query. In the case of a query that returns rows (SELECT, SHOW, etc), the execute step can be told to fetch only a limited number of rows, so that multiple execute steps might be needed to complete the operation.

The backend can keep track of multiple prepared statements and portals (but note that these exist only within a session, and are never shared across sessions). Existing prepared statements and portals are referenced by names assigned when they were created. In addition, an “unnamed” prepared statement and portal exist. Although these behave largely the same as named objects, operations on them are optimized for the case of executing a query only once and then discarding it, whereas operations on named objects are optimized on the expectation of multiple uses.

## 49.1.3. Formats and Format Codes

Data of a particular data type might be transmitted in any of several different *formats*. As of LightDB 7.4 the only supported formats are “text” and “binary”, but the protocol makes provision for future extensions. The desired format for any value is specified by a *format code*. Clients can specify a format code for each transmitted parameter value and for each column of a query result. Text has format code zero, binary has format code one, and all other format codes are reserved for future definition.

The text representation of values is whatever strings are produced and accepted by the input/output conversion functions for the particular data type. In the transmitted representation, there is no trailing null character; the frontend must add one to received values if it wants to process them as C strings. (The text format does not allow embedded nulls, by the way.)

Binary representations for integers use network byte order (most significant byte first). For other data types consult the documentation or source code to learn about the binary representation. Keep in mind that binary representations for complex data types might change across server versions; the text format is usually the more portable choice.

## 49.2. Message Flow

This section describes the message flow and the semantics of each message type. (Details of the exact representation of each message appear in Section 49.7.) There are several different sub-protocols

depending on the state of the connection: start-up, query, function call, COPY, and termination. There are also special provisions for asynchronous operations (including notification responses and command cancellation), which can occur at any time after the start-up phase.

## 49.2.1. Start-up

To begin a session, a frontend opens a connection to the server and sends a startup message. This message includes the names of the user and of the database the user wants to connect to; it also identifies the particular protocol version to be used. (Optionally, the startup message can include additional settings for run-time parameters.) The server then uses this information and the contents of its configuration files (such as `lt_hba.conf`) to determine whether the connection is provisionally acceptable, and what additional authentication is required (if any).

The server then sends an appropriate authentication request message, to which the frontend must reply with an appropriate authentication response message (such as a password). For all authentication methods except GSSAPI, SSPI and SASL, there is at most one request and one response. In some methods, no response at all is needed from the frontend, and so no authentication request occurs. For GSSAPI, SSPI and SASL, multiple exchanges of packets may be needed to complete the authentication.

The authentication cycle ends with the server either rejecting the connection attempt (ErrorResponse), or sending AuthenticationOk.

The possible messages from the server in this phase are:

### ErrorResponse

The connection attempt has been rejected. The server then immediately closes the connection.

### AuthenticationOk

The authentication exchange is successfully completed.

### AuthenticationKerberosV5

The frontend must now take part in a Kerberos V5 authentication dialog (not described here, part of the Kerberos specification) with the server. If this is successful, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse. This is no longer supported.

### AuthenticationCleartextPassword

The frontend must now send a PasswordMessage containing the password in clear-text form. If this is the correct password, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse.

### AuthenticationMD5Password

The frontend must now send a PasswordMessage containing the password (with user name) encrypted via MD5, then encrypted again using the 4-byte random salt specified in the AuthenticationMD5Password message. If this is the correct password, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse. The actual PasswordMessage can be computed in SQL as `concat('md5', md5(concat(md5(concat(password, username)), random-salt)))`. (Keep in mind the `md5()` function returns its result as a hex string.)

### AuthenticationSCMCredential

This response is only possible for local Unix-domain connections on platforms that support SCM credential messages. The frontend must issue an SCM credential message and then send a

single data byte. (The contents of the data byte are uninteresting; it's only used to ensure that the server waits long enough to receive the credential message.) If the credential is acceptable, the server responds with an `AuthenticationOk`, otherwise it responds with an `ErrorResponse`. (This message type is only issued by pre-9.1 servers. It may eventually be removed from the protocol specification.)

#### AuthenticationGSS

The frontend must now initiate a GSSAPI negotiation. The frontend will send a `GSSResponse` message with the first part of the GSSAPI data stream in response to this. If further messages are needed, the server will respond with `AuthenticationGSSContinue`.

#### AuthenticationSSPI

The frontend must now initiate a SSPI negotiation. The frontend will send a `GSSResponse` with the first part of the SSPI data stream in response to this. If further messages are needed, the server will respond with `AuthenticationGSSContinue`.

#### AuthenticationGSSContinue

This message contains the response data from the previous step of GSSAPI or SSPI negotiation (`AuthenticationGSS`, `AuthenticationSSPI` or a previous `AuthenticationGSSContinue`). If the GSSAPI or SSPI data in this message indicates more data is needed to complete the authentication, the frontend must send that data as another `GSSResponse` message. If GSSAPI or SSPI authentication is completed by this message, the server will next send `AuthenticationOk` to indicate successful authentication or `ErrorResponse` to indicate failure.

#### AuthenticationSASL

The frontend must now initiate a SASL negotiation, using one of the SASL mechanisms listed in the message. The frontend will send a `SASLInitialResponse` with the name of the selected mechanism, and the first part of the SASL data stream in response to this. If further messages are needed, the server will respond with `AuthenticationSASLContinue`. See Section 49.3 for details.

#### AuthenticationSASLContinue

This message contains challenge data from the previous step of SASL negotiation (`AuthenticationSASL`, or a previous `AuthenticationSASLContinue`). The frontend must respond with a `SASLResponse` message.

#### AuthenticationSASLFinal

SASL authentication has completed with additional mechanism-specific data for the client. The server will next send `AuthenticationOk` to indicate successful authentication, or an `ErrorResponse` to indicate failure. This message is sent only if the SASL mechanism specifies additional data to be sent from server to client at completion.

#### NegotiateProtocolVersion

The server does not support the minor protocol version requested by the client, but does support an earlier version of the protocol; this message indicates the highest supported minor version. This message will also be sent if the client requested unsupported protocol options (i.e., beginning with `_p_q_.`) in the startup packet. This message will be followed by an `ErrorResponse` or a message indicating the success or failure of authentication.

If the frontend does not support the authentication method requested by the server, then it should immediately close the connection.

After having received `AuthenticationOk`, the frontend must wait for further messages from the server. In this phase a backend process is being started, and the frontend is just an interested bystander. It

is still possible for the startup attempt to fail (`ErrorResponse`) or the server to decline support for the requested minor protocol version (`NegotiateProtocolVersion`), but in the normal case the backend will send some `ParameterStatus` messages, `BackendKeyData`, and finally `ReadyForQuery`.

During this phase the backend will attempt to apply any additional run-time parameter settings that were given in the startup message. If successful, these values become session defaults. An error causes `ErrorResponse` and exit.

The possible messages from the backend in this phase are:

#### `BackendKeyData`

This message provides secret-key data that the frontend must save if it wants to be able to issue cancel requests later. The frontend should not respond to this message, but should continue listening for a `ReadyForQuery` message.

#### `ParameterStatus`

This message informs the frontend about the current (initial) setting of backend parameters, such as `client_encoding` or `DateStyle`. The frontend can ignore this message, or record the settings for its future use; see Section 49.2.7 for more details. The frontend should not respond to this message, but should continue listening for a `ReadyForQuery` message.

#### `ReadyForQuery`

Start-up is completed. The frontend can now issue commands.

#### `ErrorResponse`

Start-up failed. The connection is closed after sending this message.

#### `NoticeResponse`

A warning message has been issued. The frontend should display the message but continue listening for `ReadyForQuery` or `ErrorResponse`.

The `ReadyForQuery` message is the same one that the backend will issue after each command cycle. Depending on the coding needs of the frontend, it is reasonable to consider `ReadyForQuery` as starting a command cycle, or to consider `ReadyForQuery` as ending the start-up phase and each subsequent command cycle.

## 49.2.2. Simple Query

A simple query cycle is initiated by the frontend sending a `Query` message to the backend. The message includes an SQL command (or commands) expressed as a text string. The backend then sends one or more response messages depending on the contents of the query command string, and finally a `ReadyForQuery` response message. `ReadyForQuery` informs the frontend that it can safely send a new command. (It is not actually necessary for the frontend to wait for `ReadyForQuery` before issuing another command, but the frontend must then take responsibility for figuring out what happens if the earlier command fails and already-issued later commands succeed.)

The possible response messages from the backend are:

#### `CommandComplete`

An SQL command completed normally.

#### `CopyInResponse`

The backend is ready to copy data from the frontend to a table; see Section 49.2.6.

### CopyOutResponse

The backend is ready to copy data from a table to the frontend; see Section 49.2.6.

### RowDescription

Indicates that rows are about to be returned in response to a `SELECT`, `FETCH`, etc query. The contents of this message describe the column layout of the rows. This will be followed by a `DataRow` message for each row being returned to the frontend.

### DataRow

One of the set of rows returned by a `SELECT`, `FETCH`, etc query.

### EmptyQueryResponse

An empty query string was recognized.

### ErrorResponse

An error has occurred.

### ReadyForQuery

Processing of the query string is complete. A separate message is sent to indicate this because the query string might contain multiple SQL commands. (`CommandComplete` marks the end of processing one SQL command, not the whole string.) `ReadyForQuery` will always be sent, whether processing terminates successfully or with an error.

### NoticeResponse

A warning message has been issued in relation to the query. Notices are in addition to other responses, i.e., the backend will continue processing the command.

The response to a `SELECT` query (or other queries that return row sets, such as `EXPLAIN` or `SHOW`) normally consists of `RowDescription`, zero or more `DataRow` messages, and then `CommandComplete`. `COPY` to or from the frontend invokes special protocol as described in Section 49.2.6. All other query types normally produce only a `CommandComplete` message.

Since a query string could contain several queries (separated by semicolons), there might be several such response sequences before the backend finishes processing the query string. `ReadyForQuery` is issued when the entire string has been processed and the backend is ready to accept a new query string.

If a completely empty (no contents other than whitespace) query string is received, the response is `EmptyQueryResponse` followed by `ReadyForQuery`.

In the event of an error, `ErrorResponse` is issued followed by `ReadyForQuery`. All further processing of the query string is aborted by `ErrorResponse` (even if more queries remained in it). Note that this might occur partway through the sequence of messages generated by an individual query.

In simple Query mode, the format of retrieved values is always text, except when the given command is a `FETCH` from a cursor declared with the `BINARY` option. In that case, the retrieved values are in binary format. The format codes given in the `RowDescription` message tell which format is being used.

A frontend must be prepared to accept `ErrorResponse` and `NoticeResponse` messages whenever it is expecting any other type of message. See also Section 49.2.7 concerning messages that the backend might generate due to outside events.

Recommended practice is to code frontends in a state-machine style that will accept any message type at any time that it could make sense, rather than wiring in assumptions about the exact sequence of messages.

### 49.2.2.1. Multiple Statements in a Simple Query

When a simple Query message contains more than one SQL statement (separated by semicolons), those statements are executed as a single transaction, unless explicit transaction control commands are included to force a different behavior. For example, if the message contains

```
INSERT INTO mytable VALUES(1);
SELECT 1/0;
INSERT INTO mytable VALUES(2);
```

then the divide-by-zero failure in the `SELECT` will force rollback of the first `INSERT`. Furthermore, because execution of the message is abandoned at the first error, the second `INSERT` is never attempted at all.

If instead the message contains

```
BEGIN;
INSERT INTO mytable VALUES(1);
COMMIT;
INSERT INTO mytable VALUES(2);
SELECT 1/0;
```

then the first `INSERT` is committed by the explicit `COMMIT` command. The second `INSERT` and the `SELECT` are still treated as a single transaction, so that the divide-by-zero failure will roll back the second `INSERT`, but not the first one.

This behavior is implemented by running the statements in a multi-statement Query message in an *implicit transaction block* unless there is some explicit transaction block for them to run in. The main difference between an implicit transaction block and a regular one is that an implicit block is closed automatically at the end of the Query message, either by an implicit commit if there was no error, or an implicit rollback if there was an error. This is similar to the implicit commit or rollback that happens for a statement executed by itself (when not in a transaction block).

If the session is already in a transaction block, as a result of a `BEGIN` in some previous message, then the Query message simply continues that transaction block, whether the message contains one statement or several. However, if the Query message contains a `COMMIT` or `ROLLBACK` closing the existing transaction block, then any following statements are executed in an implicit transaction block. Conversely, if a `BEGIN` appears in a multi-statement Query message, then it starts a regular transaction block that will only be terminated by an explicit `COMMIT` or `ROLLBACK`, whether that appears in this Query message or a later one. If the `BEGIN` follows some statements that were executed as an implicit transaction block, those statements are not immediately committed; in effect, they are retroactively included into the new regular transaction block.

A `COMMIT` or `ROLLBACK` appearing in an implicit transaction block is executed as normal, closing the implicit block; however, a warning will be issued since a `COMMIT` or `ROLLBACK` without a previous `BEGIN` might represent a mistake. If more statements follow, a new implicit transaction block will be started for them.

Savepoints are not allowed in an implicit transaction block, since they would conflict with the behavior of automatically closing the block upon any error.

Remember that, regardless of any transaction control commands that may be present, execution of the Query message stops at the first error. Thus for example given

```
BEGIN;
SELECT 1/0;
```



```
ROLLBACK;
```

in a single Query message, the session will be left inside a failed regular transaction block, since the ROLLBACK is not reached after the divide-by-zero error. Another ROLLBACK will be needed to restore the session to a usable state.

Another behavior of note is that initial lexical and syntactic analysis is done on the entire query string before any of it is executed. Thus simple errors (such as a misspelled keyword) in later statements can prevent execution of any of the statements. This is normally invisible to users since the statements would all roll back anyway when done as an implicit transaction block. However, it can be visible when attempting to do multiple transactions within a multi-statement Query. For instance, if a typo turned our previous example into

```
BEGIN;  
INSERT INTO mytable VALUES(1);  
COMMIT;  
INSERT INTO mytable VALUES(2);  
SELECT 1/0;
```

then none of the statements would get run, resulting in the visible difference that the first INSERT is not committed. Errors detected at semantic analysis or later, such as a misspelled table or column name, do not have this effect.

### 49.2.3. Extended Query

The extended query protocol breaks down the above-described simple query protocol into multiple steps. The results of preparatory steps can be re-used multiple times for improved efficiency. Furthermore, additional features are available, such as the possibility of supplying data values as separate parameters instead of having to insert them directly into a query string.

In the extended protocol, the frontend first sends a Parse message, which contains a textual query string, optionally some information about data types of parameter placeholders, and the name of a destination prepared-statement object (an empty string selects the unnamed prepared statement). The response is either ParseComplete or ErrorResponse. Parameter data types can be specified by OID; if not given, the parser attempts to infer the data types in the same way as it would do for untyped literal string constants.

#### Note

A parameter data type can be left unspecified by setting it to zero, or by making the array of parameter type OIDs shorter than the number of parameter symbols ( $\$n$ ) used in the query string. Another special case is that a parameter's type can be specified as `void` (that is, the OID of the `void` pseudo-type). This is meant to allow parameter symbols to be used for function parameters that are actually OUT parameters. Ordinarily there is no context in which a `void` parameter could be used, but if such a parameter symbol appears in a function's parameter list, it is effectively ignored. For example, a function call such as `foo($1, $2, $3, $4)` could match a function with two IN and two OUT arguments, if  $\$3$  and  $\$4$  are specified as having type `void`.

#### Note

The query string contained in a Parse message cannot include more than one SQL statement; else a syntax error is reported. This restriction does not exist in the simple-

query protocol, but it does exist in the extended protocol, because allowing prepared statements or portals to contain multiple commands would complicate the protocol unduly.

If successfully created, a named prepared-statement object lasts till the end of the current session, unless explicitly destroyed. An unnamed prepared statement lasts only until the next Parse statement specifying the unnamed statement as destination is issued. (Note that a simple Query message also destroys the unnamed statement.) Named prepared statements must be explicitly closed before they can be redefined by another Parse message, but this is not required for the unnamed statement. Named prepared statements can also be created and accessed at the SQL command level, using `PREPARE` and `EXECUTE`.

Once a prepared statement exists, it can be readied for execution using a Bind message. The Bind message gives the name of the source prepared statement (empty string denotes the unnamed prepared statement), the name of the destination portal (empty string denotes the unnamed portal), and the values to use for any parameter placeholders present in the prepared statement. The supplied parameter set must match those needed by the prepared statement. (If you declared any `void` parameters in the Parse message, pass `NULL` values for them in the Bind message.) Bind also specifies the format to use for any data returned by the query; the format can be specified overall, or per-column. The response is either `BindComplete` or `ErrorResponse`.

### Note

The choice between text and binary output is determined by the format codes given in Bind, regardless of the SQL command involved. The `BINARY` attribute in cursor declarations is irrelevant when using extended query protocol.

Query planning typically occurs when the Bind message is processed. If the prepared statement has no parameters, or is executed repeatedly, the server might save the created plan and re-use it during subsequent Bind messages for the same prepared statement. However, it will do so only if it finds that a generic plan can be created that is not much less efficient than a plan that depends on the specific parameter values supplied. This happens transparently so far as the protocol is concerned.

If successfully created, a named portal object lasts till the end of the current transaction, unless explicitly destroyed. An unnamed portal is destroyed at the end of the transaction, or as soon as the next Bind statement specifying the unnamed portal as destination is issued. (Note that a simple Query message also destroys the unnamed portal.) Named portals must be explicitly closed before they can be redefined by another Bind message, but this is not required for the unnamed portal. Named portals can also be created and accessed at the SQL command level, using `DECLARE CURSOR` and `FETCH`.

Once a portal exists, it can be executed using an Execute message. The Execute message specifies the portal name (empty string denotes the unnamed portal) and a maximum result-row count (zero meaning “fetch all rows”). The result-row count is only meaningful for portals containing commands that return row sets; in other cases the command is always executed to completion, and the row count is ignored. The possible responses to Execute are the same as those described above for queries issued via simple query protocol, except that Execute doesn't cause `ReadyForQuery` or `RowDescription` to be issued.

If Execute terminates before completing the execution of a portal (due to reaching a nonzero result-row count), it will send a `PortalSuspended` message; the appearance of this message tells the frontend that another Execute should be issued against the same portal to complete the operation. The `CommandComplete` message indicating completion of the source SQL command is not sent until the portal's execution is completed. Therefore, an Execute phase is always terminated by the appearance of exactly one of these messages: `CommandComplete`, `EmptyQueryResponse` (if the portal was created from an empty query string), `ErrorResponse`, or `PortalSuspended`.

At completion of each series of extended-query messages, the frontend should issue a Sync message. This parameterless message causes the backend to close the current transaction if it's not inside a BEGIN/COMMIT transaction block (“close” meaning to commit if no error, or roll back if error). Then a ReadyForQuery response is issued. The purpose of Sync is to provide a resynchronization point for error recovery. When an error is detected while processing any extended-query message, the backend issues ErrorResponse, then reads and discards messages until a Sync is reached, then issues ReadyForQuery and returns to normal message processing. (But note that no skipping occurs if an error is detected *while* processing Sync — this ensures that there is one and only one ReadyForQuery sent for each Sync.)

### Note

Sync does not cause a transaction block opened with BEGIN to be closed. It is possible to detect this situation since the ReadyForQuery message includes transaction status information.

In addition to these fundamental, required operations, there are several optional operations that can be used with extended-query protocol.

The Describe message (portal variant) specifies the name of an existing portal (or an empty string for the unnamed portal). The response is a RowDescription message describing the rows that will be returned by executing the portal; or a NoData message if the portal does not contain a query that will return rows; or ErrorResponse if there is no such portal.

The Describe message (statement variant) specifies the name of an existing prepared statement (or an empty string for the unnamed prepared statement). The response is a ParameterDescription message describing the parameters needed by the statement, followed by a RowDescription message describing the rows that will be returned when the statement is eventually executed (or a NoData message if the statement will not return rows). ErrorResponse is issued if there is no such prepared statement. Note that since Bind has not yet been issued, the formats to be used for returned columns are not yet known to the backend; the format code fields in the RowDescription message will be zeroes in this case.

### Tip

In most scenarios the frontend should issue one or the other variant of Describe before issuing Execute, to ensure that it knows how to interpret the results it will get back.

The Close message closes an existing prepared statement or portal and releases resources. It is not an error to issue Close against a nonexistent statement or portal name. The response is normally CloseComplete, but could be ErrorResponse if some difficulty is encountered while releasing resources. Note that closing a prepared statement implicitly closes any open portals that were constructed from that statement.

The Flush message does not cause any specific output to be generated, but forces the backend to deliver any data pending in its output buffers. A Flush must be sent after any extended-query command except Sync, if the frontend wishes to examine the results of that command before issuing more commands. Without Flush, messages returned by the backend will be combined into the minimum possible number of packets to minimize network overhead.

### Note

The simple Query message is approximately equivalent to the series Parse, Bind, portal Describe, Execute, Close, Sync, using the unnamed prepared statement and portal objects and no parameters. One difference is that it will accept multiple SQL statements

in the query string, automatically performing the bind/describe/execute sequence for each one in succession. Another difference is that it will not return ParseComplete, BindComplete, CloseComplete, or NoData messages.

## 49.2.4. Pipelining

Use of the extended query protocol allows *pipelining*, which means sending a series of queries without waiting for earlier ones to complete. This reduces the number of network round trips needed to complete a given series of operations. However, the user must carefully consider the required behavior if one of the steps fails, since later queries will already be in flight to the server.

One way to deal with that is to make the whole query series be a single transaction, that is wrap it in BEGIN ... COMMIT. However, this does not help if one wishes for some of the commands to commit independently of others.

The extended query protocol provides another way to manage this concern, which is to omit sending Sync messages between steps that are dependent. Since, after an error, the backend will skip command messages until it finds Sync, this allows later commands in a pipeline to be skipped automatically when an earlier one fails, without the client having to manage that explicitly with BEGIN and COMMIT. Independently-committable segments of the pipeline can be separated by Sync messages.

If the client has not issued an explicit BEGIN, then each Sync ordinarily causes an implicit COMMIT if the preceding step(s) succeeded, or an implicit ROLLBACK if they failed. However, there are a few DDL commands (such as CREATE DATABASE) that cannot be executed inside a transaction block. If one of these is executed in a pipeline, it will, upon success, force an immediate commit to preserve database consistency. A Sync immediately following one of these has no effect except to respond with ReadyForQuery.

When using this method, completion of the pipeline must be determined by counting ReadyForQuery messages and waiting for that to reach the number of Syncs sent. Counting command completion responses is unreliable, since some of the commands may not be executed and thus not produce a completion message.

## 49.2.5. Function Call

The Function Call sub-protocol allows the client to request a direct call of any function that exists in the database's pg\_proc system catalog. The client must have execute permission for the function.

### Note

The Function Call sub-protocol is a legacy feature that is probably best avoided in new code. Similar results can be accomplished by setting up a prepared statement that does `SELECT function($1, ...)`. The Function Call cycle can then be replaced with Bind/Execute.

A Function Call cycle is initiated by the frontend sending a FunctionCall message to the backend. The backend then sends one or more response messages depending on the results of the function call, and finally a ReadyForQuery response message. ReadyForQuery informs the frontend that it can safely send a new query or function call.

The possible response messages from the backend are:

ErrorResponse

An error has occurred.

### FunctionCallResponse

The function call was completed and returned the result given in the message. (Note that the Function Call protocol can only handle a single scalar result, not a row type or set of results.)

### ReadyForQuery

Processing of the function call is complete. ReadyForQuery will always be sent, whether processing terminates successfully or with an error.

### NoticeResponse

A warning message has been issued in relation to the function call. Notices are in addition to other responses, i.e., the backend will continue processing the command.

## 49.2.6. COPY Operations

The COPY command allows high-speed bulk data transfer to or from the server. Copy-in and copy-out operations each switch the connection into a distinct sub-protocol, which lasts until the operation is completed.

Copy-in mode (data transfer to the server) is initiated when the backend executes a COPY FROM STDIN SQL statement. The backend sends a CopyInResponse message to the frontend. The frontend should then send zero or more CopyData messages, forming a stream of input data. (The message boundaries are not required to have anything to do with row boundaries, although that is often a reasonable choice.) The frontend can terminate the copy-in mode by sending either a CopyDone message (allowing successful termination) or a CopyFail message (which will cause the COPY SQL statement to fail with an error). The backend then reverts to the command-processing mode it was in before the COPY started, which will be either simple or extended query protocol. It will next send either CommandComplete (if successful) or ErrorResponse (if not).

In the event of a backend-detected error during copy-in mode (including receipt of a CopyFail message), the backend will issue an ErrorResponse message. If the COPY command was issued via an extended-query message, the backend will now discard frontend messages until a Sync message is received, then it will issue ReadyForQuery and return to normal processing. If the COPY command was issued in a simple Query message, the rest of that message is discarded and ReadyForQuery is issued. In either case, any subsequent CopyData, CopyDone, or CopyFail messages issued by the frontend will simply be dropped.

The backend will ignore Flush and Sync messages received during copy-in mode. Receipt of any other non-copy message type constitutes an error that will abort the copy-in state as described above. (The exception for Flush and Sync is for the convenience of client libraries that always send Flush or Sync after an Execute message, without checking whether the command to be executed is a COPY FROM STDIN.)

Copy-out mode (data transfer from the server) is initiated when the backend executes a COPY TO STDOUT SQL statement. The backend sends a CopyOutResponse message to the frontend, followed by zero or more CopyData messages (always one per row), followed by CopyDone. The backend then reverts to the command-processing mode it was in before the COPY started, and sends CommandComplete. The frontend cannot abort the transfer (except by closing the connection or issuing a Cancel request), but it can discard unwanted CopyData and CopyDone messages.

In the event of a backend-detected error during copy-out mode, the backend will issue an ErrorResponse message and revert to normal processing. The frontend should treat receipt of ErrorResponse as terminating the copy-out mode.

It is possible for NoticeResponse and ParameterStatus messages to be interspersed between CopyData messages; frontends must handle these cases, and should be prepared for other asynchronous message types as well (see Section 49.2.7). Otherwise, any message type other than CopyData or CopyDone may be treated as terminating copy-out mode.

There is another Copy-related mode called `copy-both`, which allows high-speed bulk data transfer to *and* from the server. Copy-both mode is initiated when a backend in `walsender` mode executes a `START_REPLICATION` statement. The backend sends a `CopyBothResponse` message to the frontend. Both the backend and the frontend may then send `CopyData` messages until either end sends a `CopyDone` message. After the client sends a `CopyDone` message, the connection goes from `copy-both` mode to `copy-out` mode, and the client may not send any more `CopyData` messages. Similarly, when the server sends a `CopyDone` message, the connection goes into `copy-in` mode, and the server may not send any more `CopyData` messages. After both sides have sent a `CopyDone` message, the copy mode is terminated, and the backend reverts to the command-processing mode. In the event of a backend-detected error during `copy-both` mode, the backend will issue an `ErrorResponse` message, discard frontend messages until a `Sync` message is received, and then issue `ReadyForQuery` and return to normal processing. The frontend should treat receipt of `ErrorResponse` as terminating the copy in both directions; no `CopyDone` should be sent in this case. See Section 49.4 for more information on the subprotocol transmitted over `copy-both` mode.

The `CopyInResponse`, `CopyOutResponse` and `CopyBothResponse` messages include fields that inform the frontend of the number of columns per row and the format codes being used for each column. (As of the present implementation, all columns in a given `COPY` operation will use the same format, but the message design does not assume this.)

## 49.2.7. Asynchronous Operations

There are several cases in which the backend will send messages that are not specifically prompted by the frontend's command stream. Frontends must be prepared to deal with these messages at any time, even when not engaged in a query. At minimum, one should check for these cases before beginning to read a query response.

It is possible for `NoticeResponse` messages to be generated due to outside activity; for example, if the database administrator commands a “fast” database shutdown, the backend will send a `NoticeResponse` indicating this fact before closing the connection. Accordingly, frontends should always be prepared to accept and display `NoticeResponse` messages, even when the connection is nominally idle.

`ParameterStatus` messages will be generated whenever the active value changes for any of the parameters the backend believes the frontend should know about. Most commonly this occurs in response to a `SET SQL` command executed by the frontend, and this case is effectively synchronous — but it is also possible for parameter status changes to occur because the administrator changed a configuration file and then sent the `SIGHUP` signal to the server. Also, if a `SET` command is rolled back, an appropriate `ParameterStatus` message will be generated to report the current effective value.

At present there is a hard-wired set of parameters for which `ParameterStatus` will be generated: they are `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. Note that `server_version`, `server_encoding` and `integer_datetimes` are pseudo-parameters that cannot change after startup. This set might change in the future, or even become configurable. Accordingly, a frontend should simply ignore `ParameterStatus` for parameters that it does not understand or care about.

If a frontend issues a `LISTEN` command, then the backend will send a `NotificationResponse` message (not to be confused with `NoticeResponse`!) whenever a `NOTIFY` command is executed for the same channel name.

### Note

At present, `NotificationResponse` can only be sent outside a transaction, and thus it will not occur in the middle of a command-response series, though it might occur just before `ReadyForQuery`. It is unwise to design frontend logic that assumes that,

however. Good practice is to be able to accept NotificationResponse at any point in the protocol.

## 49.2.8. Canceling Requests in Progress

During the processing of a query, the frontend might request cancellation of the query. The cancel request is not sent directly on the open connection to the backend for reasons of implementation efficiency: we don't want to have the backend constantly checking for new input from the frontend during query processing. Cancel requests should be relatively infrequent, so we make them slightly cumbersome in order to avoid a penalty in the normal case.

To issue a cancel request, the frontend opens a new connection to the server and sends a CancelRequest message, rather than the StartupMessage message that would ordinarily be sent across a new connection. The server will process this request and then close the connection. For security reasons, no direct reply is made to the cancel request message.

A CancelRequest message will be ignored unless it contains the same key data (PID and secret key) passed to the frontend during connection start-up. If the request matches the PID and secret key for a currently executing backend, the processing of the current query is aborted. (In the existing implementation, this is done by sending a special signal to the backend process that is processing the query.)

The cancellation signal might or might not have any effect — for example, if it arrives after the backend has finished processing the query, then it will have no effect. If the cancellation is effective, it results in the current command being terminated early with an error message.

The upshot of all this is that for reasons of both security and efficiency, the frontend has no direct way to tell whether a cancel request has succeeded. It must continue to wait for the backend to respond to the query. Issuing a cancel simply improves the odds that the current query will finish soon, and improves the odds that it will fail with an error message instead of succeeding.

Since the cancel request is sent across a new connection to the server and not across the regular frontend/backend communication link, it is possible for the cancel request to be issued by any process, not just the frontend whose query is to be canceled. This might provide additional flexibility when building multiple-process applications. It also introduces a security risk, in that unauthorized persons might try to cancel queries. The security risk is addressed by requiring a dynamically generated secret key to be supplied in cancel requests.

## 49.2.9. Termination

The normal, graceful termination procedure is that the frontend sends a Terminate message and immediately closes the connection. On receipt of this message, the backend closes the connection and terminates.

In rare cases (such as an administrator-commanded database shutdown) the backend might disconnect without any frontend request to do so. In such cases the backend will attempt to send an error or notice message giving the reason for the disconnection before it closes the connection.

Other termination scenarios arise from various failure cases, such as core dump at one end or the other, loss of the communications link, loss of message-boundary synchronization, etc. If either frontend or backend sees an unexpected closure of the connection, it should clean up and terminate. The frontend has the option of launching a new backend by recontacting the server if it doesn't want to terminate itself. Closing the connection is also advisable if an unrecognizable message type is received, since this probably indicates loss of message-boundary sync.

For either normal or abnormal termination, any open transaction is rolled back, not committed. One should note however that if a frontend disconnects while a non-SELECT query is being processed,

the backend will probably finish the query before noticing the disconnection. If the query is outside any transaction block (BEGIN ... COMMIT sequence) then its results might be committed before the disconnection is recognized.

## 49.2.10. SSL Session Encryption

If LightDB was built with SSL support, frontend/backend communications can be encrypted using SSL. This provides communication security in environments where attackers might be able to capture the session traffic. For more information on encrypting LightDB sessions with SSL, see Section 16.9.

To initiate an SSL-encrypted connection, the frontend initially sends an SSLRequest message rather than a StartupMessage. The server then responds with a single byte containing S or N, indicating that it is willing or unwilling to perform SSL, respectively. The frontend might close the connection at this point if it is dissatisfied with the response. To continue after S, perform an SSL startup handshake (not described here, part of the SSL specification) with the server. If this is successful, continue with sending the usual StartupMessage. In this case the StartupMessage and all subsequent data will be SSL-encrypted. To continue after N, send the usual StartupMessage and proceed without encryption. (Alternatively, it is permissible to issue a GSSAPIRequest message after an N response to try to use GSSAPI encryption instead of SSL.)

The frontend should also be prepared to handle an ErrorMessage response to SSLRequest from the server. This would only occur if the server predates the addition of SSL support to LightDB. (Such servers are now very ancient, and likely do not exist in the wild anymore.) In this case the connection must be closed, but the frontend might choose to open a fresh connection and proceed without requesting SSL.

When SSL encryption can be performed, the server is expected to send only the single S byte and then wait for the frontend to initiate an SSL handshake. If additional bytes are available to read at this point, it likely means that a man-in-the-middle is attempting to perform a buffer-stuffing attack (CVE-2021-23222<sup>1</sup>). Frontends should be coded either to read exactly one byte from the socket before turning the socket over to their SSL library, or to treat it as a protocol violation if they find they have read additional bytes.

An initial SSLRequest can also be used in a connection that is being opened to send a CancelRequest message.

While the protocol itself does not provide a way for the server to force SSL encryption, the administrator can configure the server to reject unencrypted sessions as a byproduct of authentication checking.

## 49.2.11. GSSAPI Session Encryption

If LightDB was built with GSSAPI support, frontend/backend communications can be encrypted using GSSAPI. This provides communication security in environments where attackers might be able to capture the session traffic. For more information on encrypting LightDB sessions with GSSAPI, see Section 16.10.

To initiate a GSSAPI-encrypted connection, the frontend initially sends a GSSAPIRequest message rather than a StartupMessage. The server then responds with a single byte containing G or N, indicating that it is willing or unwilling to perform GSSAPI encryption, respectively. The frontend might close the connection at this point if it is dissatisfied with the response. To continue after G, using the GSSAPI C bindings as discussed in RFC2744 or equivalent, perform a GSSAPI initialization by calling `gss_init_sec_context()` in a loop and sending the result to the server, starting with an empty input and then with each result from the server, until it returns no output. When sending the results of `gss_init_sec_context()` to the server, prepend the length of the message as a four byte integer in network byte order. To continue after N, send the usual StartupMessage and

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<sup>1</sup> [www.hs.net/lightdb/support/security/CVE-2021-23222/](http://www.hs.net/lightdb/support/security/CVE-2021-23222/)



proceed without encryption. (Alternatively, it is permissible to issue an SSLRequest message after an N response to try to use SSL encryption instead of GSSAPI.)

The frontend should also be prepared to handle an ErrorMessage response to GSSENCRequest from the server. This would only occur if the server predates the addition of GSSAPI encryption support to LightDB. In this case the connection must be closed, but the frontend might choose to open a fresh connection and proceed without requesting GSSAPI encryption.

When GSSAPI encryption can be performed, the server is expected to send only the single G byte and then wait for the frontend to initiate a GSSAPI handshake. If additional bytes are available to read at this point, it likely means that a man-in-the-middle is attempting to perform a buffer-stuffing attack (CVE-2021-23222<sup>2</sup>). Frontends should be coded either to read exactly one byte from the socket before turning the socket over to their GSSAPI library, or to treat it as a protocol violation if they find they have read additional bytes.

An initial GSSENCRequest can also be used in a connection that is being opened to send a CancelRequest message.

Once GSSAPI encryption has been successfully established, use `gss_wrap()` to encrypt the usual StartupMessage and all subsequent data, prepending the length of the result from `gss_wrap()` as a four byte integer in network byte order to the actual encrypted payload. Note that the server will only accept encrypted packets from the client which are less than 16kB; `gss_wrap_size_limit()` should be used by the client to determine the size of the unencrypted message which will fit within this limit and larger messages should be broken up into multiple `gss_wrap()` calls. Typical segments are 8kB of unencrypted data, resulting in encrypted packets of slightly larger than 8kB but well within the 16kB maximum. The server can be expected to not send encrypted packets of larger than 16kB to the client.

While the protocol itself does not provide a way for the server to force GSSAPI encryption, the administrator can configure the server to reject unencrypted sessions as a byproduct of authentication checking.

## 49.3. SASL Authentication

SASL is a framework for authentication in connection-oriented protocols. At the moment, LightDB implements two SASL authentication mechanisms, SCRAM-SHA-256 and SCRAM-SHA-256-PLUS. More might be added in the future. The below steps illustrate how SASL authentication is performed in general, while the next subsection gives more details on SCRAM-SHA-256 and SCRAM-SHA-256-PLUS.

### SASL Authentication Message Flow

1. To begin a SASL authentication exchange, the server sends an AuthenticationSASL message. It includes a list of SASL authentication mechanisms that the server can accept, in the server's preferred order.
2. The client selects one of the supported mechanisms from the list, and sends a SASLInitialResponse message to the server. The message includes the name of the selected mechanism, and an optional Initial Client Response, if the selected mechanism uses that.
3. One or more server-challenge and client-response message will follow. Each server-challenge is sent in an AuthenticationSASLContinue message, followed by a response from client in an SASLResponse message. The particulars of the messages are mechanism specific.
4. Finally, when the authentication exchange is completed successfully, the server sends an AuthenticationSASLFinal message, followed immediately by an AuthenticationOk message. The AuthenticationSASLFinal contains additional server-to-client data, whose content is particular

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<sup>2</sup> [www.hs.net/lightdb/support/security/CVE-2021-23222/](http://www.hs.net/lightdb/support/security/CVE-2021-23222/)

to the selected authentication mechanism. If the authentication mechanism doesn't use additional data that's sent at completion, the `AuthenticationSASLFinal` message is not sent.

On error, the server can abort the authentication at any stage, and send an `ErrorMessage`.

### 49.3.1. SCRAM-SHA-256 Authentication

The implemented SASL mechanisms at the moment are `SCRAM-SHA-256` and its variant with channel binding `SCRAM-SHA-256-PLUS`. They are described in detail in RFC 7677 and RFC 5802.

When `SCRAM-SHA-256` is used in `LightDB`, the server will ignore the user name that the client sends in the `client-first-message`. The user name that was already sent in the startup message is used instead. `LightDB` supports multiple character encodings, while `SCRAM` dictates UTF-8 to be used for the user name, so it might be impossible to represent the `LightDB` user name in UTF-8.

The `SCRAM` specification dictates that the password is also in UTF-8, and is processed with the `SASLprep` algorithm. `LightDB`, however, does not require UTF-8 to be used for the password. When a user's password is set, it is processed with `SASLprep` as if it was in UTF-8, regardless of the actual encoding used. However, if it is not a legal UTF-8 byte sequence, or it contains UTF-8 byte sequences that are prohibited by the `SASLprep` algorithm, the raw password will be used without `SASLprep` processing, instead of throwing an error. This allows the password to be normalized when it is in UTF-8, but still allows a non-UTF-8 password to be used, and doesn't require the system to know which encoding the password is in.

*Channel binding* is supported in `LightDB` builds with SSL support. The SASL mechanism name for `SCRAM` with channel binding is `SCRAM-SHA-256-PLUS`. The channel binding type used by `LightDB` is `tls-server-end-point`.

In `SCRAM` without channel binding, the server chooses a random number that is transmitted to the client to be mixed with the user-supplied password in the transmitted password hash. While this prevents the password hash from being successfully retransmitted in a later session, it does not prevent a fake server between the real server and client from passing through the server's random value and successfully authenticating.

`SCRAM` with channel binding prevents such man-in-the-middle attacks by mixing the signature of the server's certificate into the transmitted password hash. While a fake server can retransmit the real server's certificate, it doesn't have access to the private key matching that certificate, and therefore cannot prove it is the owner, causing SSL connection failure.

#### Example

1. The server sends an `AuthenticationSASL` message. It includes a list of SASL authentication mechanisms that the server can accept. This will be `SCRAM-SHA-256-PLUS` and `SCRAM-SHA-256` if the server is built with SSL support, or else just the latter.
2. The client responds by sending a `SASLInitialResponse` message, which indicates the chosen mechanism, `SCRAM-SHA-256` or `SCRAM-SHA-256-PLUS`. (A client is free to choose either mechanism, but for better security it should choose the channel-binding variant if it can support it.) In the Initial Client response field, the message contains the `SCRAM client-first-message`. The `client-first-message` also contains the channel binding type chosen by the client.
3. Server sends an `AuthenticationSASLContinue` message, with a `SCRAM server-first-message` as the content.
4. Client sends a `SASLResponse` message, with `SCRAM client-final-message` as the content.
5. Server sends an `AuthenticationSASLFinal` message, with the `SCRAM server-final-message`, followed immediately by an `AuthenticationOk` message.

## 49.4. Streaming Replication Protocol

To initiate streaming replication, the frontend sends the `replication` parameter in the startup message. A Boolean value of `true` (or `on`, `yes`, `1`) tells the backend to go into physical replication walsender mode, wherein a small set of replication commands, shown below, can be issued instead of SQL statements.

Passing `database` as the value for the `replication` parameter instructs the backend to go into logical replication walsender mode, connecting to the database specified in the `dbname` parameter. In logical replication walsender mode, the replication commands shown below as well as normal SQL commands can be issued.

In either physical replication or logical replication walsender mode, only the simple query protocol can be used.

For the purpose of testing replication commands, you can make a replication connection via `ltsql` or any other libpq-using tool with a connection string including the `replication` option, e.g.:

```
ltsql "dbname=postgres replication=database" -c "IDENTIFY_SYSTEM;"
```

However, it is often more useful to use `lt_receivewal` (for physical replication) or `lt_recvlogical` (for logical replication).

Replication commands are logged in the server log when `log_replication_commands` is enabled.

The commands accepted in replication mode are:

`IDENTIFY_SYSTEM`

Requests the server to identify itself. Server replies with a result set of a single row, containing four fields:

`systemid` (text)

The unique system identifier identifying the cluster. This can be used to check that the base backup used to initialize the standby came from the same cluster.

`timeline` (int4)

Current timeline ID. Also useful to check that the standby is consistent with the master.

`xlogpos` (text)

Current WAL flush location. Useful to get a known location in the write-ahead log where streaming can start.

`dbname` (text)

Database connected to or null.

`SHOW name`

Requests the server to send the current setting of a run-time parameter. This is similar to the SQL command `SHOW`.

*name*

The name of a run-time parameter. Available parameters are documented in Chapter 17.

`TIMELINE_HISTORY tli`

Requests the server to send over the timeline history file for timeline `tli`. Server replies with a result set of a single row, containing two fields. While the fields are labeled as `text` and `bytea`, they effectively return raw bytes, with no escaping or encoding conversion:

`filename (text)`

File name of the timeline history file, e.g., `00000002.history`.

`content (bytea)`

Contents of the timeline history file.

```
CREATE_REPLICATION_SLOT slot_name [ TEMPORARY ] { PHYSICAL [ RESERVE_WAL ] |
LOGICAL output_plugin [ EXPORT_SNAPSHOT | NOEXPORT_SNAPSHOT | USE_SNAPSHOT
] }
```

Create a physical or logical replication slot. See Section 24.2.6 for more about replication slots.

`slot_name`

The name of the slot to create. Must be a valid replication slot name (see Section 24.2.6.1).

`output_plugin`

The name of the output plugin used for logical decoding (see Section 45.6).

`TEMPORARY`

Specify that this replication slot is a temporary one. Temporary slots are not saved to disk and are automatically dropped on error or when the session has finished.

`RESERVE_WAL`

Specify that this physical replication slot reserves WAL immediately. Otherwise, WAL is only reserved upon connection from a streaming replication client.

`EXPORT_SNAPSHOT`

`NOEXPORT_SNAPSHOT`

`USE_SNAPSHOT`

Decides what to do with the snapshot created during logical slot initialization. `EXPORT_SNAPSHOT`, which is the default, will export the snapshot for use in other sessions. This option can't be used inside a transaction. `USE_SNAPSHOT` will use the snapshot for the current transaction executing the command. This option must be used in a transaction, and `CREATE_REPLICATION_SLOT` must be the first command run in that transaction. Finally, `NOEXPORT_SNAPSHOT` will just use the snapshot for logical decoding as normal but won't do anything else with it.

In response to this command, the server will send a one-row result set containing the following fields:

`slot_name (text)`

The name of the newly-created replication slot.

`consistent_point (text)`

The WAL location at which the slot became consistent. This is the earliest location from which streaming can start on this replication slot.

snapshot\_name (text)

The identifier of the snapshot exported by the command. The snapshot is valid until a new command is executed on this connection or the replication connection is closed. Null if the created slot is physical.

output\_plugin (text)

The name of the output plugin used by the newly-created replication slot. Null if the created slot is physical.

START\_REPLICATION [ SLOT *slot\_name* ] [ PHYSICAL ] XXX/XXX [ TIMELINE *tli* ]

Instructs server to start streaming WAL, starting at WAL location *XXX/XXX*. If *TIMELINE* option is specified, streaming starts on timeline *tli*; otherwise, the server's current timeline is selected. The server can reply with an error, for example if the requested section of WAL has already been recycled. On success, the server responds with a *CopyBothResponse* message, and then starts to stream WAL to the frontend.

If a slot's name is provided via *slot\_name*, it will be updated as replication progresses so that the server knows which WAL segments, and if *hot\_standby\_feedback* is on which transactions, are still needed by the standby.

If the client requests a timeline that's not the latest but is part of the history of the server, the server will stream all the WAL on that timeline starting from the requested start point up to the point where the server switched to another timeline. If the client requests streaming at exactly the end of an old timeline, the server responds immediately with *CommandComplete* without entering *COPY* mode.

After streaming all the WAL on a timeline that is not the latest one, the server will end streaming by exiting the *COPY* mode. When the client acknowledges this by also exiting *COPY* mode, the server sends a result set with one row and two columns, indicating the next timeline in this server's history. The first column is the next timeline's ID (type *int8*), and the second column is the WAL location where the switch happened (type *text*). Usually, the switch position is the end of the WAL that was streamed, but there are corner cases where the server can send some WAL from the old timeline that it has not itself replayed before promoting. Finally, the server sends two *CommandComplete* messages (one that ends the *CopyData* and the other ends the *START\_REPLICATION* itself), and is ready to accept a new command.

WAL data is sent as a series of *CopyData* messages. (This allows other information to be intermixed; in particular the server can send an *ErrorResponse* message if it encounters a failure after beginning to stream.) The payload of each *CopyData* message from server to the client contains a message of one of the following formats:

XLogData (B)

Byte1('w')

Identifies the message as WAL data.

Int64

The starting point of the WAL data in this message.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byten

A section of the WAL data stream.

A single WAL record is never split across two XLogData messages. When a WAL record crosses a WAL page boundary, and is therefore already split using continuation records, it can be split at the page boundary. In other words, the first main WAL record and its continuation records can be sent in different XLogData messages.

Primary keepalive message (B)

Byte1('k')

Identifies the message as a sender keepalive.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

1 means that the client should reply to this message as soon as possible, to avoid a timeout disconnect. 0 otherwise.

The receiving process can send replies back to the sender at any time, using one of the following message formats (also in the payload of a CopyData message):

Standby status update (F)

Byte1('r')

Identifies the message as a receiver status update.

Int64

The location of the last WAL byte + 1 received and written to disk in the standby.

Int64

The location of the last WAL byte + 1 flushed to disk in the standby.

Int64

The location of the last WAL byte + 1 applied in the standby.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

If 1, the client requests the server to reply to this message immediately. This can be used to ping the server, to test if the connection is still healthy.

Hot Standby feedback message (F)

Byte1('h')

Identifies the message as a Hot Standby feedback message.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Int32

The standby's current global xmin, excluding the catalog\_xmin from any replication slots. If both this value and the following catalog\_xmin are 0 this is treated as a notification that Hot Standby feedback will no longer be sent on this connection. Later non-zero messages may reinitiate the feedback mechanism.

Int32

The epoch of the global xmin xid on the standby.

Int32

The lowest catalog\_xmin of any replication slots on the standby. Set to 0 if no catalog\_xmin exists on the standby or if hot standby feedback is being disabled.

Int32

The epoch of the catalog\_xmin xid on the standby.

```
START_REPLICATION SLOT slot_name LOGICAL XXX/XXX [ ( option_name [ option_value ] [, ...] ) ]
```

Instructs server to start streaming WAL for logical replication, starting at WAL location *XXX/XXX*. The server can reply with an error, for example if the requested section of WAL has already been recycled. On success, server responds with a CopyBothResponse message, and then starts to stream WAL to the frontend.

The messages inside the CopyBothResponse messages are of the same format documented for START\_REPLICATION . . . PHYSICAL, including two CommandComplete messages.

The output plugin associated with the selected slot is used to process the output for streaming.

SLOT *slot\_name*

The name of the slot to stream changes from. This parameter is required, and must correspond to an existing logical replication slot created with CREATE\_REPLICATION\_SLOT in LOGICAL mode.

*XXX/XXX*

The WAL location to begin streaming at.

*option\_name*

The name of an option passed to the slot's logical decoding plugin.

*option\_value*

Optional value, in the form of a string constant, associated with the specified option.

```
DROP_REPLICATION_SLOT slot_name [ WAIT ]
```

Drops a replication slot, freeing any reserved server-side resources. If the slot is a logical slot that was created in a database other than the database the walsender is connected to, this command fails.

*slot\_name*

The name of the slot to drop.

WAIT

This option causes the command to wait if the slot is active until it becomes inactive, instead of the default behavior of raising an error.

```
BASE_BACKUP [ LABEL 'label' ] [ PROGRESS ] [ FAST ] [ WAL ] [ NOWAIT ] [ MAX_RATE
rate ] [ TABLESPACE_MAP ] [ NOVERIFY_CHECKSUMS ] [ MANIFEST manifest_option ]
[ MANIFEST_CHECKSUMS checksum_algorithm ]
```

Instructs the server to start streaming a base backup. The system will automatically be put in backup mode before the backup is started, and taken out of it when the backup is complete. The following options are accepted:

LABEL '*label*'

Sets the label of the backup. If none is specified, a backup label of `base backup` will be used. The quoting rules for the label are the same as a standard SQL string with `standard_conforming_strings` turned on.

PROGRESS

Request information required to generate a progress report. This will send back an approximate size in the header of each tablespace, which can be used to calculate how far along the stream is done. This is calculated by enumerating all the file sizes once before the transfer is even started, and might as such have a negative impact on the performance. In particular, it might take longer before the first data is streamed. Since the database files can change during the backup, the size is only approximate and might both grow and shrink between the time of approximation and the sending of the actual files.

FAST

Request a fast checkpoint.

WAL

Include the necessary WAL segments in the backup. This will include all the files between start and stop backup in the `lt_wal` directory of the base directory tar file.

NOWAIT

By default, the backup will wait until the last required WAL segment has been archived, or emit a warning if log archiving is not enabled. Specifying `NOWAIT` disables both the waiting and the warning, leaving the client responsible for ensuring the required log is available.

MAX\_RATE *rate*

Limit (throttle) the maximum amount of data transferred from server to client per unit of time. The expected unit is kilobytes per second. If this option is specified, the value must either be equal to zero or it must fall within the range from 32 kB through 1 GB (inclusive). If zero is passed or the option is not specified, no restriction is imposed on the transfer.

TABLESPACE\_MAP

Include information about symbolic links present in the directory `lt_tblspc` in a file named `tablespace_map`. The tablespace map file includes each symbolic link name as it exists in the directory `lt_tblspc/` and the full path of that symbolic link.



**NOVERIFY\_CHECKSUMS**

By default, checksums are verified during a base backup if they are enabled. Specifying `NOVERIFY_CHECKSUMS` disables this verification.

**MANIFEST** *manifest\_option*

When this option is specified with a value of `yes` or `force-encode`, a backup manifest is created and sent along with the backup. The manifest is a list of every file present in the backup with the exception of any WAL files that may be included. It also stores the size, last modification time, and optionally a checksum for each file. A value of `force-encode` forces all filenames to be hex-encoded; otherwise, this type of encoding is performed only for files whose names are non-UTF8 octet sequences. `force-encode` is intended primarily for testing purposes, to be sure that clients which read the backup manifest can handle this case. For compatibility with previous releases, the default is `MANIFEST 'no'`.

**MANIFEST\_CHECKSUMS** *checksum\_algorithm*

Specifies the checksum algorithm that should be applied to each file included in the backup manifest. Currently, the available algorithms are `NONE`, `CRC32C`, `SHA224`, `SHA256`, `SHA384`, and `SHA512`. The default is `CRC32C`.

When the backup is started, the server will first send two ordinary result sets, followed by one or more `CopyResponse` results.

The first ordinary result set contains the starting position of the backup, in a single row with two columns. The first column contains the start position given in `XLogRecPtr` format, and the second column contains the corresponding timeline ID.

The second ordinary result set has one row for each tablespace. The fields in this row are:

`spcoid` (`oid`)

The OID of the tablespace, or null if it's the base directory.

`spclocation` (`text`)

The full path of the tablespace directory, or null if it's the base directory.

`size` (`int8`)

The approximate size of the tablespace, in kilobytes (1024 bytes), if progress report has been requested; otherwise it's null.

After the second regular result set, one or more `CopyResponse` results will be sent, one for the main data directory and one for each additional tablespace other than `pg_default` and `pg_global`. The data in the `CopyResponse` results will be a tar format (following the “ustar interchange format” specified in the POSIX 1003.1-2008 standard) dump of the tablespace contents, except that the two trailing blocks of zeroes specified in the standard are omitted. After the tar data is complete, and if a backup manifest was requested, another `CopyResponse` result is sent, containing the manifest data for the current base backup. In any case, a final ordinary result set will be sent, containing the WAL end position of the backup, in the same format as the start position.

The tar archive for the data directory and each tablespace will contain all files in the directories, regardless of whether they are `LightDB` files or other files added to the same directory. The only excluded files are:

- `lightdb.pid`
- `lightdb.opts`
- `lt_internal.init` (found in multiple directories)
- Various temporary files and directories created during the operation of the `LightDB` server, such as any file or directory beginning with `ltsql_tmp` and temporary relations.

- Unlogged relations, except for the init fork which is required to recreate the (empty) unlogged relation on recovery.
- `lt_wal`, including subdirectories. If the backup is run with WAL files included, a synthesized version of `lt_wal` will be included, but it will only contain the files necessary for the backup to work, not the rest of the contents.
- `lt_dynshmem`, `lt_notify`, `lt_replslot`, `lt_serial`, `lt_snapshots`, `lt_stat_tmp`, and `lt_subtrans` are copied as empty directories (even if they are symbolic links).
- Files other than regular files and directories, such as symbolic links (other than for the directories listed above) and special device files, are skipped. (Symbolic links in `lt_tblspc` are maintained.)

Owner, group, and file mode are set if the underlying file system on the server supports it.

## 49.5. Logical Streaming Replication Protocol

This section describes the logical replication protocol, which is the message flow started by the `START_REPLICATION SLOT slot_name LOGICAL` replication command.

The logical streaming replication protocol builds on the primitives of the physical streaming replication protocol.

### 49.5.1. Logical Streaming Replication Parameters

The logical replication `START_REPLICATION` command accepts following parameters:

`proto_version`

Protocol version. Currently only version 1 is supported.

`publication_names`

Comma separated list of publication names for which to subscribe (receive changes). The individual publication names are treated as standard objects names and can be quoted the same as needed.

### 49.5.2. Logical Replication Protocol Messages

The individual protocol messages are discussed in the following subsections. Individual messages are described in Section 49.9.

All top-level protocol messages begin with a message type byte. While represented in code as a character, this is a signed byte with no associated encoding.

Since the streaming replication protocol supplies a message length there is no need for top-level protocol messages to embed a length in their header.

### 49.5.3. Logical Replication Protocol Message Flow

With the exception of the `START_REPLICATION` command and the replay progress messages, all information flows only from the backend to the frontend.

The logical replication protocol sends individual transactions one by one. This means that all messages between a pair of Begin and Commit messages belong to the same transaction.

Every sent transaction contains zero or more DML messages (Insert, Update, Delete). In case of a cascaded setup it can also contain Origin messages. The origin message indicates that the transaction originated on different replication node. Since a replication node in the scope of logical replication

protocol can be pretty much anything, the only identifier is the origin name. It's downstream's responsibility to handle this as needed (if needed). The Origin message is always sent before any DML messages in the transaction.

Every DML message contains a relation OID, identifying the publisher's relation that was acted on. Before the first DML message for a given relation OID, a Relation message will be sent, describing the schema of that relation. Subsequently, a new Relation message will be sent if the relation's definition has changed since the last Relation message was sent for it. (The protocol assumes that the client is capable of remembering this metadata for as many relations as needed.)

Relation messages identify column types by their OIDs. In the case of a built-in type, it is assumed that the client can look up that type OID locally, so no additional data is needed. For a non-built-in type OID, a Type message will be sent before the Relation message, to provide the type name associated with that OID. Thus, a client that needs to specifically identify the types of relation columns should cache the contents of Type messages, and first consult that cache to see if the type OID is defined there. If not, look up the type OID locally.

## 49.6. Message Data Types

This section describes the base data types used in messages.

$\text{Int}_n(i)$

An  $n$ -bit integer in network byte order (most significant byte first). If  $i$  is specified it is the exact value that will appear, otherwise the value is variable. Eg.  $\text{Int}_{16}$ ,  $\text{Int}_{32}(42)$ .

$\text{Int}_n[k]$

An array of  $k$   $n$ -bit integers, each in network byte order. The array length  $k$  is always determined by an earlier field in the message. Eg.  $\text{Int}_{16}[M]$ .

$\text{String}(s)$

A null-terminated string (C-style string). There is no specific length limitation on strings. If  $s$  is specified it is the exact value that will appear, otherwise the value is variable. Eg.  $\text{String}$ ,  $\text{String}(\text{"user"})$ .

### Note

*There is no predefined limit on the length of a string that can be returned by the backend. Good coding strategy for a frontend is to use an expandable buffer so that anything that fits in memory can be accepted. If that's not feasible, read the full string and discard trailing characters that don't fit into your fixed-size buffer.*

$\text{Byte}_n(c)$

Exactly  $n$  bytes. If the field width  $n$  is not a constant, it is always determinable from an earlier field in the message. If  $c$  is specified it is the exact value. Eg.  $\text{Byte}_2$ ,  $\text{Byte}_1(\backslash'n')$ .

## 49.7. Message Formats

This section describes the detailed format of each message. Each is marked to indicate that it can be sent by a frontend (F), a backend (B), or both (F & B). Notice that although each message includes a byte count at the beginning, the message format is defined so that the message end can be found without reference to the byte count. This aids validity checking. (The CopyData message is an exception,

because it forms part of a data stream; the contents of any individual CopyData message cannot be interpretable on their own.)

AuthenticationOk (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(0)

Specifies that the authentication was successful.

AuthenticationKerberosV5 (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(2)

Specifies that Kerberos V5 authentication is required.

AuthenticationCleartextPassword (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(3)

Specifies that a clear-text password is required.

AuthenticationMD5Password (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(12)

Length of message contents in bytes, including self.

Int32(5)

Specifies that an MD5-encrypted password is required.

Byte4

The salt to use when encrypting the password.

AuthenticationSCMCredential (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(6)

Specifies that an SCM credentials message is required.

AuthenticationGSS (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(7)

Specifies that GSSAPI authentication is required.

AuthenticationSSPI (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(9)

Specifies that SSPI authentication is required.

AuthenticationGSSContinue (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(8)

Specifies that this message contains GSSAPI or SSPI data.

Byten

GSSAPI or SSPI authentication data.

AuthenticationSASL (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(10)

Specifies that SASL authentication is required.

The message body is a list of SASL authentication mechanisms, in the server's order of preference. A zero byte is required as terminator after the last authentication mechanism name. For each mechanism, there is the following:

String

Name of a SASL authentication mechanism.

AuthenticationSASLContinue (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(11)

Specifies that this message contains a SASL challenge.

Byten

SASL data, specific to the SASL mechanism being used.

AuthenticationSASLFinal (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(12)

Specifies that SASL authentication has completed.

Byten

SASL outcome "additional data", specific to the SASL mechanism being used.

BackendKeyData (B)

Byte1('K')

Identifies the message as cancellation key data. The frontend must save these values if it wishes to be able to issue CancelRequest messages later.

Int32(12)

Length of message contents in bytes, including self.

Int32

The process ID of this backend.

Int32

The secret key of this backend.

Bind (F)

Byte1('B')

Identifies the message as a Bind command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination portal (an empty string selects the unnamed portal).

String

The name of the source prepared statement (an empty string selects the unnamed prepared statement).

Int16

The number of parameter format codes that follow (denoted *C* below). This can be zero to indicate that there are no parameters or that the parameters all use the default format (text); or one, in which case the specified format code is applied to all parameters; or it can equal the actual number of parameters.

Int16[*C*]

The parameter format codes. Each must presently be zero (text) or one (binary).

Int16

The number of parameter values that follow (possibly zero). This must match the number of parameters needed by the query.

Next, the following pair of fields appear for each parameter:

Int32

The length of the parameter value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL parameter value. No value bytes follow in the NULL case.

Byte $n$

The value of the parameter, in the format indicated by the associated format code.  $n$  is the above length.

After the last parameter, the following fields appear:

Int16

The number of result-column format codes that follow (denoted *R* below). This can be zero to indicate that there are no result columns or that the result columns should all use the default

format (text); or one, in which case the specified format code is applied to all result columns (if any); or it can equal the actual number of result columns of the query.

Int16[R]

The result-column format codes. Each must presently be zero (text) or one (binary).

BindComplete (B)

Byte1('2')

Identifies the message as a Bind-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CancelRequest (F)

Int32(16)

Length of message contents in bytes, including self.

Int32(80877102)

The cancel request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5678 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

Int32

The process ID of the target backend.

Int32

The secret key for the target backend.

Close (F)

Byte1('C')

Identifies the message as a Close command.

Int32

Length of message contents in bytes, including self.

Byte1

'S' to close a prepared statement; or 'P' to close a portal.

String

The name of the prepared statement or portal to close (an empty string selects the unnamed prepared statement or portal).

CloseComplete (B)

Byte1('3')

Identifies the message as a Close-complete indicator.



Int32(4)

Length of message contents in bytes, including self.

CommandComplete (B)

Byte1('C')

Identifies the message as a command-completed response.

Int32

Length of message contents in bytes, including self.

String

The command tag. This is usually a single word that identifies which SQL command was completed.

For an INSERT command, the tag is INSERT *oid rows*, where *rows* is the number of rows inserted. *oid* used to be the object ID of the inserted row if *rows* was 1 and the target table had OIDs, but OIDs system columns are not supported anymore; therefore *oid* is always 0.

For a DELETE command, the tag is DELETE *rows* where *rows* is the number of rows deleted.

For an UPDATE command, the tag is UPDATE *rows* where *rows* is the number of rows updated.

For a SELECT or CREATE TABLE AS command, the tag is SELECT *rows* where *rows* is the number of rows retrieved.

For a MOVE command, the tag is MOVE *rows* where *rows* is the number of rows the cursor's position has been changed by.

For a FETCH command, the tag is FETCH *rows* where *rows* is the number of rows that have been retrieved from the cursor.

For a COPY command, the tag is COPY *rows* where *rows* is the number of rows copied. (Note: the row count appears only in LightDB 8.2 and later.)

CopyData (F & B)

Byte1('d')

Identifies the message as COPY data.

Int32

Length of message contents in bytes, including self.

Byten

Data that forms part of a COPY data stream. Messages sent from the backend will always correspond to single data rows, but messages sent by frontends might divide the data stream arbitrarily.

CopyDone (F & B)

Byte1('c')

Identifies the message as a COPY-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CopyFail (F)

Byte1('f')

Identifies the message as a COPY-failure indicator.

Int32

Length of message contents in bytes, including self.

String

An error message to report as the cause of failure.

CopyInResponse (B)

Byte1('G')

Identifies the message as a Start Copy In response. The frontend must now send copy-in data (if not prepared to do so, send a CopyFail message).

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted  $N$  below).

Int16[ $N$ ]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyOutResponse (B)

Byte1('H')

Identifies the message as a Start Copy Out response. This message will be followed by copy-out data.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted  $N$  below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyBothResponse (B)

Byte1('W')

Identifies the message as a Start Copy Both response. This message is used only for Streaming Replication.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

DataRow (B)

Byte1('D')

Identifies the message as a data row.

Int32

Length of message contents in bytes, including self.

Int16

The number of column values that follow (possibly zero).

Next, the following pair of fields appear for each column:

Int32

The length of the column value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL column value. No value bytes follow in the NULL case.

Byten

The value of the column, in the format indicated by the associated format code. *n* is the above length.

Describe (F)

Byte1('D')

Identifies the message as a Describe command.

Int32

Length of message contents in bytes, including self.

Byte1

'S' to describe a prepared statement; or 'P' to describe a portal.

String

The name of the prepared statement or portal to describe (an empty string selects the unnamed prepared statement or portal).

EmptyQueryResponse (B)

Byte1('I')

Identifies the message as a response to an empty query string. (This substitutes for CommandComplete.)

Int32(4)

Length of message contents in bytes, including self.

ErrorResponse (B)

Byte1('E')

Identifies the message as an error.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 49.8. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

Execute (F)

Byte1('E')

Identifies the message as an Execute command.

Int32

Length of message contents in bytes, including self.

String

The name of the portal to execute (an empty string selects the unnamed portal).

Int32

Maximum number of rows to return, if portal contains a query that returns rows (ignored otherwise). Zero denotes "no limit".

Flush (F)

Byte1('H')

Identifies the message as a Flush command.

Int32(4)

Length of message contents in bytes, including self.

FunctionCall (F)

Byte1('F')

Identifies the message as a function call.

Int32

Length of message contents in bytes, including self.

Int32

Specifies the object ID of the function to call.

Int16

The number of argument format codes that follow (denoted *C* below). This can be zero to indicate that there are no arguments or that the arguments all use the default format (text); or one, in which case the specified format code is applied to all arguments; or it can equal the actual number of arguments.

Int16[*C*]

The argument format codes. Each must presently be zero (text) or one (binary).

Int16

Specifies the number of arguments being supplied to the function.

Next, the following pair of fields appear for each argument:

Int32

The length of the argument value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL argument value. No value bytes follow in the NULL case.

Byte $n$

The value of the argument, in the format indicated by the associated format code.  $n$  is the above length.

After the last argument, the following field appears:

Int16

The format code for the function result. Must presently be zero (text) or one (binary).

FunctionCallResponse (B)

Byte1('V')

Identifies the message as a function call result.

Int32

Length of message contents in bytes, including self.

Int32

The length of the function result value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL function result. No value bytes follow in the NULL case.

Byter<sub>n</sub>

The value of the function result, in the format indicated by the associated format code. *n* is the above length.

GSSResponse (F)

Byte1('p')

Identifies the message as a GSSAPI or SSPI response. Note that this is also used for SASL and password response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

Byter<sub>n</sub>

GSSAPI/SSPI specific message data.

NegotiateProtocolVersion (B)

Byte1('v')

Identifies the message as a protocol version negotiation message.

Int32

Length of message contents in bytes, including self.

Int32

Newest minor protocol version supported by the server for the major protocol version requested by the client.

Int32

Number of protocol options not recognized by the server.

Then, for protocol option not recognized by the server, there is the following:

String

The option name.

NoData (B)

Byte1('n')

Identifies the message as a no-data indicator.

Int32(4)

Length of message contents in bytes, including self.

NoticeResponse (B)

Byte1('N')

Identifies the message as a notice.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 49.8. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

NotificationResponse (B)

Byte1('A')

Identifies the message as a notification response.

Int32

Length of message contents in bytes, including self.

Int32

The process ID of the notifying backend process.

String

The name of the channel that the notify has been raised on.

String

The “payload” string passed from the notifying process.

ParameterDescription (B)

Byte1('t')

Identifies the message as a parameter description.

Int32

Length of message contents in bytes, including self.

Int16

The number of parameters used by the statement (can be zero).

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type.

ParameterStatus (B)

Byte1('S')

Identifies the message as a run-time parameter status report.

Int32

Length of message contents in bytes, including self.

String

The name of the run-time parameter being reported.

String

The current value of the parameter.

Parse (F)

Byte1('P')

Identifies the message as a Parse command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination prepared statement (an empty string selects the unnamed prepared statement).

String

The query string to be parsed.

Int16

The number of parameter data types specified (can be zero). Note that this is not an indication of the number of parameters that might appear in the query string, only the number that the frontend wants to prespecify types for.

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type. Placing a zero here is equivalent to leaving the type unspecified.

ParseComplete (B)

Byte1('1')

Identifies the message as a Parse-complete indicator.

Int32(4)

Length of message contents in bytes, including self.



PasswordMessage (F)

Byte1('p')

Identifies the message as a password response. Note that this is also used for GSSAPI, SSPI and SASL response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

String

The password (encrypted, if requested).

PortalSuspended (B)

Byte1('s')

Identifies the message as a portal-suspended indicator. Note this only appears if an Execute message's row-count limit was reached.

Int32(4)

Length of message contents in bytes, including self.

Query (F)

Byte1('Q')

Identifies the message as a simple query.

Int32

Length of message contents in bytes, including self.

String

The query string itself.

ReadyForQuery (B)

Byte1('Z')

Identifies the message type. ReadyForQuery is sent whenever the backend is ready for a new query cycle.

Int32(5)

Length of message contents in bytes, including self.

Byte1

Current backend transaction status indicator. Possible values are 'I' if idle (not in a transaction block); 'T' if in a transaction block; or 'E' if in a failed transaction block (queries will be rejected until block is ended).

RowDescription (B)

Byte1('T')

Identifies the message as a row description.

Int32

Length of message contents in bytes, including self.

Int16

Specifies the number of fields in a row (can be zero).

Then, for each field, there is the following:

String

The field name.

Int32

If the field can be identified as a column of a specific table, the object ID of the table; otherwise zero.

Int16

If the field can be identified as a column of a specific table, the attribute number of the column; otherwise zero.

Int32

The object ID of the field's data type.

Int16

The data type size (see `pg_type.typelen`). Note that negative values denote variable-width types.

Int32

The type modifier (see `pg_attribute.atttypmod`). The meaning of the modifier is type-specific.

Int16

The format code being used for the field. Currently will be zero (text) or one (binary). In a RowDescription returned from the statement variant of Describe, the format code is not yet known and will always be zero.

SASLInitialResponse (F)

Byte1('p')

Identifies the message as an initial SASL response. Note that this is also used for GSSAPI, SSPI and password response messages. The exact message type is deduced from the context.

Int32

Length of message contents in bytes, including self.

String

Name of the SASL authentication mechanism that the client selected.

Int32

Length of SASL mechanism specific "Initial Client Response" that follows, or -1 if there is no Initial Response.

Byten

SASL mechanism specific "Initial Response".

SASLResponse (F)

Byte1('p')

Identifies the message as a SASL response. Note that this is also used for GSSAPI, SSPI and password response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

Byten

SASL mechanism specific message data.

SSLRequest (F)

Int32(8)

Length of message contents in bytes, including self.

Int32(80877103)

The SSL request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5679 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

GSSENCRequest (F)

Int32(8)

Length of message contents in bytes, including self.

Int32(80877104)

The GSSAPI Encryption request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5680 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

StartupMessage (F)

Int32

Length of message contents in bytes, including self.

Int32(196608)

The protocol version number. The most significant 16 bits are the major version number (3 for the protocol described here). The least significant 16 bits are the minor version number (0 for the protocol described here).

The protocol version number is followed by one or more pairs of parameter name and value strings. A zero byte is required as a terminator after the last name/value pair. Parameters can appear in any order. `user` is required, others are optional. Each parameter is specified as:

String

The parameter name. Currently recognized names are:

`user`

The database user name to connect as. Required; there is no default.

`database`

The database to connect to. Defaults to the user name.

`options`

Command-line arguments for the backend. (This is deprecated in favor of setting individual run-time parameters.) Spaces within this string are considered to separate arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash.

`replication`

Used to connect in streaming replication mode, where a small set of replication commands can be issued instead of SQL statements. Value can be `true`, `false`, or `database`, and the default is `false`. See Section 49.4 for details.

In addition to the above, other parameters may be listed. Parameter names beginning with `_pq_` are reserved for use as protocol extensions, while others are treated as run-time parameters to be set at backend start time. Such settings will be applied during backend start (after parsing the command-line arguments if any) and will act as session defaults.

String

The parameter value.

Sync (F)

Byte1('S')

Identifies the message as a Sync command.

Int32(4)

Length of message contents in bytes, including self.

Terminate (F)

Byte1('X')

Identifies the message as a termination.

Int32(4)

Length of message contents in bytes, including self.

## 49.8. Error and Notice Message Fields

This section describes the fields that can appear in `ErrorResponse` and `NoticeResponse` messages. Each field type has a single-byte identification token. Note that any given field type should appear at most once per message.

S

Severity: the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message), or a localized translation of one of these. Always present.

V

Severity: the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message). This is identical to the `S` field except that the contents are never localized. This is present only in messages generated by LightDB versions 9.6 and later.

C

Code: the `SQLSTATE` code for the error (see Appendix A). Not localizable. Always present.

M

Message: the primary human-readable error message. This should be accurate but terse (typically one line). Always present.

D

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

H

Hint: an optional suggestion what to do about the problem. This is intended to differ from Detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

P

Position: the field value is a decimal ASCII integer, indicating an error cursor position as an index into the original query string. The first character has index 1, and positions are measured in characters not bytes.

p

Internal position: this is defined the same as the `P` field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The `q` field will always appear when this field appears.

q

Internal query: the text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

W

Where: an indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

s

Schema name: if the error was associated with a specific database object, the name of the schema containing that object, if any.

t

Table name: if the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

c

Column name: if the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

d

Data type name: if the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

n

Constraint name: if the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

F

File: the file name of the source-code location where the error was reported.

L

Line: the line number of the source-code location where the error was reported.

R

Routine: the name of the source-code routine reporting the error.

**Note**

The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Frontends should not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, clients should not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

## 49.9. Logical Replication Message Formats

This section describes the detailed format of each logical replication message. These messages are returned either by the replication slot SQL interface or are sent by a walsender. In case of a walsender they are encapsulated inside the replication protocol WAL messages as described in Section 49.4 and generally obey same message flow as physical replication.

Begin

Byte1('B')

Identifies the message as a begin message.

Int64

The final LSN of the transaction.

Int64

Commit timestamp of the transaction. The value is in number of microseconds since LightDB epoch (2000-01-01).

Int32

Xid of the transaction.

Commit

Byte1('C')

Identifies the message as a commit message.

Int8

Flags; currently unused (must be 0).

Int64

The LSN of the commit.

Int64

The end LSN of the transaction.

Int64

Commit timestamp of the transaction. The value is in number of microseconds since LightDB epoch (2000-01-01).

Origin

Byte1('O')

Identifies the message as an origin message.

Int64

The LSN of the commit on the origin server.

String

Name of the origin.

Note that there can be multiple Origin messages inside a single transaction.

Relation

Byte1('R')

Identifies the message as a relation message.

Int32

ID of the relation.

String

Namespace (empty string for `pg_catalog`).

String

Relation name.

Int8

Replica identity setting for the relation (same as `relreplident` in `pg_class`).

Int16

Number of columns.

Next, the following message part appears for each column (except generated columns):

Int8

Flags for the column. Currently can be either 0 for no flags or 1 which marks the column as part of the key.

String

Name of the column.

Int32

ID of the column's data type.

Int32

Type modifier of the column (`atttypmod`).

Type

Byte1('Y')

Identifies the message as a type message.

Int32

ID of the data type.

String

Namespace (empty string for `pg_catalog`).

String

Name of the data type.

Insert

Byte1('I')

Identifies the message as an insert message.

Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('N')

Identifies the following TupleData message as a new tuple.

TupleData

TupleData message part representing the contents of new tuple.

Update

Byte1('U')

Identifies the message as an update message.



Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('K')

Identifies the following TupleData submessage as a key. This field is optional and is only present if the update changed data in any of the column(s) that are part of the REPLICA IDENTITY index.

Byte1('O')

Identifies the following TupleData submessage as an old tuple. This field is optional and is only present if table in which the update happened has REPLICA IDENTITY set to FULL.

TupleData

TupleData message part representing the contents of the old tuple or primary key. Only present if the previous 'O' or 'K' part is present.

Byte1('N')

Identifies the following TupleData message as a new tuple.

TupleData

TupleData message part representing the contents of a new tuple.

The Update message may contain either a 'K' message part or an 'O' message part or neither of them, but never both of them.

Delete

Byte1('D')

Identifies the message as a delete message.

Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('K')

Identifies the following TupleData submessage as a key. This field is present if the table in which the delete has happened uses an index as REPLICA IDENTITY.

Byte1('O')

Identifies the following TupleData message as an old tuple. This field is present if the table in which the delete happened has REPLICA IDENTITY set to FULL.

TupleData

TupleData message part representing the contents of the old tuple or primary key, depending on the previous field.

The Delete message may contain either a 'K' message part or an 'O' message part, but never both of them.

Truncate

Byte1('T')

Identifies the message as a truncate message.

Int32

Number of relations

Int8

Option bits for TRUNCATE: 1 for CASCADE, 2 for RESTART IDENTITY

Int32

ID of the relation corresponding to the ID in the relation message. This field is repeated for each relation.

The following message parts are shared by the above messages.

TupleData

Int16

Number of columns.

Next, one of the following submessages appears for each column (except generated columns):

Byte1('n')

Identifies the data as NULL value.

Or

Byte1('u')

Identifies unchanged TOASTed value (the actual value is not sent).

Or

Byte1('t')

Identifies the data as text formatted value.

Int32

Length of the column value.

Byten

The value of the column, in text format. (A future release might support additional formats.) *n* is the above length.

## 49.10. Summary of Changes since Protocol 2.0

This section provides a quick checklist of changes, for the benefit of developers trying to update existing client libraries to protocol 3.0.

The initial startup packet uses a flexible list-of-strings format instead of a fixed format. Notice that session default values for run-time parameters can now be specified directly in the startup packet. (Actually, you could do that before using the `options` field, but given the limited width of `options` and the lack of any way to quote whitespace in the values, it wasn't a very safe technique.)

All messages now have a length count immediately following the message type byte (except for startup packets, which have no type byte). Also note that `PasswordMessage` now has a type byte.

ErrorResponse and NoticeResponse ('E' and 'N') messages now contain multiple fields, from which the client code can assemble an error message of the desired level of verbosity. Note that individual fields will typically not end with a newline, whereas the single string sent in the older protocol always did.

The ReadyForQuery ('Z') message includes a transaction status indicator.

The distinction between BinaryRow and DataRow message types is gone; the single DataRow message type serves for returning data in all formats. Note that the layout of DataRow has changed to make it easier to parse. Also, the representation of binary values has changed: it is no longer directly tied to the server's internal representation.

There is a new “extended query” sub-protocol, which adds the frontend message types Parse, Bind, Execute, Describe, Close, Flush, and Sync, and the backend message types ParseComplete, BindComplete, PortalSuspended, ParameterDescription, NoData, and CloseComplete. Existing clients do not have to concern themselves with this sub-protocol, but making use of it might allow improvements in performance or functionality.

COPY data is now encapsulated into CopyData and CopyDone messages. There is a well-defined way to recover from errors during COPY. The special “\.” last line is not needed anymore, and is not sent during COPY OUT. (It is still recognized as a terminator during COPY IN, but its use is deprecated and will eventually be removed.) Binary COPY is supported. The CopyInResponse and CopyOutResponse messages include fields indicating the number of columns and the format of each column.

The layout of FunctionCall and FunctionCallResponse messages has changed. FunctionCall can now support passing NULL arguments to functions. It also can handle passing parameters and retrieving results in either text or binary format. There is no longer any reason to consider FunctionCall a potential security hole, since it does not offer direct access to internal server data representations.

The backend sends ParameterStatus ('S') messages during connection startup for all parameters it considers interesting to the client library. Subsequently, a ParameterStatus message is sent whenever the active value changes for any of these parameters.

The RowDescription ('T') message carries new table OID and column number fields for each column of the described row. It also shows the format code for each column.

The CursorResponse ('P') message is no longer generated by the backend.

The NotificationResponse ('A') message has an additional string field, which can carry a “payload” string passed from the NOTIFY event sender.

The EmptyQueryResponse ('I') message used to include an empty string parameter; this has been removed.

---

# Chapter 50. LightDB Coding Conventions

## 50.1. Formatting

Source code formatting uses 4 column tab spacing, with tabs preserved (i.e., tabs are not expanded to spaces). Each logical indentation level is one additional tab stop.

Layout rules (brace positioning, etc) follow BSD conventions. In particular, curly braces for the controlled blocks of `if`, `while`, `switch`, etc go on their own lines.

Limit line lengths so that the code is readable in an 80-column window. (This doesn't mean that you must never go past 80 columns. For instance, breaking a long error message string in arbitrary places just to keep the code within 80 columns is probably not a net gain in readability.)

To maintain a consistent coding style, do not use C++ style comments (`//` comments). `pgindent` will replace them with `/* ... */`.

The preferred style for multi-line comment blocks is

```
/*
 * comment text begins here
 * and continues here
 */
```

Note that comment blocks that begin in column 1 will be preserved as-is by `pgindent`, but it will re-flow indented comment blocks as though they were plain text. If you want to preserve the line breaks in an indented block, add dashes like this:

```
/*-----
 * comment text begins here
 * and continues here
 *-----
 */
```

While submitted patches do not absolutely have to follow these formatting rules, it's a good idea to do so. Your code will get run through `pgindent` before the next release, so there's no point in making it look nice under some other set of formatting conventions. A good rule of thumb for patches is "make the new code look like the existing code around it".

The `src/tools` directory contains sample settings files that can be used with the `emacs`, `xemacs` or `vim` editors to help ensure that they format code according to these conventions.

The text browsing tools `more` and `less` can be invoked as:

```
more -x4
less -x4
```

to make them show tabs appropriately.

## 50.2. Reporting Errors Within the Server

Error, warning, and log messages generated within the server code should be created using `ereport`, or its older cousin `eelog`. The use of this function is complex enough to require some explanation.

There are two required elements for every message: a severity level (ranging from `DEBUG` to `PANIC`) and a primary message text. In addition there are optional elements, the most common of which is an error identifier code that follows the SQL spec's `SQLSTATE` conventions. `ereport` itself is just a shell macro that exists mainly for the syntactic convenience of making message generation look like a single function call in the C source code. The only parameter accepted directly by `ereport` is the severity level. The primary message text and any optional message elements are generated by calling auxiliary functions, such as `errmsg`, within the `ereport` call.

A typical call to `ereport` might look like this:

```
ereport(ERROR,
        errmsg(ERRCODE_DIVISION_BY_ZERO),
        errmsg("division by zero"));
```

This specifies error severity level `ERROR` (a run-of-the-mill error). The `errmsg` call specifies the `SQLSTATE` error code using a macro defined in `src/include/utils/errcodes.h`. The `errmsg` call provides the primary message text.

You will also frequently see this older style, with an extra set of parentheses surrounding the auxiliary function calls:

```
ereport(ERROR,
        (errmsg(ERRCODE_DIVISION_BY_ZERO),
         errmsg("division by zero")));
```

The extra parentheses were required before LightDB version 12, but are now optional.

Here is a more complex example:

```
ereport(ERROR,
        errmsg(ERRCODE_AMBIGUOUS_FUNCTION),
        errmsg("function %s is not unique",
              func_signature_string(funcname, nargs,
                                   NIL, actual_arg_types)),
        errhint("Unable to choose a best candidate function. "
               "You might need to add explicit typecasts.));
```

This illustrates the use of format codes to embed run-time values into a message text. Also, an optional “hint” message is provided. The auxiliary function calls can be written in any order, but conventionally `errmsg` and `errmsg` appear first.

If the severity level is `ERROR` or higher, `ereport` aborts execution of the current query and does not return to the caller. If the severity level is lower than `ERROR`, `ereport` returns normally.

The available auxiliary routines for `ereport` are:

- `errmsg(sqlerrcode)` specifies the `SQLSTATE` error identifier code for the condition. If this routine is not called, the error identifier defaults to `ERRCODE_INTERNAL_ERROR` when the error severity level is `ERROR` or higher, `ERRCODE_WARNING` when the error level is `WARNING`, otherwise (for `NOTICE` and below) `ERRCODE_SUCCESSFUL_COMPLETION`. While these defaults are often convenient, always think whether they are appropriate before omitting the `errmsg()` call.
- `errmsg(const char *msg, ...)` specifies the primary error message text, and possibly run-time values to insert into it. Insertions are specified by `sprintf`-style format codes. In addition

to the standard format codes accepted by `sprintf`, the format code `%m` can be used to insert the error message returned by `strerror` for the current value of `errno`.<sup>1</sup> `%m` does not require any corresponding entry in the parameter list for `errmsg`. Note that the message string will be run through `gettext` for possible localization before format codes are processed.

- `errmsg_internal(const char *msg, ...)` is the same as `errmsg`, except that the message string will not be translated nor included in the internationalization message dictionary. This should be used for “cannot happen” cases that are probably not worth expending translation effort on.
- `errmsg_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errmsg`, but with support for various plural forms of the message. *fmt\_singular* is the English singular format, *fmt\_plural* is the English plural format, *n* is the integer value that determines which plural form is needed, and the remaining arguments are formatted according to the selected format string. For more information see Section 51.2.2.
- `errdetail(const char *msg, ...)` supplies an optional “detail” message; this is to be used when there is additional information that seems inappropriate to put in the primary message. The message string is processed in just the same way as for `errmsg`.
- `errdetail_internal(const char *msg, ...)` is the same as `errdetail`, except that the message string will not be translated nor included in the internationalization message dictionary. This should be used for detail messages that are not worth expending translation effort on, for instance because they are too technical to be useful to most users.
- `errdetail_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errdetail`, but with support for various plural forms of the message. For more information see Section 51.2.2.
- `errdetail_log(const char *msg, ...)` is the same as `errdetail` except that this string goes only to the server log, never to the client. If both `errdetail` (or one of its equivalents above) and `errdetail_log` are used then one string goes to the client and the other to the log. This is useful for error details that are too security-sensitive or too bulky to include in the report sent to the client.
- `errdetail_log_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errdetail_log`, but with support for various plural forms of the message. For more information see Section 51.2.2.
- `errhint(const char *msg, ...)` supplies an optional “hint” message; this is to be used when offering suggestions about how to fix the problem, as opposed to factual details about what went wrong. The message string is processed in just the same way as for `errmsg`.
- `errcontext(const char *msg, ...)` is not normally called directly from an `ereport` message site; rather it is used in `error_context_stack` callback functions to provide information about the context in which an error occurred, such as the current location in a PL function. The message string is processed in just the same way as for `errmsg`. Unlike the other auxiliary functions, this can be called more than once per `ereport` call; the successive strings thus supplied are concatenated with separating newlines.
- `errposition(int cursorpos)` specifies the textual location of an error within a query string. Currently it is only useful for errors detected in the lexical and syntactic analysis phases of query processing.
- `errtable(Relation rel)` specifies a relation whose name and schema name should be included as auxiliary fields in the error report.

---

<sup>1</sup> That is, the value that was current when the `ereport` call was reached; changes of `errno` within the auxiliary reporting routines will not affect it. That would not be true if you were to write `strerror(errno)` explicitly in `errmsg`'s parameter list; accordingly, do not do so.

- `errtablecol(Relation rel, int attnum)` specifies a column whose name, table name, and schema name should be included as auxiliary fields in the error report.
- `errtableconstraint(Relation rel, const char *conname)` specifies a table constraint whose name, table name, and schema name should be included as auxiliary fields in the error report. Indexes should be considered to be constraints for this purpose, whether or not they have an associated `pg_constraint` entry. Be careful to pass the underlying heap relation, not the index itself, as `rel`.
- `errdatatype(Oid datatypeOid)` specifies a data type whose name and schema name should be included as auxiliary fields in the error report.
- `errdomainconstraint(Oid datatypeOid, const char *conname)` specifies a domain constraint whose name, domain name, and schema name should be included as auxiliary fields in the error report.
- `errcode_for_file_access()` is a convenience function that selects an appropriate `SQLSTATE` error identifier for a failure in a file-access-related system call. It uses the saved `errno` to determine which error code to generate. Usually this should be used in combination with `%m` in the primary error message text.
- `errcode_for_socket_access()` is a convenience function that selects an appropriate `SQLSTATE` error identifier for a failure in a socket-related system call.
- `errhidestmt(bool hide_stmt)` can be called to specify suppression of the `STATEMENT:` portion of a message in the postmaster log. Generally this is appropriate if the message text includes the current statement already.
- `errhidecontext(bool hide_ctx)` can be called to specify suppression of the `CONTEXT:` portion of a message in the postmaster log. This should only be used for verbose debugging messages where the repeated inclusion of context would bloat the log too much.

### Note

At most one of the functions `errtable`, `errtablecol`, `errtableconstraint`, `errdatatype`, or `errdomainconstraint` should be used in an `ereport` call. These functions exist to allow applications to extract the name of a database object associated with the error condition without having to examine the potentially-localized error message text. These functions should be used in error reports for which it's likely that applications would wish to have automatic error handling. As of LightDB 9.3, complete coverage exists only for errors in `SQLSTATE` class 23 (integrity constraint violation), but this is likely to be expanded in future.

There is an older function `eelog` that is still heavily used. An `eelog` call:

```
eelog(level, "format string", ...);
```

is exactly equivalent to:

```
ereport(level, errmsg_internal("format string", ...));
```

Notice that the `SQLSTATE` error code is always defaulted, and the message string is not subject to translation. Therefore, `eelog` should be used only for internal errors and low-level debug logging. Any message that is likely to be of interest to ordinary users should go through `ereport`. Nonetheless, there are enough internal “cannot happen” error checks in the system that `eelog` is still widely used; it is preferred for those messages for its notational simplicity.

Advice about writing good error messages can be found in Section 50.3.

## 50.3. Error Message Style Guide

This style guide is offered in the hope of maintaining a consistent, user-friendly style throughout all the messages generated by LightDB.

### What Goes Where

The primary message should be short, factual, and avoid reference to implementation details such as specific function names. “Short” means “should fit on one line under normal conditions”. Use a detail message if needed to keep the primary message short, or if you feel a need to mention implementation details such as the particular system call that failed. Both primary and detail messages should be factual. Use a hint message for suggestions about what to do to fix the problem, especially if the suggestion might not always be applicable.

For example, instead of:

```
IpcMemoryCreate: shmget(key=%d, size=%u, 0%o) failed: %m  
(plus a long addendum that is basically a hint)
```

write:

```
Primary:    could not create shared memory segment: %m  
Detail:    Failed syscall was shmget(key=%d, size=%u, 0%o).  
Hint:      the addendum
```

Rationale: keeping the primary message short helps keep it to the point, and lets clients lay out screen space on the assumption that one line is enough for error messages. Detail and hint messages can be relegated to a verbose mode, or perhaps a pop-up error-details window. Also, details and hints would normally be suppressed from the server log to save space. Reference to implementation details is best avoided since users aren't expected to know the details.

### Formatting

Don't put any specific assumptions about formatting into the message texts. Expect clients and the server log to wrap lines to fit their own needs. In long messages, newline characters (`\n`) can be used to indicate suggested paragraph breaks. Don't end a message with a newline. Don't use tabs or other formatting characters. (In error context displays, newlines are automatically added to separate levels of context such as function calls.)

Rationale: Messages are not necessarily displayed on terminal-type displays. In GUI displays or browsers these formatting instructions are at best ignored.

### Quotation Marks

English text should use double quotes when quoting is appropriate. Text in other languages should consistently use one kind of quotes that is consistent with publishing customs and computer output of other programs.

Rationale: The choice of double quotes over single quotes is somewhat arbitrary, but tends to be the preferred use. Some have suggested choosing the kind of quotes depending on the type of object according to SQL conventions (namely, strings single quoted, identifiers double quoted). But this is a language-internal technical issue that many users aren't even familiar with, it won't scale to other kinds of quoted terms, it doesn't translate to other languages, and it's pretty pointless, too.



## Use of Quotes

Always use quotes to delimit file names, user-supplied identifiers, and other variables that might contain words. Do not use them to mark up variables that will not contain words (for example, operator names).

There are functions in the backend that will double-quote their own output as needed (for example, `format_type_be()`). Do not put additional quotes around the output of such functions.

Rationale: Objects can have names that create ambiguity when embedded in a message. Be consistent about denoting where a plugged-in name starts and ends. But don't clutter messages with unnecessary or duplicate quote marks.

## Grammar and Punctuation

The rules are different for primary error messages and for detail/hint messages:

Primary error messages: Do not capitalize the first letter. Do not end a message with a period. Do not even think about ending a message with an exclamation point.

Detail and hint messages: Use complete sentences, and end each with a period. Capitalize the first word of sentences. Put two spaces after the period if another sentence follows (for English text; might be inappropriate in other languages).

Error context strings: Do not capitalize the first letter and do not end the string with a period. Context strings should normally not be complete sentences.

Rationale: Avoiding punctuation makes it easier for client applications to embed the message into a variety of grammatical contexts. Often, primary messages are not grammatically complete sentences anyway. (And if they're long enough to be more than one sentence, they should be split into primary and detail parts.) However, detail and hint messages are longer and might need to include multiple sentences. For consistency, they should follow complete-sentence style even when there's only one sentence.

## Upper Case vs. Lower Case

Use lower case for message wording, including the first letter of a primary error message. Use upper case for SQL commands and key words if they appear in the message.

Rationale: It's easier to make everything look more consistent this way, since some messages are complete sentences and some not.

## Avoid Passive Voice

Use the active voice. Use complete sentences when there is an acting subject (“A could not do B”). Use telegram style without subject if the subject would be the program itself; do not use “I” for the program.

Rationale: The program is not human. Don't pretend otherwise.

## Present vs. Past Tense

Use past tense if an attempt to do something failed, but could perhaps succeed next time (perhaps after fixing some problem). Use present tense if the failure is certainly permanent.

There is a nontrivial semantic difference between sentences of the form:

```
could not open file "%s": %m  
and:
```

```
cannot open file "%s"
```

The first one means that the attempt to open the file failed. The message should give a reason, such as “disk full” or “file doesn't exist”. The past tense is appropriate because next time the disk might not be full anymore or the file in question might exist.

The second form indicates that the functionality of opening the named file does not exist at all in the program, or that it's conceptually impossible. The present tense is appropriate because the condition will persist indefinitely.

Rationale: Granted, the average user will not be able to draw great conclusions merely from the tense of the message, but since the language provides us with a grammar we should use it correctly.

## Type of the Object

When citing the name of an object, state what kind of object it is.

Rationale: Otherwise no one will know what “foo.bar.baz” refers to.

## Brackets

Square brackets are only to be used (1) in command synopses to denote optional arguments, or (2) to denote an array subscript.

Rationale: Anything else does not correspond to widely-known customary usage and will confuse people.

## Assembling Error Messages

When a message includes text that is generated elsewhere, embed it in this style:

```
could not open file %s: %m
```

Rationale: It would be difficult to account for all possible error codes to paste this into a single smooth sentence, so some sort of punctuation is needed. Putting the embedded text in parentheses has also been suggested, but it's unnatural if the embedded text is likely to be the most important part of the message, as is often the case.

## Reasons for Errors

Messages should always state the reason why an error occurred. For example:

```
BAD:    could not open file %s  
BETTER: could not open file %s (I/O failure)
```

If no reason is known you better fix the code.

## Function Names

Don't include the name of the reporting routine in the error text. We have other mechanisms for finding that out when needed, and for most users it's not helpful information. If the error text doesn't make as much sense without the function name, reword it.

```
BAD:    pg_strtoint32: error in "z": cannot parse "z"  
BETTER: invalid input syntax for type integer: "z"
```

Avoid mentioning called function names, either; instead say what the code was trying to do:

```
BAD:    open() failed: %m  
BETTER: could not open file %s: %m
```

If it really seems necessary, mention the system call in the detail message. (In some cases, providing the actual values passed to the system call might be appropriate information for the detail message.)

Rationale: Users don't know what all those functions do.

## Tricky Words to Avoid

**Unable.** “Unable” is nearly the passive voice. Better use “cannot” or “could not”, as appropriate.

**Bad.** Error messages like “bad result” are really hard to interpret intelligently. It's better to write why the result is “bad”, e.g., “invalid format”.

**Illegal.** “Illegal” stands for a violation of the law, the rest is “invalid”. Better yet, say why it's invalid.

**Unknown.** Try to avoid “unknown”. Consider “error: unknown response”. If you don't know what the response is, how do you know it's erroneous? “Unrecognized” is often a better choice. Also, be sure to include the value being complained of.

```
BAD:    unknown node type  
BETTER: unrecognized node type: 42
```

**Find vs. Exists.** If the program uses a nontrivial algorithm to locate a resource (e.g., a path search) and that algorithm fails, it is fair to say that the program couldn't “find” the resource. If, on the other hand, the expected location of the resource is known but the program cannot access it there then say that the resource doesn't “exist”. Using “find” in this case sounds weak and confuses the issue.

**May vs. Can vs. Might.** “May” suggests permission (e.g., “You may borrow my rake.”), and has little use in documentation or error messages. “Can” suggests ability (e.g., “I can lift that log.”), and “might” suggests possibility (e.g., “It might rain today.”). Using the proper word clarifies meaning and assists translation.

**Contractions.** Avoid contractions, like “can't”; use “cannot” instead.

**Non-negative.** Avoid “non-negative” as it is ambiguous about whether it accepts zero. It's better to use “greater than zero” or “greater than or equal to zero”.

## Proper Spelling

Spell out words in full. For instance, avoid:

- spec
- stats
- parens
- auth

- xact

Rationale: This will improve consistency.

## Localization

Keep in mind that error message texts need to be translated into other languages. Follow the guidelines in Section 51.2.2 to avoid making life difficult for translators.

# 50.4. Miscellaneous Coding Conventions

## C Standard

Code in LightDB should only rely on language features available in the C99 standard. That means a conforming C99 compiler has to be able to compile lightdb, at least aside from a few platform dependent pieces.

A few features included in the C99 standard are, at this time, not permitted to be used in core LightDB code. This currently includes variable length arrays, intermingled declarations and code, // comments, universal character names. Reasons for that include portability and historical practices.

Features from later revisions of the C standard or compiler specific features can be used, if a fallback is provided.

For example `_Static_assert()` and `__builtin_constant_p` are currently used, even though they are from newer revisions of the C standard and a GCC extension respectively. If not available we respectively fall back to using a C99 compatible replacement that performs the same checks, but emits rather cryptic messages and do not use `__builtin_constant_p`.

## Function-Like Macros and Inline Functions

Both, macros with arguments and `static inline` functions, may be used. The latter are preferable if there are multiple-evaluation hazards when written as a macro, as e.g., the case with

```
#define Max(x, y) ((x) > (y) ? (x) : (y))
```

or when the macro would be very long. In other cases it's only possible to use macros, or at least easier. For example because expressions of various types need to be passed to the macro.

When the definition of an inline function references symbols (i.e., variables, functions) that are only available as part of the backend, the function may not be visible when included from frontend code.

```
#ifndef FRONTEND
static inline MemoryContext
MemoryContextSwitchTo(MemoryContext context)
{
    MemoryContext old = CurrentMemoryContext;

    CurrentMemoryContext = context;
    return old;
}
#endif /* FRONTEND */
```

In this example `CurrentMemoryContext`, which is only available in the backend, is referenced and the function thus hidden with a `#ifndef FRONTEND`. This rule exists because some compilers emit references to symbols contained in inline functions even if the function is not used.

## Writing Signal Handlers

To be suitable to run inside a signal handler code has to be written very carefully. The fundamental problem is that, unless blocked, a signal handler can interrupt code at any time. If code inside the signal handler uses the same state as code outside chaos may ensue. As an example consider what happens if a signal handler tries to acquire a lock that's already held in the interrupted code.

Barring special arrangements code in signal handlers may only call async-signal safe functions (as defined in POSIX) and access variables of type `volatile sig_atomic_t`. A few functions in `lightdb` are also deemed signal safe, importantly `SetLatch()`.

In most cases signal handlers should do nothing more than note that a signal has arrived, and wake up code running outside of the handler using a latch. An example of such a handler is the following:

```
static void
handle_sighup(SIGNAL_ARGS)
{
    int          save_errno = errno;

    got_SIGHUP = true;
    SetLatch(MyLatch);

    errno = save_errno;
}
```

`errno` is saved and restored because `SetLatch()` might change it. If that were not done interrupted code that's currently inspecting `errno` might see the wrong value.

## Calling Function Pointers

For clarity, it is preferred to explicitly dereference a function pointer when calling the pointed-to function if the pointer is a simple variable, for example:

```
(*emit_log_hook) (edata);
```

(even though `emit_log_hook(edata)` would also work). When the function pointer is part of a structure, then the extra punctuation can and usually should be omitted, for example:

```
paramInfo->paramFetch(paramInfo, paramId);
```

---

# Chapter 51. Native Language Support

## 51.1. For the Translator

LightDB programs (server and client) can issue their messages in your favorite language — if the messages have been translated. Creating and maintaining translated message sets needs the help of people who speak their own language well and want to contribute to the LightDB effort. You do not have to be a programmer at all to do this. This section explains how to help.

### 51.1.1. Requirements

We won't judge your language skills — this section is about software tools. Theoretically, you only need a text editor. But this is only in the unlikely event that you do not want to try out your translated messages. When you configure your source tree, be sure to use the `--enable-nls` option. This will also check for the `libintl` library and the `msgfmt` program, which all end users will need anyway. To try out your work, follow the applicable portions of the installation instructions.

If you want to start a new translation effort or want to do a message catalog merge (described later), you will need the programs `xgettext` and `msgmerge`, respectively, in a GNU-compatible implementation. Later, we will try to arrange it so that if you use a packaged source distribution, you won't need `xgettext`. (If working from Git, you will still need it.) GNU Gettext 0.10.36 or later is currently recommended.

Your local `gettext` implementation should come with its own documentation. Some of that is probably duplicated in what follows, but for additional details you should look there.

### 51.1.2. Concepts

The pairs of original (English) messages and their (possibly) translated equivalents are kept in *message catalogs*, one for each program (although related programs can share a message catalog) and for each target language. There are two file formats for message catalogs: The first is the “PO” file (for Portable Object), which is a plain text file with special syntax that translators edit. The second is the “MO” file (for Machine Object), which is a binary file generated from the respective PO file and is used while the internationalized program is run. Translators do not deal with MO files; in fact hardly anyone does.

The extension of the message catalog file is to no surprise either `.po` or `.mo`. The base name is either the name of the program it accompanies, or the language the file is for, depending on the situation. This is a bit confusing. Examples are `ltsql.po` (PO file for `ltsql`) or `fr.mo` (MO file in French).

The file format of the PO files is illustrated here:

```
# comment

msgid "original string"
msgstr "translated string"

msgid "more original"
msgstr "another translated"
"string can be broken up like this"

...
```

The `msgid` lines are extracted from the program source. (They need not be, but this is the most common way.) The `msgstr` lines are initially empty and are filled in with useful strings by the translator. The strings can contain C-style escape characters and can be continued across lines as illustrated. (The next line must start at the beginning of the line.)

The # character introduces a comment. If whitespace immediately follows the # character, then this is a comment maintained by the translator. There can also be automatic comments, which have a non-whitespace character immediately following the #. These are maintained by the various tools that operate on the PO files and are intended to aid the translator.

```
#. automatic comment
#: filename.c:1023
#, flags, flags
```

The #. style comments are extracted from the source file where the message is used. Possibly the programmer has inserted information for the translator, such as about expected alignment. The #: comments indicate the exact locations where the message is used in the source. The translator need not look at the program source, but can if there is doubt about the correct translation. The #, comments contain flags that describe the message in some way. There are currently two flags: `fuzzy` is set if the message has possibly been outdated because of changes in the program source. The translator can then verify this and possibly remove the fuzzy flag. Note that fuzzy messages are not made available to the end user. The other flag is `c-format`, which indicates that the message is a `printf`-style format template. This means that the translation should also be a format string with the same number and type of placeholders. There are tools that can verify this, which key off the `c-format` flag.

### 51.1.3. Creating and Maintaining Message Catalogs

OK, so how does one create a “blank” message catalog? First, go into the directory that contains the program whose messages you want to translate. If there is a file `nls.mk`, then this program has been prepared for translation.

If there are already some `.po` files, then someone has already done some translation work. The files are named `language.po`, where `language` is the ISO 639-1 two-letter language code (in lower case)<sup>1</sup>, e.g., `fr.po` for French. If there is really a need for more than one translation effort per language then the files can also be named `language_region.po` where `region` is the ISO 3166-1 two-letter country code (in upper case)<sup>2</sup>, e.g., `pt_BR.po` for Portuguese in Brazil. If you find the language you wanted you can just start working on that file.

If you need to start a new translation effort, then first run the command:

```
make init-po
```

This will create a file `prognamename.pot`. (`.pot` to distinguish it from PO files that are “in production”. The T stands for “template”.) Copy this file to `language.po` and edit it. To make it known that the new language is available, also edit the file `nls.mk` and add the language (or language and country) code to the line that looks like:

```
AVAIL_LANGUAGES := de fr
```

(Other languages can appear, of course.)

As the underlying program or library changes, messages might be changed or added by the programmers. In this case you do not need to start from scratch. Instead, run the command:

```
make update-po
```

which will create a new blank message catalog file (the `pot` file you started with) and will merge it with the existing PO files. If the merge algorithm is not sure about a particular message it marks it “fuzzy” as explained above. The new PO file is saved with a `.po.new` extension.

---

<sup>1</sup> [https://www.loc.gov/standards/iso639-2/php/English\\_list.php](https://www.loc.gov/standards/iso639-2/php/English_list.php)

<sup>2</sup> <https://www.iso.org/iso-3166-country-codes.html>

## 51.1.4. Editing the PO Files

The PO files can be edited with a regular text editor. The translator should only change the area between the quotes after the `msgstr` directive, add comments, and alter the fuzzy flag. There is (unsurprisingly) a PO mode for Emacs, which I find quite useful.

The PO files need not be completely filled in. The software will automatically fall back to the original string if no translation (or an empty translation) is available. It is no problem to submit incomplete translations for inclusions in the source tree; that gives room for other people to pick up your work. However, you are encouraged to give priority to removing fuzzy entries after doing a merge. Remember that fuzzy entries will not be installed; they only serve as reference for what might be the right translation.

Here are some things to keep in mind while editing the translations:

- Make sure that if the original ends with a newline, the translation does, too. Similarly for tabs, etc.
- If the original is a `printf` format string, the translation also needs to be. The translation also needs to have the same format specifiers in the same order. Sometimes the natural rules of the language make this impossible or at least awkward. In that case you can modify the format specifiers like this:

```
msgstr "Die Datei %2$s hat %1$u Zeichen."
```

Then the first placeholder will actually use the second argument from the list. The `digits$` needs to follow the `%` immediately, before any other format manipulators. (This feature really exists in the `printf` family of functions. You might not have heard of it before because there is little use for it outside of message internationalization.)

- If the original string contains a linguistic mistake, report that (or fix it yourself in the program source) and translate normally. The corrected string can be merged in when the program sources have been updated. If the original string contains a factual mistake, report that (or fix it yourself) and do not translate it. Instead, you can mark the string with a comment in the PO file.
- Maintain the style and tone of the original string. Specifically, messages that are not sentences (`cannot open file %s`) should probably not start with a capital letter (if your language distinguishes letter case) or end with a period (if your language uses punctuation marks). It might help to read Section 50.3.
- If you don't know what a message means, or if it is ambiguous, ask on the developers' mailing list. Chances are that English speaking end users might also not understand it or find it ambiguous, so it's best to improve the message.

## 51.2. For the Programmer

### 51.2.1. Mechanics

This section describes how to implement native language support in a program or library that is part of the LightDB distribution. Currently, it only applies to C programs.

#### Adding NLS Support to a Program

1. Insert this code into the start-up sequence of the program:

```
#ifdef ENABLE-NLS
#include <locale.h>
#endif
```



...

```
#ifdef ENABLE-NLS
setlocale(LC_ALL, "");
bindtextdomain("programe", LOCALEDIR);
textdomain("programe");
#endif
```

(The *programe* can actually be chosen freely.)

2. Wherever a message that is a candidate for translation is found, a call to `gettext()` needs to be inserted. E.g.:

```
fprintf(stderr, "panic level %d\n", lvl);
```

would be changed to:

```
fprintf(stderr, gettext("panic level %d\n"), lvl);
```

(`gettext` is defined as a no-op if NLS support is not configured.)

This tends to add a lot of clutter. One common shortcut is to use:

```
#define _(x) gettext(x)
```

Another solution is feasible if the program does much of its communication through one or a few functions, such as `ereport()` in the backend. Then you make this function call `gettext` internally on all input strings.

3. Add a file `nls.mk` in the directory with the program sources. This file will be read as a makefile. The following variable assignments need to be made here:

`CATALOG_NAME`

The program name, as provided in the `textdomain()` call.

`AVAIL_LANGUAGES`

List of provided translations — initially empty.

`GETTEXT_FILES`

List of files that contain translatable strings, i.e., those marked with `gettext` or an alternative solution. Eventually, this will include nearly all source files of the program. If this list gets too long you can make the first “file” be a `+` and the second word be a file that contains one file name per line.

`GETTEXT_TRIGGERS`

The tools that generate message catalogs for the translators to work on need to know what function calls contain translatable strings. By default, only `gettext()` calls are known. If you used `_` or other identifiers you need to list them here. If the translatable string is not the first argument, the item needs to be of the form `func:2` (for the second argument). If you have a function that supports pluralized messages, the item should look like `func:1,2` (identifying the singular and plural message arguments).

---

The build system will automatically take care of building and installing the message catalogs.

## 51.2.2. Message-Writing Guidelines

Here are some guidelines for writing messages that are easily translatable.

- Do not construct sentences at run-time, like:

```
printf("Files were %s.\n", flag ? "copied" : "removed");
```

The word order within the sentence might be different in other languages. Also, even if you remember to call `gettext()` on each fragment, the fragments might not translate well separately. It's better to duplicate a little code so that each message to be translated is a coherent whole. Only numbers, file names, and such-like run-time variables should be inserted at run time into a message text.

- For similar reasons, this won't work:

```
printf("copied %d file%s", n, n!=1 ? "s" : "");
```

because it assumes how the plural is formed. If you figured you could solve it like this:

```
if (n==1)
    printf("copied 1 file");
else
    printf("copied %d files", n);
```

then be disappointed. Some languages have more than two forms, with some peculiar rules. It's often best to design the message to avoid the issue altogether, for instance like this:

```
printf("number of copied files: %d", n);
```

If you really want to construct a properly pluralized message, there is support for this, but it's a bit awkward. When generating a primary or detail error message in `ereport()`, you can write something like this:

```
errmsg_plural("copied %d file",
             "copied %d files",
             n,
             n)
```

The first argument is the format string appropriate for English singular form, the second is the format string appropriate for English plural form, and the third is the integer control value that determines which plural form to use. Subsequent arguments are formatted per the format string as usual. (Normally, the pluralization control value will also be one of the values to be formatted, so it has to be written twice.) In English it only matters whether *n* is 1 or not 1, but in other languages there can be many different plural forms. The translator sees the two English forms as a group and has the opportunity to supply multiple substitute strings, with the appropriate one being selected based on the run-time value of *n*.

If you need to pluralize a message that isn't going directly to an `errmsg` or `errdetail` report, you have to use the underlying function `ngettext`. See the `gettext` documentation.

- If you want to communicate something to the translator, such as about how a message is intended to line up with other output, precede the occurrence of the string with a comment that starts with `translator`, e.g.:

`/* translator: This message is not what it seems to be. */`

These comments are copied to the message catalog files so that the translators can see them.

---

# Chapter 52. Writing a Procedural Language Handler

All calls to functions that are written in a language other than the current “version 1” interface for compiled languages (this includes functions in user-defined procedural languages and functions written in SQL) go through a *call handler* function for the specific language. It is the responsibility of the call handler to execute the function in a meaningful way, such as by interpreting the supplied source text. This chapter outlines how a new procedural language's call handler can be written.

The call handler for a procedural language is a “normal” function that must be written in a compiled language such as C, using the version-1 interface, and registered with LightDB as taking no arguments and returning the type `language_handler`. This special pseudo-type identifies the function as a call handler and prevents it from being called directly in SQL commands. For more details on C language calling conventions and dynamic loading, see Section 36.10.

The call handler is called in the same way as any other function: It receives a pointer to a `FunctionCallInfoBaseData` struct containing argument values and information about the called function, and it is expected to return a `Datum` result (and possibly set the `isnull` field of the `FunctionCallInfoBaseData` structure, if it wishes to return an SQL null result). The difference between a call handler and an ordinary callee function is that the `flinfo->fn_oid` field of the `FunctionCallInfoBaseData` structure will contain the OID of the actual function to be called, not of the call handler itself. The call handler must use this field to determine which function to execute. Also, the passed argument list has been set up according to the declaration of the target function, not of the call handler.

It's up to the call handler to fetch the entry of the function from the `pg_proc` system catalog and to analyze the argument and return types of the called function. The `AS` clause from the `CREATE FUNCTION` command for the function will be found in the `prosrc` column of the `pg_proc` row. This is commonly source text in the procedural language, but in theory it could be something else, such as a path name to a file, or anything else that tells the call handler what to do in detail.

Often, the same function is called many times per SQL statement. A call handler can avoid repeated lookups of information about the called function by using the `flinfo->fn_extra` field. This will initially be `NULL`, but can be set by the call handler to point at information about the called function. On subsequent calls, if `flinfo->fn_extra` is already non-`NULL` then it can be used and the information lookup step skipped. The call handler must make sure that `flinfo->fn_extra` is made to point at memory that will live at least until the end of the current query, since an `FmgrInfo` data structure could be kept that long. One way to do this is to allocate the extra data in the memory context specified by `flinfo->fn_mcxt`; such data will normally have the same lifespan as the `FmgrInfo` itself. But the handler could also choose to use a longer-lived memory context so that it can cache function definition information across queries.

When a procedural-language function is invoked as a trigger, no arguments are passed in the usual way, but the `FunctionCallInfoBaseData`'s `context` field points at a `TriggerData` structure, rather than being `NULL` as it is in a plain function call. A language handler should provide mechanisms for procedural-language functions to get at the trigger information.

This is a template for a procedural-language handler written in C:

```
#include "postgres.h"
#include "executor/spi.h"
#include "commands/trigger.h"
#include "fmgr.h"
#include "access/heapam.h"
#include "utils/syscache.h"
#include "catalog/pg_proc.h"
```

```
#include "catalog/pg_type.h"

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(plsample_call_handler);

Datum
plsample_call_handler(PG_FUNCTION_ARGS)
{
    Datum          retval;

    if (CALLED_AS_TRIGGER(fcinfo))
    {
        /*
         * Called as a trigger function
         */
        TriggerData *trigdata = (TriggerData *) fcinfo->context;

        retval = ...
    }
    else
    {
        /*
         * Called as a function
         */

        retval = ...
    }

    return retval;
}
```

Only a few thousand lines of code have to be added instead of the dots to complete the call handler.

After having compiled the handler function into a loadable module (see Section 36.10.5), the following commands then register the sample procedural language:

```
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
AS 'filename'
LANGUAGE C;
CREATE LANGUAGE plsample
HANDLER plsample_call_handler;
```

Although providing a call handler is sufficient to create a minimal procedural language, there are two other functions that can optionally be provided to make the language more convenient to use. These are a *validator* and an *inline handler*. A validator can be provided to allow language-specific checking to be done during CREATE FUNCTION. An inline handler can be provided to allow the language to support anonymous code blocks executed via the DO command.

If a validator is provided by a procedural language, it must be declared as a function taking a single parameter of type `oid`. The validator's result is ignored, so it is customarily declared to return `void`. The validator will be called at the end of a CREATE FUNCTION command that has created or updated a function written in the procedural language. The passed-in OID is the OID of the function's `pg_proc` row. The validator must fetch this row in the usual way, and do whatever checking is appropriate. First, call `CheckFunctionValidatorAccess()` to diagnose explicit calls to the validator that the user could not achieve through CREATE FUNCTION. Typical checks then include verifying that the function's argument and result types are supported by the language, and that the function's body is syntactically correct in the language. If the validator finds the function to be okay, it

should just return. If it finds an error, it should report that via the normal `ereport ( )` error reporting mechanism. Throwing an error will force a transaction rollback and thus prevent the incorrect function definition from being committed.

Validator functions should typically honor the `check_function_bodies` parameter: if it is turned off then any expensive or context-sensitive checking should be skipped. If the language provides for code execution at compilation time, the validator must suppress checks that would induce such execution. In particular, this parameter is turned off by `lt_dump` so that it can load procedural language functions without worrying about side effects or dependencies of the function bodies on other database objects. (Because of this requirement, the call handler should avoid assuming that the validator has fully checked the function. The point of having a validator is not to let the call handler omit checks, but to notify the user immediately if there are obvious errors in a `CREATE FUNCTION` command.) While the choice of exactly what to check is mostly left to the discretion of the validator function, note that the core `CREATE FUNCTION` code only executes `SET` clauses attached to a function when `check_function_bodies` is on. Therefore, checks whose results might be affected by GUC parameters definitely should be skipped when `check_function_bodies` is off, to avoid false failures when restoring a dump.

If an inline handler is provided by a procedural language, it must be declared as a function taking a single parameter of type `internal`. The inline handler's result is ignored, so it is customarily declared to return `void`. The inline handler will be called when a `DO` statement is executed specifying the procedural language. The parameter actually passed is a pointer to an `InlineCodeBlock` struct, which contains information about the `DO` statement's parameters, in particular the text of the anonymous code block to be executed. The inline handler should execute this code and return.

It's recommended that you wrap all these function declarations, as well as the `CREATE LANGUAGE` command itself, into an *extension* so that a simple `CREATE EXTENSION` command is sufficient to install the language. See Section 36.17 for information about writing extensions.

The procedural languages included in the standard distribution are good references when trying to write your own language handler. Look into the `src/pl` subdirectory of the source tree. The `CREATE LANGUAGE` reference page also has some useful details.

---

# Chapter 53. Writing a Foreign Data Wrapper

All operations on a foreign table are handled through its foreign data wrapper, which consists of a set of functions that the core server calls. The foreign data wrapper is responsible for fetching data from the remote data source and returning it to the LightDB executor. If updating foreign tables is to be supported, the wrapper must handle that, too. This chapter outlines how to write a new foreign data wrapper.

The foreign data wrappers included in the standard distribution are good references when trying to write your own. Look into the `contrib` subdirectory of the source tree. The `CREATE FOREIGN DATA WRAPPER` reference page also has some useful details.

## Note

The SQL standard specifies an interface for writing foreign data wrappers. However, LightDB does not implement that API, because the effort to accommodate it into LightDB would be large, and the standard API hasn't gained wide adoption anyway.

## 53.1. Foreign Data Wrapper Functions

The FDW author needs to implement a handler function, and optionally a validator function. Both functions must be written in a compiled language such as C, using the version-1 interface. For details on C language calling conventions and dynamic loading, see Section 36.10.

The handler function simply returns a struct of function pointers to callback functions that will be called by the planner, executor, and various maintenance commands. Most of the effort in writing an FDW is in implementing these callback functions. The handler function must be registered with LightDB as taking no arguments and returning the special pseudo-type `fdw_handler`. The callback functions are plain C functions and are not visible or callable at the SQL level. The callback functions are described in Section 53.2.

The validator function is responsible for validating options given in `CREATE` and `ALTER` commands for its foreign data wrapper, as well as foreign servers, user mappings, and foreign tables using the wrapper. The validator function must be registered as taking two arguments, a text array containing the options to be validated, and an OID representing the type of object the options are associated with (in the form of the OID of the system catalog the object would be stored in, either `ForeignDataWrapperRelationId`, `ForeignServerRelationId`, `UserMappingRelationId`, or `ForeignTableRelationId`). If no validator function is supplied, options are not checked at object creation time or object alteration time.

## 53.2. Foreign Data Wrapper Callback Routines

The FDW handler function returns a palloc'd `FdwRoutine` struct containing pointers to the callback functions described below. The scan-related functions are required, the rest are optional.

The `FdwRoutine` struct type is declared in `src/include/foreign/fdwapi.h`, which see for additional details.

### 53.2.1. FDW Routines for Scanning Foreign Tables

```
void
GetForeignRelSize(PlannerInfo *root,
                 RelOptInfo *baserel,
                 Oid foreigntableid);
```

Obtain relation size estimates for a foreign table. This is called at the beginning of planning for a query that scans a foreign table. `root` is the planner's global information about the query; `baserel` is the planner's information about this table; and `foreigntableid` is the `pg_class` OID of the foreign table. (`foreigntableid` could be obtained from the planner data structures, but it's passed explicitly to save effort.)

This function should update `baserel->rows` to be the expected number of rows returned by the table scan, after accounting for the filtering done by the restriction quals. The initial value of `baserel->rows` is just a constant default estimate, which should be replaced if at all possible. The function may also choose to update `baserel->width` if it can compute a better estimate of the average result row width. (The initial value is based on column data types and on column average-width values measured by the last `ANALYZE`.) Also, this function may update `baserel->tuples` if it can compute a better estimate of the foreign table's total row count. (The initial value is from `pg_class.reltuples` which represents the total row count seen by the last `ANALYZE`.)

See Section 53.4 for additional information.

```
void
GetForeignPaths(PlannerInfo *root,
               RelOptInfo *baserel,
               Oid foreigntableid);
```

Create possible access paths for a scan on a foreign table. This is called during query planning. The parameters are the same as for `GetForeignRelSize`, which has already been called.

This function must generate at least one access path (`ForeignPath` node) for a scan on the foreign table and must call `add_path` to add each such path to `baserel->pathlist`. It's recommended to use `create_foreignscan_path` to build the `ForeignPath` nodes. The function can generate multiple access paths, e.g., a path which has valid `pathkeys` to represent a pre-sorted result. Each access path must contain cost estimates, and can contain any FDW-private information that is needed to identify the specific scan method intended.

See Section 53.4 for additional information.

```
ForeignScan *
GetForeignPlan(PlannerInfo *root,
              RelOptInfo *baserel,
              Oid foreigntableid,
              ForeignPath *best_path,
              List *tlist,
              List *scan_clauses,
              Plan *outer_plan);
```

Create a `ForeignScan` plan node from the selected foreign access path. This is called at the end of query planning. The parameters are as for `GetForeignRelSize`, plus the selected `ForeignPath` (previously produced by `GetForeignPaths`, `GetForeignJoinPaths`, or `GetForeignUpperPaths`), the target list to be emitted by the plan node, the restriction clauses to be enforced by the plan node, and the outer subplan of the `ForeignScan`, which is used for rechecks performed by `RecheckForeignScan`. (If the path is for a join rather than a base relation, `foreigntableid` is `InvalidOid`.)

This function must create and return a `ForeignScan` plan node; it's recommended to use `make_foreignscan` to build the `ForeignScan` node.



See Section 53.4 for additional information.

```
void
BeginForeignScan(ForeignScanState *node,
                 int eflags);
```

Begin executing a foreign scan. This is called during executor startup. It should perform any initialization needed before the scan can start, but not start executing the actual scan (that should be done upon the first call to `IterateForeignScan`). The `ForeignScanState` node has already been created, but its `fdw_state` field is still `NULL`. Information about the table to scan is accessible through the `ForeignScanState` node (in particular, from the underlying `ForeignScan` plan node, which contains any FDW-private information provided by `GetForeignPlan`). `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainForeignScan` and `EndForeignScan`.

```
TupleTableSlot *
IterateForeignScan(ForeignScanState *node);
```

Fetch one row from the foreign source, returning it in a tuple table slot (the node's `ScanTupleSlot` should be used for this purpose). Return `NULL` if no more rows are available. The tuple table slot infrastructure allows either a physical or virtual tuple to be returned; in most cases the latter choice is preferable from a performance standpoint. Note that this is called in a short-lived memory context that will be reset between invocations. Create a memory context in `BeginForeignScan` if you need longer-lived storage, or use the `es_query_cxt` of the node's `EState`.

The rows returned must match the `fdw_scan_tlist` target list if one was supplied, otherwise they must match the row type of the foreign table being scanned. If you choose to optimize away fetching columns that are not needed, you should insert nulls in those column positions, or else generate a `fdw_scan_tlist` list with those columns omitted.

Note that `LightDB`'s executor doesn't care whether the rows returned violate any constraints that were defined on the foreign table — but the planner does care, and may optimize queries incorrectly if there are rows visible in the foreign table that do not satisfy a declared constraint. If a constraint is violated when the user has declared that the constraint should hold true, it may be appropriate to raise an error (just as you would need to do in the case of a data type mismatch).

```
void
ReScanForeignScan(ForeignScanState *node);
```

Restart the scan from the beginning. Note that any parameters the scan depends on may have changed value, so the new scan does not necessarily return exactly the same rows.

```
void
EndForeignScan(ForeignScanState *node);
```

End the scan and release resources. It is normally not important to release `palloc'd` memory, but for example open files and connections to remote servers should be cleaned up.

## 53.2.2. FDW Routines for Scanning Foreign Joins

If an FDW supports performing foreign joins remotely (rather than by fetching both tables' data and doing the join locally), it should provide this callback function:

```
void
GetForeignJoinPaths(PlannerInfo *root,
                   RelOptInfo *joinrel,
                   RelOptInfo *outerrel,
                   RelOptInfo *innerrel,
                   JoinType jointype,
                   JoinPathExtraData *extra);
```

Create possible access paths for a join of two (or more) foreign tables that all belong to the same foreign server. This optional function is called during query planning. As with `GetForeignPaths`, this function should generate `ForeignPath` path(s) for the supplied `joinrel` (use `create_foreign_join_path` to build them), and call `add_path` to add these paths to the set of paths considered for the join. But unlike `GetForeignPaths`, it is not necessary that this function succeed in creating at least one path, since paths involving local joining are always possible.

Note that this function will be invoked repeatedly for the same join relation, with different combinations of inner and outer relations; it is the responsibility of the FDW to minimize duplicated work.

If a `ForeignPath` path is chosen for the join, it will represent the entire join process; paths generated for the component tables and subsidiary joins will not be used. Subsequent processing of the join path proceeds much as it does for a path scanning a single foreign table. One difference is that the `scanrelid` of the resulting `ForeignScan` plan node should be set to zero, since there is no single relation that it represents; instead, the `fs_relids` field of the `ForeignScan` node represents the set of relations that were joined. (The latter field is set up automatically by the core planner code, and need not be filled by the FDW.) Another difference is that, because the column list for a remote join cannot be found from the system catalogs, the FDW must fill `fdw_scan_tlist` with an appropriate list of `TargetEntry` nodes, representing the set of columns it will supply at run time in the tuples it returns.

See Section 53.4 for additional information.

### 53.2.3. FDW Routines for Planning Post-Scan/Join Processing

If an FDW supports performing remote post-scan/join processing, such as remote aggregation, it should provide this callback function:

```
void
GetForeignUpperPaths(PlannerInfo *root,
                    UpperRelationKind stage,
                    RelOptInfo *input_rel,
                    RelOptInfo *output_rel,
                    void *extra);
```

Create possible access paths for *upper relation* processing, which is the planner's term for all post-scan/join query processing, such as aggregation, window functions, sorting, and table updates. This optional function is called during query planning. Currently, it is called only if all base relation(s) involved in the query belong to the same FDW. This function should generate `ForeignPath` path(s) for any post-scan/join processing that the FDW knows how to perform remotely (use `create_foreign_upper_path` to build them), and call `add_path` to add these paths to the indicated upper relation. As with `GetForeignJoinPaths`, it is not necessary that this function succeed in creating any paths, since paths involving local processing are always possible.

The `stage` parameter identifies which post-scan/join step is currently being considered. `output_rel` is the upper relation that should receive paths representing computation of this

step, and `input_rel` is the relation representing the input to this step. The `extra` parameter provides additional details, currently, it is set only for `UPPERREL_PARTIAL_GROUP_AGG` or `UPPERREL_GROUP_AGG`, in which case it points to a `GroupPathExtraData` structure; or for `UPPERREL_FINAL`, in which case it points to a `FinalPathExtraData` structure. (Note that `ForeignPath` paths added to `output_rel` would typically not have any direct dependency on paths of the `input_rel`, since their processing is expected to be done externally. However, examining paths previously generated for the previous processing step can be useful to avoid redundant planning work.)

See Section 53.4 for additional information.

## 53.2.4. FDW Routines for Updating Foreign Tables

If an FDW supports writable foreign tables, it should provide some or all of the following callback functions depending on the needs and capabilities of the FDW:

```
void
AddForeignUpdateTargets(Query *parsetree,
                        RangeTblEntry *target_rte,
                        Relation target_relation);
```

UPDATE and DELETE operations are performed against rows previously fetched by the table-scanning functions. The FDW may need extra information, such as a row ID or the values of primary-key columns, to ensure that it can identify the exact row to update or delete. To support that, this function can add extra hidden, or “junk”, target columns to the list of columns that are to be retrieved from the foreign table during an UPDATE or DELETE.

To do that, add `TargetEntry` items to `parsetree->targetList`, containing expressions for the extra values to be fetched. Each such entry must be marked `resjunk = true`, and must have a distinct `resname` that will identify it at execution time. Avoid using names matching `ctidN`, `wholerow`, or `wholerowN`, as the core system can generate junk columns of these names. If the extra expressions are more complex than simple `Vars`, they must be run through `eval_const_expressions` before adding them to the target list.

Although this function is called during planning, the information provided is a bit different from that available to other planning routines. `parsetree` is the parse tree for the UPDATE or DELETE command, while `target_rte` and `target_relation` describe the target foreign table.

If the `AddForeignUpdateTargets` pointer is set to `NULL`, no extra target expressions are added. (This will make it impossible to implement DELETE operations, though UPDATE may still be feasible if the FDW relies on an unchanging primary key to identify rows.)

```
List *
PlanForeignModify(PlannerInfo *root,
                  ModifyTable *plan,
                  Index resultRelation,
                  int subplan_index);
```

Perform any additional planning actions needed for an insert, update, or delete on a foreign table. This function generates the FDW-private information that will be attached to the `ModifyTable` plan node that performs the update action. This private information must have the form of a `List`, and will be delivered to `BeginForeignModify` during the execution stage.

`root` is the planner's global information about the query. `plan` is the `ModifyTable` plan node, which is complete except for the `fdwPrivLists` field. `resultRelation` identifies the target foreign table by its range table index. `subplan_index` identifies which target of the `ModifyTable` plan node this is, counting from zero; use this if you want to index into `plan->plans` or other substructure of the plan node.

See Section 53.4 for additional information.

If the `PlanForeignModify` pointer is set to `NULL`, no additional plan-time actions are taken, and the `fdw_private` list delivered to `BeginForeignModify` will be `NIL`.

```
void
BeginForeignModify(ModifyTableState *mtstate,
                  ResultRelInfo *rinfo,
                  List *fdw_private,
                  int subplan_index,
                  int eflags);
```

Begin executing a foreign table modification operation. This routine is called during executor startup. It should perform any initialization needed prior to the actual table modifications. Subsequently, `ExecForeignInsert`, `ExecForeignUpdate` or `ExecForeignDelete` will be called for each tuple to be inserted, updated, or deleted.

`mtstate` is the overall state of the `ModifyTable` plan node being executed; global data about the plan and execution state is available via this structure. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. (The `ri_FdwState` field of `ResultRelInfo` is available for the FDW to store any private state it needs for this operation.) `fdw_private` contains the private data generated by `PlanForeignModify`, if any. `subplan_index` identifies which target of the `ModifyTable` plan node this is. `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainForeignModify` and `EndForeignModify`.

If the `BeginForeignModify` pointer is set to `NULL`, no action is taken during executor startup.

```
TupleTableSlot *
ExecForeignInsert(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);
```

Insert one tuple into the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains the tuple to be inserted; it will match the row-type definition of the foreign table. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; it differs from `slot` in possibly containing additional "junk" columns. (The `planSlot` is typically of little interest for `INSERT` cases, but is provided for completeness.)

The return value is either a slot containing the data that was actually inserted (this might differ from the data supplied, for example as a result of trigger actions), or `NULL` if no row was actually inserted (again, typically as a result of triggers). The passed-in `slot` can be re-used for this purpose.

The data in the returned slot is used only if the `INSERT` statement has a `RETURNING` clause or involves a view `WITH CHECK OPTION`; or if the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause or `WITH CHECK OPTION` constraints. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignInsert` pointer is set to `NULL`, attempts to insert into the foreign table will fail with an error message.

Note that this function is also called when inserting routed tuples into a foreign-table partition or executing `COPY FROM` on a foreign table, in which case it is called in a different way than it is in the `INSERT` case. See the callback functions described below that allow the FDW to support that.

```

TupleTableSlot *
ExecForeignUpdate(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);

```

Update one tuple in the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains the new data for the tuple; it will match the row-type definition of the foreign table. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; it differs from `slot` in possibly containing additional “junk” columns. In particular, any junk columns that were requested by `AddForeignUpdateTargets` will be available from this slot.

The return value is either a slot containing the row as it was actually updated (this might differ from the data supplied, for example as a result of trigger actions), or `NULL` if no row was actually updated (again, typically as a result of triggers). The passed-in `slot` can be re-used for this purpose.

The data in the returned slot is used only if the `UPDATE` statement has a `RETURNING` clause or involves a view `WITH CHECK OPTION`; or if the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause or `WITH CHECK OPTION` constraints. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignUpdate` pointer is set to `NULL`, attempts to update the foreign table will fail with an error message.

```

TupleTableSlot *
ExecForeignDelete(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);

```

Delete one tuple from the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains nothing useful upon call, but can be used to hold the returned tuple. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; in particular, it will carry any junk columns that were requested by `AddForeignUpdateTargets`. The junk column(s) must be used to identify the tuple to be deleted.

The return value is either a slot containing the row that was deleted, or `NULL` if no row was deleted (typically as a result of triggers). The passed-in `slot` can be used to hold the tuple to be returned.

The data in the returned slot is used only if the `DELETE` query has a `RETURNING` clause or the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignDelete` pointer is set to `NULL`, attempts to delete from the foreign table will fail with an error message.

```

void
EndForeignModify(EState *estate,

```

```
ResultRelInfo *rinfo);
```

End the table update and release resources. It is normally not important to release palloc'd memory, but for example open files and connections to remote servers should be cleaned up.

If the `EndForeignModify` pointer is set to `NULL`, no action is taken during executor shutdown.

Tuples inserted into a partitioned table by `INSERT` or `COPY FROM` are routed to partitions. If an FDW supports routable foreign-table partitions, it should also provide the following callback functions. These functions are also called when `COPY FROM` is executed on a foreign table.

```
void
BeginForeignInsert(ModifyTableState *mtstate,
                  ResultRelInfo *rinfo);
```

Begin executing an insert operation on a foreign table. This routine is called right before the first tuple is inserted into the foreign table in both cases when it is the partition chosen for tuple routing and the target specified in a `COPY FROM` command. It should perform any initialization needed prior to the actual insertion. Subsequently, `ExecForeignInsert` will be called for each tuple to be inserted into the foreign table.

`mtstate` is the overall state of the `ModifyTable` plan node being executed; global data about the plan and execution state is available via this structure. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. (The `ri_FdwState` field of `ResultRelInfo` is available for the FDW to store any private state it needs for this operation.)

When this is called by a `COPY FROM` command, the plan-related global data in `mtstate` is not provided and the `planSlot` parameter of `ExecForeignInsert` subsequently called for each inserted tuple is `NULL`, whether the foreign table is the partition chosen for tuple routing or the target specified in the command.

If the `BeginForeignInsert` pointer is set to `NULL`, no action is taken for the initialization.

Note that if the FDW does not support routable foreign-table partitions and/or executing `COPY FROM` on foreign tables, this function or `ExecForeignInsert` subsequently called must throw error as needed.

```
void
EndForeignInsert(EState *estate,
                ResultRelInfo *rinfo);
```

End the insert operation and release resources. It is normally not important to release palloc'd memory, but for example open files and connections to remote servers should be cleaned up.

If the `EndForeignInsert` pointer is set to `NULL`, no action is taken for the termination.

```
int
IsForeignRelUpdatable(Relation rel);
```

Report which update operations the specified foreign table supports. The return value should be a bit mask of rule event numbers indicating which operations are supported by the foreign table, using the `CmdType` enumeration; that is,  $(1 \ll \text{CMD\_UPDATE}) = 4$  for `UPDATE`,  $(1 \ll \text{CMD\_INSERT}) = 8$  for `INSERT`, and  $(1 \ll \text{CMD\_DELETE}) = 16$  for `DELETE`.

If the `IsForeignRelUpdatable` pointer is set to `NULL`, foreign tables are assumed to be insertable, updatable, or deletable if the FDW provides `ExecForeignInsert`, `ExecForeignUpdate`, or `ExecForeignDelete` respectively. This function is only needed if

the FDW supports some tables that are updatable and some that are not. (Even then, it's permissible to throw an error in the execution routine instead of checking in this function. However, this function is used to determine updatability for display in the `information_schema` views.)

Some inserts, updates, and deletes to foreign tables can be optimized by implementing an alternative set of interfaces. The ordinary interfaces for inserts, updates, and deletes fetch rows from the remote server and then modify those rows one at a time. In some cases, this row-by-row approach is necessary, but it can be inefficient. If it is possible for the foreign server to determine which rows should be modified without actually retrieving them, and if there are no local structures which would affect the operation (row-level local triggers, stored generated columns, or `WITH CHECK OPTION` constraints from parent views), then it is possible to arrange things so that the entire operation is performed on the remote server. The interfaces described below make this possible.

```
bool
PlanDirectModify(PlannerInfo *root,
                 ModifyTable *plan,
                 Index resultRelation,
                 int subplan_index);
```

Decide whether it is safe to execute a direct modification on the remote server. If so, return `true` after performing planning actions needed for that. Otherwise, return `false`. This optional function is called during query planning. If this function succeeds, `BeginDirectModify`, `IterateDirectModify` and `EndDirectModify` will be called at the execution stage, instead. Otherwise, the table modification will be executed using the table-updating functions described above. The parameters are the same as for `PlanForeignModify`.

To execute the direct modification on the remote server, this function must rewrite the target subplan with a `ForeignScan` plan node that executes the direct modification on the remote server. The `operation` field of the `ForeignScan` must be set to the `CmdType` enumeration appropriately; that is, `CMD_UPDATE` for `UPDATE`, `CMD_INSERT` for `INSERT`, and `CMD_DELETE` for `DELETE`.

See Section 53.4 for additional information.

If the `PlanDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

```
void
BeginDirectModify(ForeignScanState *node,
                 int eflags);
```

Prepare to execute a direct modification on the remote server. This is called during executor startup. It should perform any initialization needed prior to the direct modification (that should be done upon the first call to `IterateDirectModify`). The `ForeignScanState` node has already been created, but its `fdw_state` field is still `NULL`. Information about the table to modify is accessible through the `ForeignScanState` node (in particular, from the underlying `ForeignScan` plan node, which contains any FDW-private information provided by `PlanDirectModify`). `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainDirectModify` and `EndDirectModify`.

If the `BeginDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

```
TupleTableSlot *
IterateDirectModify(ForeignScanState *node);
```

When the INSERT, UPDATE or DELETE query doesn't have a RETURNING clause, just return NULL after a direct modification on the remote server. When the query has the clause, fetch one result containing the data needed for the RETURNING calculation, returning it in a tuple table slot (the node's ScanTupleSlot should be used for this purpose). The data that was actually inserted, updated or deleted must be stored in the `es_result_relation_info->ri_projectReturning->pi_exprContext->ecxt_scantuple` of the node's EState. Return NULL if no more rows are available. Note that this is called in a short-lived memory context that will be reset between invocations. Create a memory context in `BeginDirectModify` if you need longer-lived storage, or use the `es_query_cxt` of the node's EState.

The rows returned must match the `fdw_scan_tlist` target list if one was supplied, otherwise they must match the row type of the foreign table being updated. If you choose to optimize away fetching columns that are not needed for the RETURNING calculation, you should insert nulls in those column positions, or else generate a `fdw_scan_tlist` list with those columns omitted.

Whether the query has the clause or not, the query's reported row count must be incremented by the FDW itself. When the query doesn't have the clause, the FDW must also increment the row count for the `ForeignScanState` node in the EXPLAIN ANALYZE case.

If the `IteratedDirectModify` pointer is set to NULL, no attempts to execute a direct modification on the remote server are taken.

```
void
EndDirectModify(ForeignScanState *node);
```

Clean up following a direct modification on the remote server. It is normally not important to release `malloc'd` memory, but for example open files and connections to the remote server should be cleaned up.

If the `EndDirectModify` pointer is set to NULL, no attempts to execute a direct modification on the remote server are taken.

## 53.2.5. FDW Routines for Row Locking

If an FDW wishes to support *late row locking* (as described in Section 53.5), it must provide the following callback functions:

```
RowMarkType
GetForeignRowMarkType(RangeTblEntry *rte,
                      LockClauseStrength strength);
```

Report which row-marking option to use for a foreign table. `rte` is the `RangeTblEntry` node for the table and `strength` describes the lock strength requested by the relevant FOR UPDATE/SHARE clause, if any. The result must be a member of the `RowMarkType` enum type.

This function is called during query planning for each foreign table that appears in an UPDATE, DELETE, or SELECT FOR UPDATE/SHARE query and is not the target of UPDATE or DELETE.

If the `GetForeignRowMarkType` pointer is set to NULL, the `ROW_MARK_COPY` option is always used. (This implies that `RefetchForeignRow` will never be called, so it need not be provided either.)

See Section 53.5 for more information.

```
void
RefetchForeignRow(EState *estate,
                  ExecRowMark *erm,
                  Datum rowid,
```



```

TupleTableSlot *slot,
bool *updated);

```

Re-fetch one tuple slot from the foreign table, after locking it if required. `estate` is global execution state for the query. `erm` is the `ExecRowMark` struct describing the target foreign table and the row lock type (if any) to acquire. `rowid` identifies the tuple to be fetched. `slot` contains nothing useful upon call, but can be used to hold the returned tuple. `updated` is an output parameter.

This function should store the tuple into the provided slot, or clear it if the row lock couldn't be obtained. The row lock type to acquire is defined by `erm->markType`, which is the value previously returned by `GetForeignRowMarkType`. (`ROW_MARK_REFERENCE` means to just re-fetch the tuple without acquiring any lock, and `ROW_MARK_COPY` will never be seen by this routine.)

In addition, `*updated` should be set to `true` if what was fetched was an updated version of the tuple rather than the same version previously obtained. (If the FDW cannot be sure about this, always returning `true` is recommended.)

Note that by default, failure to acquire a row lock should result in raising an error; returning with an empty slot is only appropriate if the `SKIP_LOCKED` option is specified by `erm->waitPolicy`.

The `rowid` is the `ctid` value previously read for the row to be re-fetched. Although the `rowid` value is passed as a `Datum`, it can currently only be a `tid`. The function API is chosen in hopes that it may be possible to allow other data types for row IDs in future.

If the `RefetchForeignRow` pointer is set to `NULL`, attempts to re-fetch rows will fail with an error message.

See Section 53.5 for more information.

```

bool
RecheckForeignScan(ForeignScanState *node,
                  TupleTableSlot *slot);

```

Recheck that a previously-returned tuple still matches the relevant scan and join qualifiers, and possibly provide a modified version of the tuple. For foreign data wrappers which do not perform join pushdown, it will typically be more convenient to set this to `NULL` and instead set `fdw_recheck_qual` appropriately. When outer joins are pushed down, however, it isn't sufficient to reapply the checks relevant to all the base tables to the result tuple, even if all needed attributes are present, because failure to match some qualifier might result in some attributes going to `NULL`, rather than in no tuple being returned. `RecheckForeignScan` can recheck qualifiers and return `true` if they are still satisfied and `false` otherwise, but it can also store a replacement tuple into the supplied slot.

To implement join pushdown, a foreign data wrapper will typically construct an alternative local join plan which is used only for rechecks; this will become the outer subplan of the `ForeignScan`. When a recheck is required, this subplan can be executed and the resulting tuple can be stored in the slot. This plan need not be efficient since no base table will return more than one row; for example, it may implement all joins as nested loops. The function `GetExistingLocalJoinPath` may be used to search existing paths for a suitable local join path, which can be used as the alternative local join plan. `GetExistingLocalJoinPath` searches for an unparameterized path in the path list of the specified join relation. (If it does not find such a path, it returns `NULL`, in which case a foreign data wrapper may build the local path by itself or may choose not to create access paths for that join.)

## 53.2.6. FDW Routines for EXPLAIN

```

void
ExplainForeignScan(ForeignScanState *node,
                  ExplainState *es);

```

Print additional `EXPLAIN` output for a foreign table scan. This function can call `ExplainPropertyText` and related functions to add fields to the `EXPLAIN` output. The flag fields in `es` can be used to determine what to print, and the state of the `ForeignScanState` node can be inspected to provide run-time statistics in the `EXPLAIN ANALYZE` case.

If the `ExplainForeignScan` pointer is set to `NULL`, no additional information is printed during `EXPLAIN`.

```
void
ExplainForeignModify(ModifyTableState *mtstate,
                    ResultRelInfo *rinfo,
                    List *fdw_private,
                    int subplan_index,
                    struct ExplainState *es);
```

Print additional `EXPLAIN` output for a foreign table update. This function can call `ExplainPropertyText` and related functions to add fields to the `EXPLAIN` output. The flag fields in `es` can be used to determine what to print, and the state of the `ModifyTableState` node can be inspected to provide run-time statistics in the `EXPLAIN ANALYZE` case. The first four arguments are the same as for `BeginForeignModify`.

If the `ExplainForeignModify` pointer is set to `NULL`, no additional information is printed during `EXPLAIN`.

```
void
ExplainDirectModify(ForeignScanState *node,
                   ExplainState *es);
```

Print additional `EXPLAIN` output for a direct modification on the remote server. This function can call `ExplainPropertyText` and related functions to add fields to the `EXPLAIN` output. The flag fields in `es` can be used to determine what to print, and the state of the `ForeignScanState` node can be inspected to provide run-time statistics in the `EXPLAIN ANALYZE` case.

If the `ExplainDirectModify` pointer is set to `NULL`, no additional information is printed during `EXPLAIN`.

## 53.2.7. FDW Routines for ANALYZE

```
bool
AnalyzeForeignTable(Relation relation,
                   AcquireSampleRowsFunc *func,
                   BlockNumber *totalpages);
```

This function is called when `ANALYZE` is executed on a foreign table. If the FDW can collect statistics for this foreign table, it should return `true`, and provide a pointer to a function that will collect sample rows from the table in `func`, plus the estimated size of the table in pages in `totalpages`. Otherwise, return `false`.

If the FDW does not support collecting statistics for any tables, the `AnalyzeForeignTable` pointer can be set to `NULL`.

If provided, the sample collection function must have the signature

```
int
AcquireSampleRowsFunc(Relation relation,
                     int elevel,
```

```

HeapTuple *rows,
int targrows,
double *totalrows,
double *totaldeadrows);

```

A random sample of up to *targrows* rows should be collected from the table and stored into the caller-provided *rows* array. The actual number of rows collected must be returned. In addition, store estimates of the total numbers of live and dead rows in the table into the output parameters *totalrows* and *totaldeadrows*. (Set *totaldeadrows* to zero if the FDW does not have any concept of dead rows.)

## 53.2.8. FDW Routines for IMPORT FOREIGN SCHEMA

```

List *
ImportForeignSchema(ImportForeignSchemaStmt *stmt, Oid serverOid);

```

Obtain a list of foreign table creation commands. This function is called when executing IMPORT FOREIGN SCHEMA, and is passed the parse tree for that statement, as well as the OID of the foreign server to use. It should return a list of C strings, each of which must contain a CREATE FOREIGN TABLE command. These strings will be parsed and executed by the core server.

Within the ImportForeignSchemaStmt struct, *remote\_schema* is the name of the remote schema from which tables are to be imported. *list\_type* identifies how to filter table names: FDW\_IMPORT\_SCHEMA\_ALL means that all tables in the remote schema should be imported (in this case *table\_list* is empty), FDW\_IMPORT\_SCHEMA\_LIMIT\_TO means to include only tables listed in *table\_list*, and FDW\_IMPORT\_SCHEMA\_EXCEPT means to exclude the tables listed in *table\_list*. *options* is a list of options used for the import process. The meanings of the options are up to the FDW. For example, an FDW could use an option to define whether the NOT NULL attributes of columns should be imported. These options need not have anything to do with those supported by the FDW as database object options.

The FDW may ignore the *local\_schema* field of the ImportForeignSchemaStmt, because the core server will automatically insert that name into the parsed CREATE FOREIGN TABLE commands.

The FDW does not have to concern itself with implementing the filtering specified by *list\_type* and *table\_list*, either, as the core server will automatically skip any returned commands for tables excluded according to those options. However, it's often useful to avoid the work of creating commands for excluded tables in the first place. The function *IsImportableForeignTable()* may be useful to test whether a given foreign-table name will pass the filter.

If the FDW does not support importing table definitions, the *ImportForeignSchema* pointer can be set to NULL.

## 53.2.9. FDW Routines for Parallel Execution

A *ForeignScan* node can, optionally, support parallel execution. A parallel *ForeignScan* will be executed in multiple processes and must return each row exactly once across all cooperating processes. To do this, processes can coordinate through fixed-size chunks of dynamic shared memory. This shared memory is not guaranteed to be mapped at the same address in every process, so it must not contain pointers. The following functions are all optional, but most are required if parallel execution is to be supported.

```

bool
IsForeignScanParallelSafe(PlannerInfo *root, RelOptInfo *rel,
                          RangeTblEntry *rte);

```

Test whether a scan can be performed within a parallel worker. This function will only be called when the planner believes that a parallel plan might be possible, and should return true if it is safe for that scan to run within a parallel worker. This will generally not be the case if the remote data source has transaction semantics, unless the worker's connection to the data can somehow be made to share the same transaction context as the leader.

If this function is not defined, it is assumed that the scan must take place within the parallel leader. Note that returning true does not mean that the scan itself can be done in parallel, only that the scan can be performed within a parallel worker. Therefore, it can be useful to define this method even when parallel execution is not supported.

Size

```
EstimateDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt);
```

Estimate the amount of dynamic shared memory that will be required for parallel operation. This may be higher than the amount that will actually be used, but it must not be lower. The return value is in bytes. This function is optional, and can be omitted if not needed; but if it is omitted, the next three functions must be omitted as well, because no shared memory will be allocated for the FDW's use.

```
void
InitializeDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt,
                        void *coordinate);
```

Initialize the dynamic shared memory that will be required for parallel operation. `coordinate` points to a shared memory area of size equal to the return value of `EstimateDSMForeignScan`. This function is optional, and can be omitted if not needed.

```
void
ReInitializeDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt,
                        void *coordinate);
```

Re-initialize the dynamic shared memory required for parallel operation when the foreign-scan plan node is about to be re-scanned. This function is optional, and can be omitted if not needed. Recommended practice is that this function reset only shared state, while the `ReScanForeignScan` function resets only local state. Currently, this function will be called before `ReScanForeignScan`, but it's best not to rely on that ordering.

```
void
InitializeWorkerForeignScan(ForeignScanState *node, shm_toc *toc,
    void *coordinate);
```

Initialize a parallel worker's local state based on the shared state set up by the leader during `InitializeDSMForeignScan`. This function is optional, and can be omitted if not needed.

```
void
ShutdownForeignScan(ForeignScanState *node);
```

Release resources when it is anticipated the node will not be executed to completion. This is not called in all cases; sometimes, `EndForeignScan` may be called without this function having been called first. Since the DSM segment used by parallel query is destroyed just after this callback is invoked, foreign data wrappers that wish to take some action before the DSM segment goes away should implement this method.

## 53.2.10. FDW Routines for Reparameterization of Paths

```
List *
ReparameterizeForeignPathByChild(PlannerInfo *root, List
    *fdw_private,
                                RelOptInfo *child_rel);
```

This function is called while converting a path parameterized by the top-most parent of the given child relation `child_rel` to be parameterized by the child relation. The function is used to reparameterize any paths or translate any expression nodes saved in the given `fdw_private` member of a `ForeignPath`. The callback may use `reparameterize_path_by_child`, `adjust_appendrel_attrs` or `adjust_appendrel_attrs_multilevel` as required.

## 53.3. Foreign Data Wrapper Helper Functions

Several helper functions are exported from the core server so that authors of foreign data wrappers can get easy access to attributes of FDW-related objects, such as FDW options. To use any of these functions, you need to include the header file `foreign/foreign.h` in your source file. That header also defines the struct types that are returned by these functions.

```
ForeignDataWrapper *
GetForeignDataWrapperExtended(Oid fdwid, bits16 flags);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given OID. A `ForeignDataWrapper` object contains properties of the FDW (see `foreign/foreign.h` for details). `flags` is a bitwise-or'd bit mask indicating an extra set of options. It can take the value `FDW_MISSING_OK`, in which case a NULL result is returned to the caller instead of an error for an undefined object.

```
ForeignDataWrapper *
GetForeignDataWrapper(Oid fdwid);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given OID. A `ForeignDataWrapper` object contains properties of the FDW (see `foreign/foreign.h` for details).

```
ForeignServer *
GetForeignServerExtended(Oid serverid, bits16 flags);
```

This function returns a `ForeignServer` object for the foreign server with the given OID. A `ForeignServer` object contains properties of the server (see `foreign/foreign.h` for details). `flags` is a bitwise-or'd bit mask indicating an extra set of options. It can take the value `FSV_MISSING_OK`, in which case a NULL result is returned to the caller instead of an error for an undefined object.

```
ForeignServer *
GetForeignServer(Oid serverid);
```

This function returns a `ForeignServer` object for the foreign server with the given OID. A `ForeignServer` object contains properties of the server (see `foreign/foreign.h` for details).

```
UserMapping *
GetUserMapping(Oid userid, Oid serverid);
```

This function returns a `UserMapping` object for the user mapping of the given role on the given server. (If there is no mapping for the specific user, it will return the mapping for `PUBLIC`, or throw error if there is none.) A `UserMapping` object contains properties of the user mapping (see `foreign/foreign.h` for details).

```
ForeignTable *  
GetForeignTable(Oid relid);
```

This function returns a `ForeignTable` object for the foreign table with the given OID. A `ForeignTable` object contains properties of the foreign table (see `foreign/foreign.h` for details).

```
List *  
GetForeignColumnOptions(Oid relid, AttrNumber attnum);
```

This function returns the per-column FDW options for the column with the given foreign table OID and attribute number, in the form of a list of `DefElem`. `NIL` is returned if the column has no options.

Some object types have name-based lookup functions in addition to the OID-based ones:

```
ForeignDataWrapper *  
GetForeignDataWrapperByName(const char *name, bool missing_ok);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given name. If the wrapper is not found, return `NULL` if `missing_ok` is true, otherwise raise an error.

```
ForeignServer *  
GetForeignServerByName(const char *name, bool missing_ok);
```

This function returns a `ForeignServer` object for the foreign server with the given name. If the server is not found, return `NULL` if `missing_ok` is true, otherwise raise an error.

## 53.4. Foreign Data Wrapper Query Planning

The FDW callback functions `GetForeignRelSize`, `GetForeignPaths`, `GetForeignPlan`, `PlanForeignModify`, `GetForeignJoinPaths`, `GetForeignUpperPaths`, and `PlanDirectModify` must fit into the workings of the `LightDB` planner. Here are some notes about what they must do.

The information in `root` and `baserel` can be used to reduce the amount of information that has to be fetched from the foreign table (and therefore reduce the cost). `baserel->baserestrictinfo` is particularly interesting, as it contains restriction quals (`WHERE` clauses) that should be used to filter the rows to be fetched. (The FDW itself is not required to enforce these quals, as the core executor can check them instead.) `baserel->reltarget->exprs` can be used to determine which columns need to be fetched; but note that it only lists columns that have to be emitted by the `ForeignScan` plan node, not columns that are used in qual evaluation but not output by the query.

Various private fields are available for the FDW planning functions to keep information in. Generally, whatever you store in FDW private fields should be `palloc'd`, so that it will be reclaimed at the end of planning.

`baserel->fdw_private` is a `void` pointer that is available for FDW planning functions to store information relevant to the particular foreign table. The core planner does not touch it except to initialize it to `NULL` when the `RelOptInfo` node is created. It is useful for passing information forward from `GetForeignRelSize` to `GetForeignPaths` and/or `GetForeignPlan`, thereby avoiding recalculation.

`GetForeignPaths` can identify the meaning of different access paths by storing private information in the `fdw_private` field of `ForeignPath` nodes. `fdw_private` is declared as a `List` pointer, but could actually contain anything since the core planner does not touch it. However, best practice is to use a representation that's dumpable by `nodeToString`, for use with debugging support available in the backend.

`GetForeignPlan` can examine the `fdw_private` field of the selected `ForeignPath` node, and can generate `fdw_exprs` and `fdw_private` lists to be placed in the `ForeignScan` plan node, where they will be available at execution time. Both of these lists must be represented in a form that `copyObject` knows how to copy. The `fdw_private` list has no other restrictions and is not interpreted by the core backend in any way. The `fdw_exprs` list, if not `NIL`, is expected to contain expression trees that are intended to be executed at run time. These trees will undergo post-processing by the planner to make them fully executable.

In `GetForeignPlan`, generally the passed-in target list can be copied into the plan node as-is. The passed `scan_clauses` list contains the same clauses as `baserel->baserestrictinfo`, but may be re-ordered for better execution efficiency. In simple cases the FDW can just strip `RestrictInfo` nodes from the `scan_clauses` list (using `extract_actual_clauses`) and put all the clauses into the plan node's qual list, which means that all the clauses will be checked by the executor at run time. More complex FDWs may be able to check some of the clauses internally, in which case those clauses can be removed from the plan node's qual list so that the executor doesn't waste time rechecking them.

As an example, the FDW might identify some restriction clauses of the form *foreign\_variable = sub\_expression*, which it determines can be executed on the remote server given the locally-evaluated value of the *sub\_expression*. The actual identification of such a clause should happen during `GetForeignPaths`, since it would affect the cost estimate for the path. The path's `fdw_private` field would probably include a pointer to the identified clause's `RestrictInfo` node. Then `GetForeignPlan` would remove that clause from `scan_clauses`, but add the *sub\_expression* to `fdw_exprs` to ensure that it gets massaged into executable form. It would probably also put control information into the plan node's `fdw_private` field to tell the execution functions what to do at run time. The query transmitted to the remote server would involve something like `WHERE foreign_variable = $1`, with the parameter value obtained at run time from evaluation of the `fdw_exprs` expression tree.

Any clauses removed from the plan node's qual list must instead be added to `fdw_recheckquals` or rechecked by `RecheckForeignScan` in order to ensure correct behavior at the `READ COMMITTED` isolation level. When a concurrent update occurs for some other table involved in the query, the executor may need to verify that all of the original quals are still satisfied for the tuple, possibly against a different set of parameter values. Using `fdw_recheckquals` is typically easier than implementing checks inside `RecheckForeignScan`, but this method will be insufficient when outer joins have been pushed down, since the join tuples in that case might have some fields go to `NULL` without rejecting the tuple entirely.

Another `ForeignScan` field that can be filled by FDWs is `fdw_scan_tlist`, which describes the tuples returned by the FDW for this plan node. For simple foreign table scans this can be set to `NIL`, implying that the returned tuples have the row type declared for the foreign table. A non-`NIL` value must be a target list (list of `TargetEntry`s) containing `Vars` and/or expressions representing the returned columns. This might be used, for example, to show that the FDW has omitted some columns that it noticed won't be needed for the query. Also, if the FDW can compute expressions used by the query more cheaply than can be done locally, it could add those expressions to `fdw_scan_tlist`. Note that join plans (created from paths made by `GetForeignJoinPaths`) must always supply `fdw_scan_tlist` to describe the set of columns they will return.

The FDW should always construct at least one path that depends only on the table's restriction clauses. In join queries, it might also choose to construct path(s) that depend on join clauses, for example *foreign\_variable = local\_variable*. Such clauses will not be found in `baserel->baserestrictinfo` but must be sought in the relation's join lists. A path using such a clause is called a "parameterized path". It must identify the other relations used in the selected join clause(s)

with a suitable value of `param_info`; use `get_baserel_parampathinfo` to compute that value. In `GetForeignPlan`, the `local_variable` portion of the join clause would be added to `fdw_exprs`, and then at run time the case works the same as for an ordinary restriction clause.

If an FDW supports remote joins, `GetForeignJoinPaths` should produce `ForeignPaths` for potential remote joins in much the same way as `GetForeignPaths` works for base tables. Information about the intended join can be passed forward to `GetForeignPlan` in the same ways described above. However, `baserestrictinfo` is not relevant for join relations; instead, the relevant join clauses for a particular join are passed to `GetForeignJoinPaths` as a separate parameter (`extra->restrictlist`).

An FDW might additionally support direct execution of some plan actions that are above the level of scans and joins, such as grouping or aggregation. To offer such options, the FDW should generate paths and insert them into the appropriate *upper relation*. For example, a path representing remote aggregation should be inserted into the `UPPERREL_GROUP_AGG` relation, using `add_path`. This path will be compared on a cost basis with local aggregation performed by reading a simple scan path for the foreign relation (note that such a path must also be supplied, else there will be an error at plan time). If the remote-aggregation path wins, which it usually would, it will be converted into a plan in the usual way, by calling `GetForeignPlan`. The recommended place to generate such paths is in the `GetForeignUpperPaths` callback function, which is called for each upper relation (i.e., each post-scan/join processing step), if all the base relations of the query come from the same FDW.

`PlanForeignModify` and the other callbacks described in Section 53.2.4 are designed around the assumption that the foreign relation will be scanned in the usual way and then individual row updates will be driven by a local `ModifyTable` plan node. This approach is necessary for the general case where an update requires reading local tables as well as foreign tables. However, if the operation could be executed entirely by the foreign server, the FDW could generate a path representing that and insert it into the `UPPERREL_FINAL` upper relation, where it would compete against the `ModifyTable` approach. This approach could also be used to implement remote `SELECT FOR UPDATE`, rather than using the row locking callbacks described in Section 53.2.5. Keep in mind that a path inserted into `UPPERREL_FINAL` is responsible for implementing *all* behavior of the query.

When planning an `UPDATE` or `DELETE`, `PlanForeignModify` and `PlanDirectModify` can look up the `RelOptInfo` struct for the foreign table and make use of the `baserel->fdw_private` data previously created by the scan-planning functions. However, in `INSERT` the target table is not scanned so there is no `RelOptInfo` for it. The `List` returned by `PlanForeignModify` has the same restrictions as the `fdw_private` list of a `ForeignScan` plan node, that is it must contain only structures that `copyObject` knows how to copy.

`INSERT` with an `ON CONFLICT` clause does not support specifying the conflict target, as unique constraints or exclusion constraints on remote tables are not locally known. This in turn implies that `ON CONFLICT DO UPDATE` is not supported, since the specification is mandatory there.

## 53.5. Row Locking in Foreign Data Wrappers

If an FDW's underlying storage mechanism has a concept of locking individual rows to prevent concurrent updates of those rows, it is usually worthwhile for the FDW to perform row-level locking with as close an approximation as practical to the semantics used in ordinary LightDB tables. There are multiple considerations involved in this.

One key decision to be made is whether to perform *early locking* or *late locking*. In early locking, a row is locked when it is first retrieved from the underlying store, while in late locking, the row is locked only when it is known that it needs to be locked. (The difference arises because some rows may be discarded by locally-checked restriction or join conditions.) Early locking is much simpler and avoids extra round trips to a remote store, but it can cause locking of rows that need not have been locked, resulting in reduced concurrency or even unexpected deadlocks. Also, late locking is only possible if the row to be locked can be uniquely re-identified later. Preferably the row identifier should identify a specific version of the row, as LightDB TIDs do.



By default, LightDB ignores locking considerations when interfacing to FDWs, but an FDW can perform early locking without any explicit support from the core code. The API functions described in Section 53.2.5, which were added in LightDB 9.5, allow an FDW to use late locking if it wishes.

An additional consideration is that in `READ COMMITTED` isolation mode, LightDB may need to re-check restriction and join conditions against an updated version of some target tuple. Rechecking join conditions requires re-obtaining copies of the non-target rows that were previously joined to the target tuple. When working with standard LightDB tables, this is done by including the TIDs of the non-target tables in the column list projected through the join, and then re-fetching non-target rows when required. This approach keeps the join data set compact, but it requires inexpensive re-fetch capability, as well as a TID that can uniquely identify the row version to be re-fetched. By default, therefore, the approach used with foreign tables is to include a copy of the entire row fetched from a foreign table in the column list projected through the join. This puts no special demands on the FDW but can result in reduced performance of merge and hash joins. An FDW that is capable of meeting the re-fetch requirements can choose to do it the first way.

For an `UPDATE` or `DELETE` on a foreign table, it is recommended that the `ForeignScan` operation on the target table perform early locking on the rows that it fetches, perhaps via the equivalent of `SELECT FOR UPDATE`. An FDW can detect whether a table is an `UPDATE/DELETE` target at plan time by comparing its `relid` to `root->parse->resultRelation`, or at execution time by using `ExecRelationIsTargetRelation()`. An alternative possibility is to perform late locking within the `ExecForeignUpdate` or `ExecForeignDelete` callback, but no special support is provided for this.

For foreign tables that are specified to be locked by a `SELECT FOR UPDATE/SHARE` command, the `ForeignScan` operation can again perform early locking by fetching tuples with the equivalent of `SELECT FOR UPDATE/SHARE`. To perform late locking instead, provide the callback functions defined in Section 53.2.5. In `GetForeignRowMarkType`, select rowmark option `ROW_MARK_EXCLUSIVE`, `ROW_MARK_NOKEYEXCLUSIVE`, `ROW_MARK_SHARE`, or `ROW_MARK_KEYSHARE` depending on the requested lock strength. (The core code will act the same regardless of which of these four options you choose.) Elsewhere, you can detect whether a foreign table was specified to be locked by this type of command by using `get_plan_rowmark` at plan time, or `ExecFindRowMark` at execution time; you must check not only whether a non-null rowmark struct is returned, but that its `strength` field is not `LCS_NONE`.

Lastly, for foreign tables that are used in an `UPDATE`, `DELETE` or `SELECT FOR UPDATE/SHARE` command but are not specified to be row-locked, you can override the default choice to copy entire rows by having `GetForeignRowMarkType` select option `ROW_MARK_REFERENCE` when it sees lock strength `LCS_NONE`. This will cause `RefetchForeignRow` to be called with that value for `markType`; it should then re-fetch the row without acquiring any new lock. (If you have a `GetForeignRowMarkType` function but don't wish to re-fetch unlocked rows, select option `ROW_MARK_COPY` for `LCS_NONE`.)

See `src/include/nodes/lockoptions.h`, the comments for `RowMarkType` and `PlanRowMark` in `src/include/nodes/plannodes.h`, and the comments for `ExecRowMark` in `src/include/nodes/execnodes.h` for additional information.

---

# Chapter 54. Writing a Table Sampling Method

LightDB's implementation of the `TABLESAMPLE` clause supports custom table sampling methods, in addition to the `BERNOULLI` and `SYSTEM` methods that are required by the SQL standard. The sampling method determines which rows of the table will be selected when the `TABLESAMPLE` clause is used.

At the SQL level, a table sampling method is represented by a single SQL function, typically implemented in C, having the signature

```
method_name(internal) RETURNS tsm_handler
```

The name of the function is the same method name appearing in the `TABLESAMPLE` clause. The `internal` argument is a dummy (always having value zero) that simply serves to prevent this function from being called directly from a SQL command. The result of the function must be a palloc'd struct of type `TsmRoutine`, which contains pointers to support functions for the sampling method. These support functions are plain C functions and are not visible or callable at the SQL level. The support functions are described in Section 54.1.

In addition to function pointers, the `TsmRoutine` struct must provide these additional fields:

```
List *parameterTypes
```

This is an OID list containing the data type OIDs of the parameter(s) that will be accepted by the `TABLESAMPLE` clause when this sampling method is used. For example, for the built-in methods, this list contains a single item with value `FLOAT4OID`, which represents the sampling percentage. Custom sampling methods can have more or different parameters.

```
bool repeatable_across_queries
```

If `true`, the sampling method can deliver identical samples across successive queries, if the same parameters and `REPEATABLE` seed value are supplied each time and the table contents have not changed. When this is `false`, the `REPEATABLE` clause is not accepted for use with the sampling method.

```
bool repeatable_across_scans
```

If `true`, the sampling method can deliver identical samples across successive scans in the same query (assuming unchanging parameters, seed value, and snapshot). When this is `false`, the planner will not select plans that would require scanning the sampled table more than once, since that might result in inconsistent query output.

The `TsmRoutine` struct type is declared in `src/include/access/tsmapi.h`, which see for additional details.

The table sampling methods included in the standard distribution are good references when trying to write your own. Look into the `src/backend/access/tablesample` subdirectory of the source tree for the built-in sampling methods, and into the `contrib` subdirectory for add-on methods.

## 54.1. Sampling Method Support Functions

The TSM handler function returns a palloc'd `TsmRoutine` struct containing pointers to the support functions described below. Most of the functions are required, but some are optional, and those pointers can be `NULL`.

```

void
SampleScanGetSampleSize (PlannerInfo *root,
                        RelOptInfo *baserel,
                        List *paramexprs,
                        BlockNumber *pages,
                        double *tuples);

```

This function is called during planning. It must estimate the number of relation pages that will be read during a sample scan, and the number of tuples that will be selected by the scan. (For example, these might be determined by estimating the sampling fraction, and then multiplying the `baserel->pages` and `baserel->tuples` numbers by that, being sure to round the results to integral values.) The `paramexprs` list holds the expression(s) that are parameters to the TABLESAMPLE clause. It is recommended to use `estimate_expression_value()` to try to reduce these expressions to constants, if their values are needed for estimation purposes; but the function must provide size estimates even if they cannot be reduced, and it should not fail even if the values appear invalid (remember that they're only estimates of what the run-time values will be). The `pages` and `tuples` parameters are outputs.

```

void
InitSampleScan (SampleScanState *node,
               int eflags);

```

Initialize for execution of a SampleScan plan node. This is called during executor startup. It should perform any initialization needed before processing can start. The `SampleScanState` node has already been created, but its `tsm_state` field is NULL. The `InitSampleScan` function can `palloc` whatever internal state data is needed by the sampling method, and store a pointer to it in `node->tsm_state`. Information about the table to scan is accessible through other fields of the `SampleScanState` node (but note that the `node->ss.ss_currentScanDesc` scan descriptor is not set up yet). `eflags` contains flag bits describing the executor's operating mode for this plan node.

When `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, the scan will not actually be performed, so this function should only do the minimum required to make the node state valid for `EXPLAIN` and `EndSampleScan`.

This function can be omitted (set the pointer to NULL), in which case `BeginSampleScan` must perform all initialization needed by the sampling method.

```

void
BeginSampleScan (SampleScanState *node,
                Datum *params,
                int nparams,
                uint32 seed);

```

Begin execution of a sampling scan. This is called just before the first attempt to fetch a tuple, and may be called again if the scan needs to be restarted. Information about the table to scan is accessible through fields of the `SampleScanState` node (but note that the `node->ss.ss_currentScanDesc` scan descriptor is not set up yet). The `params` array, of length `nparams`, contains the values of the parameters supplied in the TABLESAMPLE clause. These will have the number and types specified in the sampling method's `parameterTypes` list, and have been checked to not be null. `seed` contains a seed to use for any random numbers generated within the sampling method; it is either a hash derived from the REPEATABLE value if one was given, or the result of `random()` if not.

This function may adjust the fields `node->use_bulkread` and `node->use_pagemode`. If `node->use_bulkread` is true, which it is by default, the scan will use a buffer access strategy that encourages recycling buffers after use. It might be reasonable to set this to false if the scan will

visit only a small fraction of the table's pages. If `node->use_pagemode` is true, which it is by default, the scan will perform visibility checking in a single pass for all tuples on each visited page. It might be reasonable to set this to false if the scan will select only a small fraction of the tuples on each visited page. That will result in fewer tuple visibility checks being performed, though each one will be more expensive because it will require more locking.

If the sampling method is marked `repeatable_across_scans`, it must be able to select the same set of tuples during a rescan as it did originally, that is a fresh call of `BeginSampleScan` must lead to selecting the same tuples as before (if the `TABLESAMPLE` parameters and seed don't change).

```
BlockNumber
NextSampleBlock (SampleScanState *node, BlockNumber nblocks);
```

Returns the block number of the next page to be scanned, or `InvalidBlockNumber` if no pages remain to be scanned.

This function can be omitted (set the pointer to NULL), in which case the core code will perform a sequential scan of the entire relation. Such a scan can use synchronized scanning, so that the sampling method cannot assume that the relation pages are visited in the same order on each scan.

```
OffsetNumber
NextSampleTuple (SampleScanState *node,
                BlockNumber blockno,
                OffsetNumber maxoffset);
```

Returns the offset number of the next tuple to be sampled on the specified page, or `InvalidOffsetNumber` if no tuples remain to be sampled. `maxoffset` is the largest offset number in use on the page.

**Note**

`NextSampleTuple` is not explicitly told which of the offset numbers in the range 1 .. `maxoffset` actually contain valid tuples. This is not normally a problem since the core code ignores requests to sample missing or invisible tuples; that should not result in any bias in the sample. However, if necessary, the function can use `node->donetuples` to examine how many of the tuples it returned were valid and visible.

**Note**

`NextSampleTuple` must *not* assume that `blockno` is the same page number returned by the most recent `NextSampleBlock` call. It was returned by some previous `NextSampleBlock` call, but the core code is allowed to call `NextSampleBlock` in advance of actually scanning pages, so as to support prefetching. It is OK to assume that once sampling of a given page begins, successive `NextSampleTuple` calls all refer to the same page until `InvalidOffsetNumber` is returned.

```
void
EndSampleScan (SampleScanState *node);
```

End the scan and release resources. It is normally not important to release `palloc'd` memory, but any externally-visible resources should be cleaned up. This function can be omitted (set the pointer to NULL) in the common case where no such resources exist.

---

# Chapter 55. Writing a Custom Scan Provider

LightDB supports a set of experimental facilities which are intended to allow extension modules to add new scan types to the system. Unlike a foreign data wrapper, which is only responsible for knowing how to scan its own foreign tables, a custom scan provider can provide an alternative method of scanning any relation in the system. Typically, the motivation for writing a custom scan provider will be to allow the use of some optimization not supported by the core system, such as caching or some form of hardware acceleration. This chapter outlines how to write a new custom scan provider.

Implementing a new type of custom scan is a three-step process. First, during planning, it is necessary to generate access paths representing a scan using the proposed strategy. Second, if one of those access paths is selected by the planner as the optimal strategy for scanning a particular relation, the access path must be converted to a plan. Finally, it must be possible to execute the plan and generate the same results that would have been generated for any other access path targeting the same relation.

## 55.1. Creating Custom Scan Paths

A custom scan provider will typically add paths for a base relation by setting the following hook, which is called after the core code has generated all the access paths it can for the relation (except for Gather paths, which are made after this call so that they can use partial paths added by the hook):

```
typedef void (*set_rel_pathlist_hook_type) (PlannerInfo *root,
                                           RelOptInfo *rel,
                                           Index rti,
                                           RangeTblEntry *rte);
extern PGDLLIMPORT set_rel_pathlist_hook_type
set_rel_pathlist_hook;
```

Although this hook function can be used to examine, modify, or remove paths generated by the core system, a custom scan provider will typically confine itself to generating `CustomPath` objects and adding them to `rel` using `add_path`. The custom scan provider is responsible for initializing the `CustomPath` object, which is declared like this:

```
typedef struct CustomPath
{
    Path      path;
    uint32    flags;
    List      *custom_paths;
    List      *custom_private;
    const CustomPathMethods *methods;
} CustomPath;
```

`path` must be initialized as for any other path, including the row-count estimate, start and total cost, and sort ordering provided by this path. `flags` is a bit mask, which should include `CUSTOMPATH_SUPPORT_BACKWARD_SCAN` if the custom path can support a backward scan and `CUSTOMPATH_SUPPORT_MARK_RESTORE` if it can support mark and restore. Both capabilities are optional. An optional `custom_paths` is a list of `Path` nodes used by this custom-path node; these will be transformed into `Plan` nodes by planner. `custom_private` can be used to store the custom path's private data. Private data should be stored in a form that can be handled by `nodeToString`, so that debugging routines that attempt to print the custom path will work as designed. `methods` must point to a (usually statically allocated) object implementing the required custom path methods, of which there is currently only one.

A custom scan provider can also provide join paths. Just as for base relations, such a path must produce the same output as would normally be produced by the join it replaces. To do this, the join provider should set the following hook, and then within the hook function, create `CustomPath` path(s) for the join relation.

```
typedef void (*set_join_pathlist_hook_type) (PlannerInfo *root,
                                             RelOptInfo *joinrel,
                                             RelOptInfo *outerrel,
                                             RelOptInfo *innerrel,
                                             JoinType jointype,
                                             JoinPathExtraData
                                             *extra);
extern PGDLLIMPORT set_join_pathlist_hook_type
set_join_pathlist_hook;
```

This hook will be invoked repeatedly for the same join relation, with different combinations of inner and outer relations; it is the responsibility of the hook to minimize duplicated work.

### 55.1.1. Custom Scan Path Callbacks

```
Plan *(*PlanCustomPath) (PlannerInfo *root,
                          RelOptInfo *rel,
                          CustomPath *best_path,
                          List *tlist,
                          List *clauses,
                          List *custom_plans);
```

Convert a custom path to a finished plan. The return value will generally be a `CustomScan` object, which the callback must allocate and initialize. See Section 55.2 for more details.

## 55.2. Creating Custom Scan Plans

A custom scan is represented in a finished plan tree using the following structure:

```
typedef struct CustomScan
{
    Scan        scan;
    uint32      flags;
    List        *custom_plans;
    List        *custom_exprs;
    List        *custom_private;
    List        *custom_scan_tlist;
    Bitmapset   *custom_relids;
    const CustomScanMethods *methods;
} CustomScan;
```

`scan` must be initialized as for any other scan, including estimated costs, target lists, qualifications, and so on. `flags` is a bit mask with the same meaning as in `CustomPath`. `custom_plans` can be used to store child `Plan` nodes. `custom_exprs` should be used to store expression trees that will need to be fixed up by `setrefs.c` and `subselect.c`, while `custom_private` should be used to store other private data that is only used by the custom scan provider itself. `custom_scan_tlist` can be `NIL` when scanning a base relation, indicating that the custom scan returns scan tuples that match the base relation's row type. Otherwise it is a target list describing the actual scan tuples. `custom_scan_tlist` must be provided for joins, and could be provided for scans if the custom

scan provider can compute some non-Var expressions. `custom_relids` is set by the core code to the set of relations (range table indexes) that this scan node handles; except when this scan is replacing a join, it will have only one member. `methods` must point to a (usually statically allocated) object implementing the required custom scan methods, which are further detailed below.

When a `CustomScan` scans a single relation, `scan.scanrelid` must be the range table index of the table to be scanned. When it replaces a join, `scan.scanrelid` should be zero.

Plan trees must be able to be duplicated using `copyObject`, so all the data stored within the “custom” fields must consist of nodes that that function can handle. Furthermore, custom scan providers cannot substitute a larger structure that embeds a `CustomScan` for the structure itself, as would be possible for a `CustomPath` or `CustomScanState`.

## 55.2.1. Custom Scan Plan Callbacks

```
Node *(*CreateCustomScanState) (CustomScan *cscan);
```

Allocate a `CustomScanState` for this `CustomScan`. The actual allocation will often be larger than required for an ordinary `CustomScanState`, because many providers will wish to embed that as the first field of a larger structure. The value returned must have the node tag and `methods` set appropriately, but other fields should be left as zeroes at this stage; after `ExecInitCustomScan` performs basic initialization, the `BeginCustomScan` callback will be invoked to give the custom scan provider a chance to do whatever else is needed.

## 55.3. Executing Custom Scans

When a `CustomScan` is executed, its execution state is represented by a `CustomScanState`, which is declared as follows:

```
typedef struct CustomScanState
{
    ScanState ss;
    uint32    flags;
    const CustomExecMethods *methods;
} CustomScanState;
```

`ss` is initialized as for any other scan state, except that if the scan is for a join rather than a base relation, `ss.ss_currentRelation` is left `NULL`. `flags` is a bit mask with the same meaning as in `CustomPath` and `CustomScan`. `methods` must point to a (usually statically allocated) object implementing the required custom scan state methods, which are further detailed below. Typically, a `CustomScanState`, which need not support `copyObject`, will actually be a larger structure embedding the above as its first member.

### 55.3.1. Custom Scan Execution Callbacks

```
void (*BeginCustomScan) (CustomScanState *node,
                        EState *estate,
                        int eflags);
```

Complete initialization of the supplied `CustomScanState`. Standard fields have been initialized by `ExecInitCustomScan`, but any private fields should be initialized here.

```
TupleTableSlot *(*ExecCustomScan) (CustomScanState *node);
```

Fetch the next scan tuple. If any tuples remain, it should fill `ps_ResultTupleSlot` with the next tuple in the current scan direction, and then return the tuple slot. If not, `NULL` or an empty slot should be returned.

```
void (*EndCustomScan) (CustomScanState *node);
```

Clean up any private data associated with the `CustomScanState`. This method is required, but it does not need to do anything if there is no associated data or it will be cleaned up automatically.

```
void (*ReScanCustomScan) (CustomScanState *node);
```

Rewind the current scan to the beginning and prepare to rescan the relation.

```
void (*MarkPosCustomScan) (CustomScanState *node);
```

Save the current scan position so that it can subsequently be restored by the `RestrPosCustomScan` callback. This callback is optional, and need only be supplied if the `CUSTOMPATH_SUPPORT_MARK_RESTORE` flag is set.

```
void (*RestrPosCustomScan) (CustomScanState *node);
```

Restore the previous scan position as saved by the `MarkPosCustomScan` callback. This callback is optional, and need only be supplied if the `CUSTOMPATH_SUPPORT_MARK_RESTORE` flag is set.

```
Size (*EstimateDSMCustomScan) (CustomScanState *node,
                               ParallelContext *pcxt);
```

Estimate the amount of dynamic shared memory that will be required for parallel operation. This may be higher than the amount that will actually be used, but it must not be lower. The return value is in bytes. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*InitializeDSMCustomScan) (CustomScanState *node,
                                ParallelContext *pcxt,
                                void *coordinate);
```

Initialize the dynamic shared memory that will be required for parallel operation. `coordinate` points to a shared memory area of size equal to the return value of `EstimateDSMCustomScan`. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*ReInitializeDSMCustomScan) (CustomScanState *node,
                                   ParallelContext *pcxt,
                                   void *coordinate);
```

Re-initialize the dynamic shared memory required for parallel operation when the custom-scan plan node is about to be re-scanned. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution. Recommended practice is that this callback reset only shared state, while the `ReScanCustomScan` callback resets only local state. Currently, this callback will be called before `ReScanCustomScan`, but it's best not to rely on that ordering.

```
void (*InitializeWorkerCustomScan) (CustomScanState *node,
                                    shm_toc *toc,
                                    void *coordinate);
```



Initialize a parallel worker's local state based on the shared state set up by the leader during `InitializeDSMCustomScan`. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*ShutdownCustomScan) (CustomScanState *node);
```

Release resources when it is anticipated the node will not be executed to completion. This is not called in all cases; sometimes, `EndCustomScan` may be called without this function having been called first. Since the DSM segment used by parallel query is destroyed just after this callback is invoked, custom scan providers that wish to take some action before the DSM segment goes away should implement this method.

```
void (*ExplainCustomScan) (CustomScanState *node,  
                           List *ancestors,  
                           ExplainState *es);
```

Output additional information for `EXPLAIN` of a custom-scan plan node. This callback is optional. Common data stored in the `ScanState`, such as the target list and scan relation, will be shown even without this callback, but the callback allows the display of additional, private state.

---

# Chapter 56. Genetic Query Optimizer

## Author

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## 56.1. Query Handling as a Complex Optimization Problem

Among all relational operators the most difficult one to process and optimize is the *join*. The number of possible query plans grows exponentially with the number of joins in the query. Further optimization effort is caused by the support of a variety of *join methods* (e.g., nested loop, hash join, merge join in LightDB) to process individual joins and a diversity of *indexes* (e.g., B-tree, hash, GiST and GIN in LightDB) as access paths for relations.

The normal LightDB query optimizer performs a *near-exhaustive search* over the space of alternative strategies. This algorithm, first introduced in IBM's System R database, produces a near-optimal join order, but can take an enormous amount of time and memory space when the number of joins in the query grows large. This makes the ordinary LightDB query optimizer inappropriate for queries that join a large number of tables.

The Institute of Automatic Control at the University of Mining and Technology, in Freiberg, Germany, encountered some problems when it wanted to use LightDB as the backend for a decision support knowledge based system for the maintenance of an electrical power grid. The DBMS needed to handle large join queries for the inference machine of the knowledge based system. The number of joins in these queries made using the normal query optimizer infeasible.

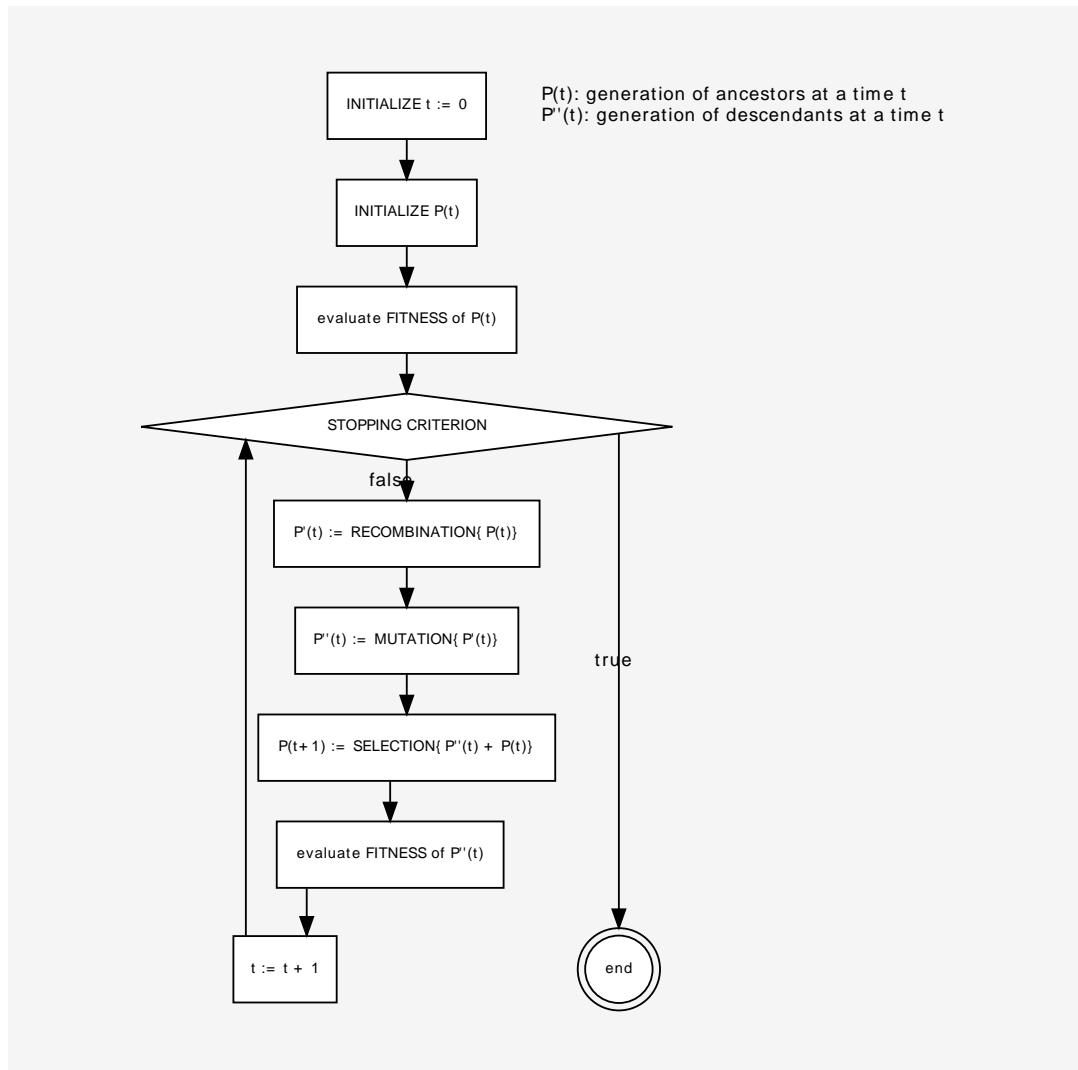
In the following we describe the implementation of a *genetic algorithm* to solve the join ordering problem in a manner that is efficient for queries involving large numbers of joins.

## 56.2. Genetic Algorithms

The genetic algorithm (GA) is a heuristic optimization method which operates through randomized search. The set of possible solutions for the optimization problem is considered as a *population* of *individuals*. The degree of adaptation of an individual to its environment is specified by its *fitness*.

The coordinates of an individual in the search space are represented by *chromosomes*, in essence a set of character strings. A *gene* is a subsection of a chromosome which encodes the value of a single parameter being optimized. Typical encodings for a gene could be *binary* or *integer*.

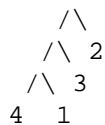
Through simulation of the evolutionary operations *recombination*, *mutation*, and *selection* new generations of search points are found that show a higher average fitness than their ancestors. Figure 56.1 illustrates these steps.

**Figure 56.1. Structure of a Genetic Algorithm**

According to the comp.ai.genetic FAQ it cannot be stressed too strongly that a GA is not a pure random search for a solution to a problem. A GA uses stochastic processes, but the result is distinctly non-random (better than random).

## 56.3. Genetic Query Optimization (GEQO) in LightDB

The GEQO module approaches the query optimization problem as though it were the well-known traveling salesman problem (TSP). Possible query plans are encoded as integer strings. Each string represents the join order from one relation of the query to the next. For example, the join tree



is encoded by the integer string '4-1-3-2', which means, first join relation '4' and '1', then '3', and then '2', where 1, 2, 3, 4 are relation IDs within the LightDB optimizer.

Specific characteristics of the GEQO implementation in LightDB are:

- Usage of a *steady state* GA (replacement of the least fit individuals in a population, not whole-generational replacement) allows fast convergence towards improved query plans. This is essential for query handling with reasonable time;
- Usage of *edge recombination crossover* which is especially suited to keep edge losses low for the solution of the TSP by means of a GA;
- Mutation as genetic operator is deprecated so that no repair mechanisms are needed to generate legal TSP tours.

Parts of the GEQO module are adapted from D. Whitley's Genitor algorithm.

The GEQO module allows the LightDB query optimizer to support large join queries effectively through non-exhaustive search.

### 56.3.1. Generating Possible Plans with GEQO

The GEQO planning process uses the standard planner code to generate plans for scans of individual relations. Then join plans are developed using the genetic approach. As shown above, each candidate join plan is represented by a sequence in which to join the base relations. In the initial stage, the GEQO code simply generates some possible join sequences at random. For each join sequence considered, the standard planner code is invoked to estimate the cost of performing the query using that join sequence. (For each step of the join sequence, all three possible join strategies are considered; and all the initially-determined relation scan plans are available. The estimated cost is the cheapest of these possibilities.) Join sequences with lower estimated cost are considered “more fit” than those with higher cost. The genetic algorithm discards the least fit candidates. Then new candidates are generated by combining genes of more-fit candidates — that is, by using randomly-chosen portions of known low-cost join sequences to create new sequences for consideration. This process is repeated until a preset number of join sequences have been considered; then the best one found at any time during the search is used to generate the finished plan.

This process is inherently nondeterministic, because of the randomized choices made during both the initial population selection and subsequent “mutation” of the best candidates. To avoid surprising changes of the selected plan, each run of the GEQO algorithm restarts its random number generator with the current `geqo_seed` parameter setting. As long as `geqo_seed` and the other GEQO parameters are kept fixed, the same plan will be generated for a given query (and other planner inputs such as statistics). To experiment with different search paths, try changing `geqo_seed`.

### 56.3.2. Future Implementation Tasks for LightDB GEQO

Work is still needed to improve the genetic algorithm parameter settings. In file `src/backend/optimizer/geqo/geqo_main.c`, routines `gimme_pool_size` and `gimme_number_generations`, we have to find a compromise for the parameter settings to satisfy two competing demands:

- Optimality of the query plan
- Computing time

In the current implementation, the fitness of each candidate join sequence is estimated by running the standard planner's join selection and cost estimation code from scratch. To the extent that different candidates use similar sub-sequences of joins, a great deal of work will be repeated. This could be made significantly faster by retaining cost estimates for sub-joins. The problem is to avoid expending unreasonable amounts of memory on retaining that state.

At a more basic level, it is not clear that solving query optimization with a GA algorithm designed for TSP is appropriate. In the TSP case, the cost associated with any substring (partial tour) is independent of the rest of the tour, but this is certainly not true for query optimization. Thus it is questionable whether edge recombination crossover is the most effective mutation procedure.

## 56.4. Further Reading

The following resources contain additional information about genetic algorithms:

- The Hitch-Hiker's Guide to Evolutionary Computation<sup>1</sup>, (FAQ for news://comp.ai.genetic)
- Evolutionary Computation and its application to art and design<sup>2</sup>, by Craig Reynolds
- [elma04]
- [fong]

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<sup>1</sup> <http://www.faqs.org/faqs/ai-faq/genetic/part1/>

<sup>2</sup> <https://www.red3d.com/cwr/evolve.html>

---

# Chapter 57. Table Access Method Interface Definition

This chapter explains the interface between the core LightDB system and *table access methods*, which manage the storage for tables. The core system knows little about these access methods beyond what is specified here, so it is possible to develop entirely new access method types by writing add-on code.

Each table access method is described by a row in the `pg_am` system catalog. The `pg_am` entry specifies a name and a *handler function* for the table access method. These entries can be created and deleted using the `CREATE ACCESS METHOD` and `DROP ACCESS METHOD` SQL commands.

A table access method handler function must be declared to accept a single argument of type `internal` and to return the pseudo-type `table_am_handler`. The argument is a dummy value that simply serves to prevent handler functions from being called directly from SQL commands. The result of the function must be a pointer to a struct of type `TableAmRoutine`, which contains everything that the core code needs to know to make use of the table access method. The return value needs to be of server lifetime, which is typically achieved by defining it as a `static const` variable in global scope. The `TableAmRoutine` struct, also called the access method's *API struct*, defines the behavior of the access method using callbacks. These callbacks are pointers to plain C functions and are not visible or callable at the SQL level. All the callbacks and their behavior is defined in the `TableAmRoutine` structure (with comments inside the struct defining the requirements for callbacks). Most callbacks have wrapper functions, which are documented from the point of view of a user (rather than an implementor) of the table access method. For details, please refer to the `src/include/access/tableam.h`<sup>1</sup> file.

To implement an access method, an implementor will typically need to implement an AM-specific type of tuple table slot (see `src/include/executor/tuptable.h`<sup>2</sup>), which allows code outside the access method to hold references to tuples of the AM, and to access the columns of the tuple.

Currently, the way an AM actually stores data is fairly unconstrained. For example, it's possible, but not required, to use postgres' shared buffer cache. In case it is used, it likely makes sense to use LightDB's standard page layout as described in Section 64.6.

One fairly large constraint of the table access method API is that, currently, if the AM wants to support modifications and/or indexes, it is necessary for each tuple to have a tuple identifier (TID) consisting of a block number and an item number (see also Section 64.6). It is not strictly necessary that the sub-parts of TIDs have the same meaning they e.g., have for `heap`, but if bitmap scan support is desired (it is optional), the block number needs to provide locality.

For crash safety, an AM can use postgres' WAL, or a custom implementation. If WAL is chosen, either Generic WAL Records can be used, or a new type of WAL records can be implemented. Generic WAL Records are easy, but imply higher WAL volume. Implementation of a new type of WAL record currently requires modifications to core code (specifically, `src/include/access/rmgrlist.h`).

To implement transactional support in a manner that allows different table access methods be accessed within a single transaction, it likely is necessary to closely integrate with the machinery in `src/backend/access/transam/xlog.c`.

Any developer of a new table access method can refer to the existing heap implementation present in `src/backend/access/heap/heapam_handler.c` for details of its implementation.

---

<sup>1</sup> <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/include/access/tableam.h;hb=HEAD>

<sup>2</sup> <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/include/executor/tuptable.h;hb=HEAD>

---

# Chapter 58. Index Access Method Interface Definition

This chapter defines the interface between the core LightDB system and *index access methods*, which manage individual index types. The core system knows nothing about indexes beyond what is specified here, so it is possible to develop entirely new index types by writing add-on code.

All indexes in LightDB are what are known technically as *secondary indexes*; that is, the index is physically separate from the table file that it describes. Each index is stored as its own physical *relation* and so is described by an entry in the `pg_class` catalog. The contents of an index are entirely under the control of its index access method. In practice, all index access methods divide indexes into standard-size pages so that they can use the regular storage manager and buffer manager to access the index contents. (All the existing index access methods furthermore use the standard page layout described in Section 64.6, and most use the same format for index tuple headers; but these decisions are not forced on an access method.)

An index is effectively a mapping from some data key values to *tuple identifiers*, or TIDs, of row versions (tuples) in the index's parent table. A TID consists of a block number and an item number within that block (see Section 64.6). This is sufficient information to fetch a particular row version from the table. Indexes are not directly aware that under MVCC, there might be multiple extant versions of the same logical row; to an index, each tuple is an independent object that needs its own index entry. Thus, an update of a row always creates all-new index entries for the row, even if the key values did not change. (HOT tuples are an exception to this statement; but indexes do not deal with those, either.) Index entries for dead tuples are reclaimed (by vacuuming) when the dead tuples themselves are reclaimed.

## 58.1. Basic API Structure for Indexes

Each index access method is described by a row in the `pg_am` system catalog. The `pg_am` entry specifies a name and a *handler function* for the index access method. These entries can be created and deleted using the `CREATE ACCESS METHOD` and `DROP ACCESS METHOD` SQL commands.

An index access method handler function must be declared to accept a single argument of type `internal` and to return the pseudo-type `index_am_handler`. The argument is a dummy value that simply serves to prevent handler functions from being called directly from SQL commands. The result of the function must be a palloc'd struct of type `IndexAmRoutine`, which contains everything that the core code needs to know to make use of the index access method. The `IndexAmRoutine` struct, also called the access method's *API struct*, includes fields specifying assorted fixed properties of the access method, such as whether it can support multicolumn indexes. More importantly, it contains pointers to support functions for the access method, which do all of the real work to access indexes. These support functions are plain C functions and are not visible or callable at the SQL level. The support functions are described in Section 58.2.

The structure `IndexAmRoutine` is defined thus:

```
typedef struct IndexAmRoutine
{
    NodeTag      type;

    /*
     * Total number of strategies (operators) by which we can
     * traverse/search
     * this AM. Zero if AM does not have a fixed set of strategy
     * assignments.
     */
}
```

Index Access Method  
Interface Definition

---

```
uint16      amstrategies;
/* total number of support functions that this AM uses */
uint16      amsupport;
/* opclass options support function number or 0 */
uint16      amoptsprocnum;
/* does AM support ORDER BY indexed column's value? */
bool        amcanorder;
/* does AM support ORDER BY result of an operator on indexed
column? */
bool        amcanorderbyop;
/* does AM support backward scanning? */
bool        amcanbackward;
/* does AM support UNIQUE indexes? */
bool        amcanunique;
/* does AM support multi-column indexes? */
bool        amcanmulticol;
/* does AM require scans to have a constraint on the first
index column? */
bool        amoptionalkey;
/* does AM handle ScalarArrayOpExpr quals? */
bool        amsearcharray;
/* does AM handle IS NULL/IS NOT NULL quals? */
bool        amsearchnulls;
/* can index storage data type differ from column data type? */
bool        amstorage;
/* can an index of this type be clustered on? */
bool        amclusterable;
/* does AM handle predicate locks? */
bool        ampredlocks;
/* does AM support parallel scan? */
bool        amcanparallel;
/* does AM support columns included with clause INCLUDE? */
bool        amcaninclude;
/* does AM use maintenance_work_mem? */
bool        amusemaintenanceworkmem;
/* OR of parallel vacuum flags */
uint8       amparallelvacuumoptions;
/* type of data stored in index, or InvalidOid if variable */
Oid         amkeytype;

/* interface functions */
ambuild_function ambuild;
ambuildempty_function ambuildempty;
aminsert_function aminsert;
ambulkdelete_function ambulkdelete;
amvacuumcleanup_function amvacuumcleanup;
amcanreturn_function amcanreturn; /* can be NULL */
amcostestimate_function amcostestimate;
amoptions_function amoptions;
amproperty_function amproperty; /* can be NULL */
ambuildphasename_function ambuildphasename; /* can be NULL */
amvalidate_function amvalidate;
ambeginscan_function ambeginscan;
amrescan_function amrescan;
amgettuple_function amgettuple; /* can be NULL */
amgetbitmap_function amgetbitmap; /* can be NULL */
amendscan_function amendscan;
ammarkpos_function ammarkpos; /* can be NULL */
```



```

    amrestrpos_function amrestrpos;        /* can be NULL */

    /* interface functions to support parallel index scans */
    amestimateparallelscan_function amestimateparallelscan; /*
can be NULL */
    aminitparallelscan_function aminitparallelscan;        /* can be
NULL */
    amparallelrescan_function amparallelrescan;        /* can be NULL
*/
} IndexAmRoutine;

```

To be useful, an index access method must also have one or more *operator families* and *operator classes* defined in `pg_opfamily`, `pg_opclass`, `pg_amop`, and `pg_amproc`. These entries allow the planner to determine what kinds of query qualifications can be used with indexes of this access method. Operator families and classes are described in Section 36.16, which is prerequisite material for reading this chapter.

An individual index is defined by a `pg_class` entry that describes it as a physical relation, plus a `pg_index` entry that shows the logical content of the index — that is, the set of index columns it has and the semantics of those columns, as captured by the associated operator classes. The index columns (key values) can be either simple columns of the underlying table or expressions over the table rows. The index access method normally has no interest in where the index key values come from (it is always handed precomputed key values) but it will be very interested in the operator class information in `pg_index`. Both of these catalog entries can be accessed as part of the `Relation` data structure that is passed to all operations on the index.

Some of the flag fields of `IndexAmRoutine` have nonobvious implications. The requirements of `amcanunique` are discussed in Section 58.5. The `amcanmulticol` flag asserts that the access method supports multi-key-column indexes, while `amoptionalkey` asserts that it allows scans where no indexable restriction clause is given for the first index column. When `amcanmulticol` is false, `amoptionalkey` essentially says whether the access method supports full-index scans without any restriction clause. Access methods that support multiple index columns *must* support scans that omit restrictions on any or all of the columns after the first; however they are permitted to require some restriction to appear for the first index column, and this is signaled by setting `amoptionalkey` false. One reason that an index AM might set `amoptionalkey` false is if it doesn't index null values. Since most indexable operators are strict and hence cannot return true for null inputs, it is at first sight attractive to not store index entries for null values: they could never be returned by an index scan anyway. However, this argument fails when an index scan has no restriction clause for a given index column. In practice this means that indexes that have `amoptionalkey` true must index nulls, since the planner might decide to use such an index with no scan keys at all. A related restriction is that an index access method that supports multiple index columns *must* support indexing null values in columns after the first, because the planner will assume the index can be used for queries that do not restrict these columns. For example, consider an index on (a,b) and a query with `WHERE a = 4`. The system will assume the index can be used to scan for rows with `a = 4`, which is wrong if the index omits rows where `b` is null. It is, however, OK to omit rows where the first indexed column is null. An index access method that does index nulls may also set `amsearchnulls`, indicating that it supports `IS NULL` and `IS NOT NULL` clauses as search conditions.

The `amcaninclude` flag indicates whether the access method supports “included” columns, that is it can store (without processing) additional columns beyond the key column(s). The requirements of the preceding paragraph apply only to the key columns. In particular, the combination of `amcanmulticol=false` and `amcaninclude=true` is sensible: it means that there can only be one key column, but there can also be included column(s). Also, included columns must be allowed to be null, independently of `amoptionalkey`.

## 58.2. Index Access Method Functions

The index construction and maintenance functions that an index access method must provide in `IndexAmRoutine` are:

```
IndexBuildResult *
ambuild (Relation heapRelation,
         Relation indexRelation,
         IndexInfo *indexInfo);
```

Build a new index. The index relation has been physically created, but is empty. It must be filled in with whatever fixed data the access method requires, plus entries for all tuples already existing in the table. Ordinarily the `ambuild` function will call `table_index_build_scan()` to scan the table for existing tuples and compute the keys that need to be inserted into the index. The function must return a `palloc'd` struct containing statistics about the new index.

```
void
ambuildempty (Relation indexRelation);
```

Build an empty index, and write it to the initialization fork (`INIT_FORKNUM`) of the given relation. This method is called only for unlogged indexes; the empty index written to the initialization fork will be copied over the main relation fork on each server restart.

```
bool
aminsert (Relation indexRelation,
          Datum *values,
          bool *isnull,
          ItemPointer heap_tid,
          Relation heapRelation,
          IndexUniqueCheck checkUnique,
          IndexInfo *indexInfo);
```

Insert a new tuple into an existing index. The `values` and `isnull` arrays give the key values to be indexed, and `heap_tid` is the TID to be indexed. If the access method supports unique indexes (its `amcanunique` flag is true) then `checkUnique` indicates the type of uniqueness check to perform. This varies depending on whether the unique constraint is deferrable; see Section 58.5 for details. Normally the access method only needs the `heapRelation` parameter when performing uniqueness checking (since then it will have to look into the heap to verify tuple liveness).

The function's Boolean result value is significant only when `checkUnique` is `UNIQUE_CHECK_PARTIAL`. In this case a true result means the new entry is known unique, whereas false means it might be non-unique (and a deferred uniqueness check must be scheduled). For other cases a constant false result is recommended.

Some indexes might not index all tuples. If the tuple is not to be indexed, `aminsert` should just return without doing anything.

If the index AM wishes to cache data across successive index insertions within a SQL statement, it can allocate space in `indexInfo->ii_Context` and store a pointer to the data in `indexInfo->ii_AmCache` (which will be NULL initially).

```
IndexBulkDeleteResult *
ambulkdelete (IndexVacuumInfo *info,
             IndexBulkDeleteResult *stats,
             IndexBulkDeleteCallback callback,
             void *callback_state);
```

Delete tuple(s) from the index. This is a “bulk delete” operation that is intended to be implemented by scanning the whole index and checking each entry to see if it should be deleted. The passed-in `callback` function must be called, in the style `callback(TID, callback_state)` returns `bool`, to determine whether any particular index entry, as identified by its referenced

TID, is to be deleted. Must return either NULL or a palloc'd struct containing statistics about the effects of the deletion operation. It is OK to return NULL if no information needs to be passed on to `amvacuumcleanup`.

Because of limited `maintenance_work_mem`, `ambulkdelete` might need to be called more than once when many tuples are to be deleted. The `stats` argument is the result of the previous call for this index (it is NULL for the first call within a VACUUM operation). This allows the AM to accumulate statistics across the whole operation. Typically, `ambulkdelete` will modify and return the same struct if the passed `stats` is not null.

```
IndexBulkDeleteResult *
amvacuumcleanup (IndexVacuumInfo *info,
                 IndexBulkDeleteResult *stats);
```

Clean up after a VACUUM operation (zero or more `ambulkdelete` calls). This does not have to do anything beyond returning index statistics, but it might perform bulk cleanup such as reclaiming empty index pages. `stats` is whatever the last `ambulkdelete` call returned, or NULL if `ambulkdelete` was not called because no tuples needed to be deleted. If the result is not NULL it must be a palloc'd struct. The statistics it contains will be used to update `pg_class`, and will be reported by VACUUM if VERBOSE is given. It is OK to return NULL if the index was not changed at all during the VACUUM operation, but otherwise correct stats should be returned.

As of LightDB 8.4, `amvacuumcleanup` will also be called at completion of an ANALYZE operation. In this case `stats` is always NULL and any return value will be ignored. This case can be distinguished by checking `info->analyze_only`. It is recommended that the access method do nothing except post-insert cleanup in such a call, and that only in an autovacuum worker process.

```
bool
amcanreturn (Relation indexRelation, int attno);
```

Check whether the index can support *index-only scans* on the given column, by returning the column's original indexed value. The attribute number is 1-based, i.e., the first column's `attno` is 1. Returns true if supported, else false. This function should always return true for included columns (if those are supported), since there's little point in an included column that can't be retrieved. If the access method does not support index-only scans at all, the `amcanreturn` field in its `IndexAmRoutine` struct can be set to NULL.

```
void
amcostestimate (PlannerInfo *root,
                IndexPath *path,
                double loop_count,
                Cost *indexStartupCost,
                Cost *indexTotalCost,
                Selectivity *indexSelectivity,
                double *indexCorrelation,
                double *indexPages);
```

Estimate the costs of an index scan. This function is described fully in Section 58.6, below.

```
bytea *
amoptions (ArrayType *reloptions,
           bool validate);
```

Parse and validate the `reloptions` array for an index. This is called only when a non-null `reloptions` array exists for the index. `reloptions` is a text array containing entries of the form `name=value`. The function should construct a `bytea` value, which will be copied into the `rd_options` field of

the index's relcache entry. The data contents of the `bytea` value are open for the access method to define; most of the standard access methods use `struct StdRdOptions`. When `validate` is true, the function should report a suitable error message if any of the options are unrecognized or have invalid values; when `validate` is false, invalid entries should be silently ignored. (`validate` is false when loading options already stored in `pg_catalog`; an invalid entry could only be found if the access method has changed its rules for options, and in that case ignoring obsolete entries is appropriate.) It is OK to return NULL if default behavior is wanted.

```
bool  
amproperty (Oid index_oid, int attno,  
            IndexAMProperty prop, const char *propname,  
            bool *res, bool *isnull);
```

The `amproperty` method allows index access methods to override the default behavior of `pg_index_column_has_property` and related functions. If the access method does not have any special behavior for index property inquiries, the `amproperty` field in its `IndexAmRoutine` struct can be set to NULL. Otherwise, the `amproperty` method will be called with `index_oid` and `attno` both zero for `pg_indexam_has_property` calls, or with `index_oid` valid and `attno` zero for `pg_index_has_property` calls, or with `index_oid` valid and `attno` greater than zero for `pg_index_column_has_property` calls. `prop` is an enum value identifying the property being tested, while `propname` is the original property name string. If the core code does not recognize the property name then `prop` is `AMPROP_UNKNOWN`. Access methods can define custom property names by checking `propname` for a match (use `pg_strcasecmp` to match, for consistency with the core code); for names known to the core code, it's better to inspect `prop`. If the `amproperty` method returns true then it has determined the property test result: it must set `*res` to the boolean value to return, or set `*isnull` to true to return a NULL. (Both of the referenced variables are initialized to false before the call.) If the `amproperty` method returns false then the core code will proceed with its normal logic for determining the property test result.

Access methods that support ordering operators should implement `AMPROP_DISTANCE_ORDERABLE` property testing, as the core code does not know how to do that and will return NULL. It may also be advantageous to implement `AMPROP_RETURNABLE` testing, if that can be done more cheaply than by opening the index and calling `amcanreturn`, which is the core code's default behavior. The default behavior should be satisfactory for all other standard properties.

```
char *  
ambuildphasename (int64 phasenum);
```

Return the textual name of the given build phase number. The phase numbers are those reported during an index build via the `pgstat_progress_update_param` interface. The phase names are then exposed in the `pg_stat_progress_create_index` view.

```
bool  
amvalidate (Oid opclassoid);
```

Validate the catalog entries for the specified operator class, so far as the access method can reasonably do that. For example, this might include testing that all required support functions are provided. The `amvalidate` function must return false if the opclass is invalid. Problems should be reported with `ereport` messages.

The purpose of an index, of course, is to support scans for tuples matching an indexable WHERE condition, often called a *qualifier* or *scan key*. The semantics of index scanning are described more fully in Section 58.3, below. An index access method can support “plain” index scans, “bitmap” index scans, or both. The scan-related functions that an index access method must or may provide are:

IndexScanDesc

## Index Access Method Interface Definition

---

```
ambeginscan (Relation indexRelation,  
            int nkeys,  
            int norderbys);
```

Prepare for an index scan. The `nkeys` and `norderbys` parameters indicate the number of quals and ordering operators that will be used in the scan; these may be useful for space allocation purposes. Note that the actual values of the scan keys aren't provided yet. The result must be a palloc'd struct. For implementation reasons the index access method *must* create this struct by calling `RelationGetIndexScan()`. In most cases `ambeginscan` does little beyond making that call and perhaps acquiring locks; the interesting parts of index-scan startup are in `amrescan`.

```
void  
amrescan (IndexScanDesc scan,  
         ScanKey keys,  
         int nkeys,  
         ScanKey orderbys,  
         int norderbys);
```

Start or restart an index scan, possibly with new scan keys. (To restart using previously-passed keys, NULL is passed for `keys` and/or `orderbys`.) Note that it is not allowed for the number of keys or order-by operators to be larger than what was passed to `ambeginscan`. In practice the restart feature is used when a new outer tuple is selected by a nested-loop join and so a new key comparison value is needed, but the scan key structure remains the same.

```
bool  
amgettupple (IndexScanDesc scan,  
            ScanDirection direction);
```

Fetch the next tuple in the given scan, moving in the given direction (forward or backward in the index). Returns true if a tuple was obtained, false if no matching tuples remain. In the true case the tuple TID is stored into the `scan` structure. Note that “success” means only that the index contains an entry that matches the scan keys, not that the tuple necessarily still exists in the heap or will pass the caller's snapshot test. On success, `amgettupple` must also set `scan->xs_recheck` to true or false. False means it is certain that the index entry matches the scan keys. True means this is not certain, and the conditions represented by the scan keys must be rechecked against the heap tuple after fetching it. This provision supports “lossy” index operators. Note that rechecking will extend only to the scan conditions; a partial index predicate (if any) is never rechecked by `amgettupple` callers.

If the index supports index-only scans (i.e., `amcanreturn` returns true for any of its columns), then on success the AM must also check `scan->xs_want_itup`, and if that is true it must return the originally indexed data for the index entry. Columns for which `amcanreturn` returns false can be returned as nulls. The data can be returned in the form of an `IndexTuple` pointer stored at `scan->xs_itup`, with tuple descriptor `scan->xs_itupdesc`; or in the form of a `HeapTuple` pointer stored at `scan->xs_hitup`, with tuple descriptor `scan->xs_hitupdesc`. (The latter format should be used when reconstructing data that might possibly not fit into an `IndexTuple`.) In either case, management of the data referenced by the pointer is the access method's responsibility. The data must remain good at least until the next `amgettupple`, `amrescan`, or `amendscan` call for the scan.

The `amgettupple` function need only be provided if the access method supports “plain” index scans. If it doesn't, the `amgettupple` field in its `IndexAmRoutine` struct must be set to NULL.

```
int64  
amgetbitmap (IndexScanDesc scan,  
            TIDBitmap *tbm);
```

Fetch all tuples in the given scan and add them to the caller-supplied `TIDBitmap` (that is, OR the set of tuple IDs into whatever set is already in the bitmap). The number of tuples fetched is

returned (this might be just an approximate count, for instance some AMs do not detect duplicates). While inserting tuple IDs into the bitmap, `amgetbitmap` can indicate that rechecking of the scan conditions is required for specific tuple IDs. This is analogous to the `xs_recheck` output parameter of `amgettupple`. Note: in the current implementation, support for this feature is conflated with support for lossy storage of the bitmap itself, and therefore callers recheck both the scan conditions and the partial index predicate (if any) for recheckable tuples. That might not always be true, however. `amgetbitmap` and `amgettupple` cannot be used in the same index scan; there are other restrictions too when using `amgetbitmap`, as explained in Section 58.3.

The `amgetbitmap` function need only be provided if the access method supports “bitmap” index scans. If it doesn't, the `amgetbitmap` field in its `IndexAmRoutine` struct must be set to `NULL`.

```
void  
amendscan (IndexScanDesc scan);
```

End a scan and release resources. The `scan` struct itself should not be freed, but any locks or pins taken internally by the access method must be released, as well as any other memory allocated by `ambeginscan` and other scan-related functions.

```
void  
ammarkpos (IndexScanDesc scan);
```

Mark current scan position. The access method need only support one remembered scan position per scan.

The `ammarkpos` function need only be provided if the access method supports ordered scans. If it doesn't, the `ammarkpos` field in its `IndexAmRoutine` struct may be set to `NULL`.

```
void  
amrestrpos (IndexScanDesc scan);
```

Restore the scan to the most recently marked position.

The `amrestrpos` function need only be provided if the access method supports ordered scans. If it doesn't, the `amrestrpos` field in its `IndexAmRoutine` struct may be set to `NULL`.

In addition to supporting ordinary index scans, some types of index may wish to support *parallel index scans*, which allow multiple backends to cooperate in performing an index scan. The index access method should arrange things so that each cooperating process returns a subset of the tuples that would be performed by an ordinary, non-parallel index scan, but in such a way that the union of those subsets is equal to the set of tuples that would be returned by an ordinary, non-parallel index scan. Furthermore, while there need not be any global ordering of tuples returned by a parallel scan, the ordering of that subset of tuples returned within each cooperating backend must match the requested ordering. The following functions may be implemented to support parallel index scans:

```
Size  
amestimateparallelscale (void);
```

Estimate and return the number of bytes of dynamic shared memory which the access method will be needed to perform a parallel scan. (This number is in addition to, not in lieu of, the amount of space needed for AM-independent data in `ParallelIndexScanDescData`.)

It is not necessary to implement this function for access methods which do not support parallel scans or for which the number of additional bytes of storage required is zero.

```
void  
aminitparallelscale (void *target);
```

This function will be called to initialize dynamic shared memory at the beginning of a parallel scan. *target* will point to at least the number of bytes previously returned by `amestimateparallelscore`, and this function may use that amount of space to store whatever data it wishes.

It is not necessary to implement this function for access methods which do not support parallel scans or in cases where the shared memory space required needs no initialization.

```
void  
amparallelrescan (IndexScanDesc scan);
```

This function, if implemented, will be called when a parallel index scan must be restarted. It should reset any shared state set up by `aminitparallelscore` such that the scan will be restarted from the beginning.

## 58.3. Index Scanning

In an index scan, the index access method is responsible for regurgitating the TIDs of all the tuples it has been told about that match the *scan keys*. The access method is *not* involved in actually fetching those tuples from the index's parent table, nor in determining whether they pass the scan's visibility test or other conditions.

A scan key is the internal representation of a `WHERE` clause of the form *index\_key operator constant*, where the index key is one of the columns of the index and the operator is one of the members of the operator family associated with that index column. An index scan has zero or more scan keys, which are implicitly ANDed — the returned tuples are expected to satisfy all the indicated conditions.

The access method can report that the index is *lossy*, or requires rechecks, for a particular query. This implies that the index scan will return all the entries that pass the scan key, plus possibly additional entries that do not. The core system's index-scan machinery will then apply the index conditions again to the heap tuple to verify whether or not it really should be selected. If the recheck option is not specified, the index scan must return exactly the set of matching entries.

Note that it is entirely up to the access method to ensure that it correctly finds all and only the entries passing all the given scan keys. Also, the core system will simply hand off all the `WHERE` clauses that match the index keys and operator families, without any semantic analysis to determine whether they are redundant or contradictory. As an example, given `WHERE x > 4 AND x > 14` where *x* is a b-tree indexed column, it is left to the b-tree `amrescan` function to realize that the first scan key is redundant and can be discarded. The extent of preprocessing needed during `amrescan` will depend on the extent to which the index access method needs to reduce the scan keys to a “normalized” form.

Some access methods return index entries in a well-defined order, others do not. There are actually two different ways that an access method can support sorted output:

- Access methods that always return entries in the natural ordering of their data (such as `btree`) should set `amcanorder` to true. Currently, such access methods must use `btree-compatible` strategy numbers for their equality and ordering operators.
- Access methods that support ordering operators should set `amcanorderbyop` to true. This indicates that the index is capable of returning entries in an order satisfying `ORDER BY index_key operator constant`. Scan modifiers of that form can be passed to `amrescan` as described previously.

The `amgettuple` function has a `direction` argument, which can be either `ForwardScanDirection` (the normal case) or `BackwardScanDirection`. If the first call after `amrescan` specifies `BackwardScanDirection`, then the set of matching index entries is to be scanned back-to-front rather than in the normal front-to-back direction, so `amgettuple` must return the last matching tuple in the index, rather than the first one as it normally would. (This will

only occur for access methods that set `amcanorder` to true.) After the first call, `amgettupple` must be prepared to advance the scan in either direction from the most recently returned entry. (But if `amcanbackward` is false, all subsequent calls will have the same direction as the first one.)

Access methods that support ordered scans must support “marking” a position in a scan and later returning to the marked position. The same position might be restored multiple times. However, only one position need be remembered per scan; a new `ammarkpos` call overrides the previously marked position. An access method that does not support ordered scans need not provide `ammarkpos` and `amrestrpos` functions in `IndexAmRoutine`; set those pointers to NULL instead.

Both the scan position and the mark position (if any) must be maintained consistently in the face of concurrent insertions or deletions in the index. It is OK if a freshly-inserted entry is not returned by a scan that would have found the entry if it had existed when the scan started, or for the scan to return such an entry upon rescanning or backing up even though it had not been returned the first time through. Similarly, a concurrent delete might or might not be reflected in the results of a scan. What is important is that insertions or deletions not cause the scan to miss or multiply return entries that were not themselves being inserted or deleted.

If the index stores the original indexed data values (and not some lossy representation of them), it is useful to support index-only scans, in which the index returns the actual data not just the TID of the heap tuple. This will only avoid I/O if the visibility map shows that the TID is on an all-visible page; else the heap tuple must be visited anyway to check MVCC visibility. But that is no concern of the access method's.

Instead of using `amgettupple`, an index scan can be done with `amgetbitmap` to fetch all tuples in one call. This can be noticeably more efficient than `amgettupple` because it allows avoiding lock/unlock cycles within the access method. In principle `amgetbitmap` should have the same effects as repeated `amgettupple` calls, but we impose several restrictions to simplify matters. First of all, `amgetbitmap` returns all tuples at once and marking or restoring scan positions isn't supported. Secondly, the tuples are returned in a bitmap which doesn't have any specific ordering, which is why `amgetbitmap` doesn't take a `direction` argument. (Ordering operators will never be supplied for such a scan, either.) Also, there is no provision for index-only scans with `amgetbitmap`, since there is no way to return the contents of index tuples. Finally, `amgetbitmap` does not guarantee any locking of the returned tuples, with implications spelled out in Section 58.4.

Note that it is permitted for an access method to implement only `amgetbitmap` and not `amgettupple`, or vice versa, if its internal implementation is unsuited to one API or the other.

## 58.4. Index Locking Considerations

Index access methods must handle concurrent updates of the index by multiple processes. The core LightDB system obtains `AccessShareLock` on the index during an index scan, and `RowExclusiveLock` when updating the index (including plain `VACUUM`). Since these lock types do not conflict, the access method is responsible for handling any fine-grained locking it might need. An `ACCESS EXCLUSIVE` lock on the index as a whole will be taken only during index creation, destruction, or `REINDEX (SHARE UPDATE EXCLUSIVE)` is taken instead with `CONCURRENTLY`).

Building an index type that supports concurrent updates usually requires extensive and subtle analysis of the required behavior. For the b-tree and hash index types, you can read about the design decisions involved in `src/backend/access/nbtree/README` and `src/backend/access/hash/README`.

Aside from the index's own internal consistency requirements, concurrent updates create issues about consistency between the parent table (the *heap*) and the index. Because LightDB separates accesses and updates of the heap from those of the index, there are windows in which the index might be inconsistent with the heap. We handle this problem with the following rules:

- A new heap entry is made before making its index entries. (Therefore a concurrent index scan is likely to fail to see the heap entry. This is okay because the index reader would be uninterested in an uncommitted row anyway. But see Section 58.5.)



- When a heap entry is to be deleted (by `VACUUM`), all its index entries must be removed first.
- An index scan must maintain a pin on the index page holding the item last returned by `amgettuple`, and `ambulkdelete` cannot delete entries from pages that are pinned by other backends. The need for this rule is explained below.

Without the third rule, it is possible for an index reader to see an index entry just before it is removed by `VACUUM`, and then to arrive at the corresponding heap entry after that was removed by `VACUUM`. This creates no serious problems if that item number is still unused when the reader reaches it, since an empty item slot will be ignored by `heap_fetch()`. But what if a third backend has already re-used the item slot for something else? When using an MVCC-compliant snapshot, there is no problem because the new occupant of the slot is certain to be too new to pass the snapshot test. However, with a non-MVCC-compliant snapshot (such as `SnapshotAny`), it would be possible to accept and return a row that does not in fact match the scan keys. We could defend against this scenario by requiring the scan keys to be rechecked against the heap row in all cases, but that is too expensive. Instead, we use a pin on an index page as a proxy to indicate that the reader might still be “in flight” from the index entry to the matching heap entry. Making `ambulkdelete` block on such a pin ensures that `VACUUM` cannot delete the heap entry before the reader is done with it. This solution costs little in run time, and adds blocking overhead only in the rare cases where there actually is a conflict.

This solution requires that index scans be “synchronous”: we have to fetch each heap tuple immediately after scanning the corresponding index entry. This is expensive for a number of reasons. An “asynchronous” scan in which we collect many TIDs from the index, and only visit the heap tuples sometime later, requires much less index locking overhead and can allow a more efficient heap access pattern. Per the above analysis, we must use the synchronous approach for non-MVCC-compliant snapshots, but an asynchronous scan is workable for a query using an MVCC snapshot.

In an `amgetbitmap` index scan, the access method does not keep an index pin on any of the returned tuples. Therefore it is only safe to use such scans with MVCC-compliant snapshots.

When the `ampredlocks` flag is not set, any scan using that index access method within a serializable transaction will acquire a nonblocking predicate lock on the full index. This will generate a read-write conflict with the insert of any tuple into that index by a concurrent serializable transaction. If certain patterns of read-write conflicts are detected among a set of concurrent serializable transactions, one of those transactions may be canceled to protect data integrity. When the flag is set, it indicates that the index access method implements finer-grained predicate locking, which will tend to reduce the frequency of such transaction cancellations.

## 58.5. Index Uniqueness Checks

LightDB enforces SQL uniqueness constraints using *unique indexes*, which are indexes that disallow multiple entries with identical keys. An access method that supports this feature sets `amcanunique` true. (At present, only b-tree supports it.) Columns listed in the `INCLUDE` clause are not considered when enforcing uniqueness.

Because of MVCC, it is always necessary to allow duplicate entries to exist physically in an index: the entries might refer to successive versions of a single logical row. The behavior we actually want to enforce is that no MVCC snapshot could include two rows with equal index keys. This breaks down into the following cases that must be checked when inserting a new row into a unique index:

- If a conflicting valid row has been deleted by the current transaction, it's okay. (In particular, since an `UPDATE` always deletes the old row version before inserting the new version, this will allow an `UPDATE` on a row without changing the key.)
- If a conflicting row has been inserted by an as-yet-uncommitted transaction, the would-be inserter must wait to see if that transaction commits. If it rolls back then there is no conflict. If it commits without deleting the conflicting row again, there is a uniqueness violation. (In practice we just wait for the other transaction to end and then redo the visibility check in toto.)

- Similarly, if a conflicting valid row has been deleted by an as-yet-uncommitted transaction, the would-be inserter must wait for that transaction to commit or abort, and then repeat the test.

Furthermore, immediately before reporting a uniqueness violation according to the above rules, the access method must recheck the liveness of the row being inserted. If it is committed dead then no violation should be reported. (This case cannot occur during the ordinary scenario of inserting a row that's just been created by the current transaction. It can happen during `CREATE UNIQUE INDEX CONCURRENTLY`, however.)

We require the index access method to apply these tests itself, which means that it must reach into the heap to check the commit status of any row that is shown to have a duplicate key according to the index contents. This is without a doubt ugly and non-modular, but it saves redundant work: if we did a separate probe then the index lookup for a conflicting row would be essentially repeated while finding the place to insert the new row's index entry. What's more, there is no obvious way to avoid race conditions unless the conflict check is an integral part of insertion of the new index entry.

If the unique constraint is deferrable, there is additional complexity: we need to be able to insert an index entry for a new row, but defer any uniqueness-violation error until end of statement or even later. To avoid unnecessary repeat searches of the index, the index access method should do a preliminary uniqueness check during the initial insertion. If this shows that there is definitely no conflicting live tuple, we are done. Otherwise, we schedule a recheck to occur when it is time to enforce the constraint. If, at the time of the recheck, both the inserted tuple and some other tuple with the same key are live, then the error must be reported. (Note that for this purpose, “live” actually means “any tuple in the index entry's HOT chain is live”.) To implement this, the `amininsert` function is passed a `checkUnique` parameter having one of the following values:

- `UNIQUE_CHECK_NO` indicates that no uniqueness checking should be done (this is not a unique index).
- `UNIQUE_CHECK_YES` indicates that this is a non-deferrable unique index, and the uniqueness check must be done immediately, as described above.
- `UNIQUE_CHECK_PARTIAL` indicates that the unique constraint is deferrable. LightDB will use this mode to insert each row's index entry. The access method must allow duplicate entries into the index, and report any potential duplicates by returning false from `amininsert`. For each row for which false is returned, a deferred recheck will be scheduled.

The access method must identify any rows which might violate the unique constraint, but it is not an error for it to report false positives. This allows the check to be done without waiting for other transactions to finish; conflicts reported here are not treated as errors and will be rechecked later, by which time they may no longer be conflicts.

- `UNIQUE_CHECK_EXISTING` indicates that this is a deferred recheck of a row that was reported as a potential uniqueness violation. Although this is implemented by calling `amininsert`, the access method must *not* insert a new index entry in this case. The index entry is already present. Rather, the access method must check to see if there is another live index entry. If so, and if the target row is also still live, report error.

It is recommended that in a `UNIQUE_CHECK_EXISTING` call, the access method further verify that the target row actually does have an existing entry in the index, and report error if not. This is a good idea because the index tuple values passed to `amininsert` will have been recomputed. If the index definition involves functions that are not really immutable, we might be checking the wrong area of the index. Checking that the target row is found in the recheck verifies that we are scanning for the same tuple values as were used in the original insertion.

## 58.6. Index Cost Estimation Functions

The `amcostestimate` function is given information describing a possible index scan, including lists of `WHERE` and `ORDER BY` clauses that have been determined to be usable with the index. It

must return estimates of the cost of accessing the index and the selectivity of the WHERE clauses (that is, the fraction of parent-table rows that will be retrieved during the index scan). For simple cases, nearly all the work of the cost estimator can be done by calling standard routines in the optimizer; the point of having an `amcostestimate` function is to allow index access methods to provide index-type-specific knowledge, in case it is possible to improve on the standard estimates.

Each `amcostestimate` function must have the signature:

```
void  
amcostestimate (PlannerInfo *root,  
                IndexPath *path,  
                double loop_count,  
                Cost *indexStartupCost,  
                Cost *indexTotalCost,  
                Selectivity *indexSelectivity,  
                double *indexCorrelation,  
                double *indexPages);
```

The first three parameters are inputs:

*root*

The planner's information about the query being processed.

*path*

The index access path being considered. All fields except cost and selectivity values are valid.

*loop\_count*

The number of repetitions of the index scan that should be factored into the cost estimates. This will typically be greater than one when considering a parameterized scan for use in the inside of a nestloop join. Note that the cost estimates should still be for just one scan; a larger *loop\_count* means that it may be appropriate to allow for some caching effects across multiple scans.

The last five parameters are pass-by-reference outputs:

*\*indexStartupCost*

Set to cost of index start-up processing

*\*indexTotalCost*

Set to total cost of index processing

*\*indexSelectivity*

Set to index selectivity

*\*indexCorrelation*

Set to correlation coefficient between index scan order and underlying table's order

*\*indexPages*

Set to number of index leaf pages

Note that cost estimate functions must be written in C, not in SQL or any available procedural language, because they must access internal data structures of the planner/optimizer.

The index access costs should be computed using the parameters used by `src/backend/optimizer/path/costsize.c`: a sequential disk block fetch has cost `seq_page_cost`, a

nonsequential fetch has cost `random_page_cost`, and the cost of processing one index row should usually be taken as `cpu_index_tuple_cost`. In addition, an appropriate multiple of `cpu_operator_cost` should be charged for any comparison operators invoked during index processing (especially evaluation of the `indexquals` themselves).

The access costs should include all disk and CPU costs associated with scanning the index itself, but *not* the costs of retrieving or processing the parent-table rows that are identified by the index.

The “start-up cost” is the part of the total scan cost that must be expended before we can begin to fetch the first row. For most indexes this can be taken as zero, but an index type with a high start-up cost might want to set it nonzero.

The `indexSelectivity` should be set to the estimated fraction of the parent table rows that will be retrieved during the index scan. In the case of a lossy query, this will typically be higher than the fraction of rows that actually pass the given qual conditions.

The `indexCorrelation` should be set to the correlation (ranging between -1.0 and 1.0) between the index order and the table order. This is used to adjust the estimate for the cost of fetching rows from the parent table.

The `indexPages` should be set to the number of leaf pages. This is used to estimate the number of workers for parallel index scan.

When `loop_count` is greater than one, the returned numbers should be averages expected for any one scan of the index.

## Cost Estimation

A typical cost estimator will proceed as follows:

1. Estimate and return the fraction of parent-table rows that will be visited based on the given qual conditions. In the absence of any index-type-specific knowledge, use the standard optimizer function `clauselist_selectivity()`:

```
*indexSelectivity = clauselist_selectivity(root, path->indexquals,
                                           path->indexinfo->rel->reloid,
                                           JOIN_INNER, NULL);
```

2. Estimate the number of index rows that will be visited during the scan. For many index types this is the same as `indexSelectivity` times the number of rows in the index, but it might be more. (Note that the index's size in pages and rows is available from the `path->indexinfo` struct.)
3. Estimate the number of index pages that will be retrieved during the scan. This might be just `indexSelectivity` times the index's size in pages.
4. Compute the index access cost. A generic estimator might do this:

```
/*
 * Our generic assumption is that the index pages will be read
 * sequentially, so they cost seq_page_cost each, not
 * random_page_cost.
 * Also, we charge for evaluation of the indexquals at each
 * index row.
 * All the costs are assumed to be paid incrementally during
 * the scan.
```

```
*/  
cost_qual_eval(&index_qual_cost, path->indexquals, root);  
*indexStartupCost = index_qual_cost.startup;  
*indexTotalCost = seq_page_cost * numIndexPages +  
    (cpu_index_tuple_cost + index_qual_cost.per_tuple) *  
    numIndexTuples;
```

However, the above does not account for amortization of index reads across repeated index scans.

5. Estimate the index correlation. For a simple ordered index on a single field, this can be retrieved from `pg_statistic`. If the correlation is not known, the conservative estimate is zero (no correlation).

Examples of cost estimator functions can be found in `src/backend/utils/adt/selfuncs.c`.

---

# Chapter 59. Generic WAL Records

Although all built-in WAL-logged modules have their own types of WAL records, there is also a generic WAL record type, which describes changes to pages in a generic way. This is useful for extensions that provide custom access methods, because they cannot register their own WAL redo routines.

The API for constructing generic WAL records is defined in `access/generic_xlog.h` and implemented in `access/transam/generic_xlog.c`.

To perform a WAL-logged data update using the generic WAL record facility, follow these steps:

1. `state = GenericXLogStart(relation)` — start construction of a generic WAL record for the given relation.
2. `page = GenericXLogRegisterBuffer(state, buffer, flags)` — register a buffer to be modified within the current generic WAL record. This function returns a pointer to a temporary copy of the buffer's page, where modifications should be made. (Do not modify the buffer's contents directly.) The third argument is a bit mask of flags applicable to the operation. Currently the only such flag is `GENERIC_XLOG_FULL_IMAGE`, which indicates that a full-page image rather than a delta update should be included in the WAL record. Typically this flag would be set if the page is new or has been rewritten completely. `GenericXLogRegisterBuffer` can be repeated if the WAL-logged action needs to modify multiple pages.
3. Apply modifications to the page images obtained in the previous step.
4. `GenericXLogFinish(state)` — apply the changes to the buffers and emit the generic WAL record.

WAL record construction can be canceled between any of the above steps by calling `GenericXLogAbort(state)`. This will discard all changes to the page image copies.

Please note the following points when using the generic WAL record facility:

- No direct modifications of buffers are allowed! All modifications must be done in copies acquired from `GenericXLogRegisterBuffer()`. In other words, code that makes generic WAL records should never call `BufferGetPage()` for itself. However, it remains the caller's responsibility to pin/unpin and lock/unlock the buffers at appropriate times. Exclusive lock must be held on each target buffer from before `GenericXLogRegisterBuffer()` until after `GenericXLogFinish()`.
- Registrations of buffers (step 2) and modifications of page images (step 3) can be mixed freely, i.e., both steps may be repeated in any sequence. Keep in mind that buffers should be registered in the same order in which locks are to be obtained on them during replay.
- The maximum number of buffers that can be registered for a generic WAL record is `MAX_GENERIC_XLOG_PAGES`. An error will be thrown if this limit is exceeded.
- Generic WAL assumes that the pages to be modified have standard layout, and in particular that there is no useful data between `pd_lower` and `pd_upper`.
- Since you are modifying copies of buffer pages, `GenericXLogStart()` does not start a critical section. Thus, you can safely do memory allocation, error throwing, etc. between `GenericXLogStart()` and `GenericXLogFinish()`. The only actual critical section is present inside `GenericXLogFinish()`. There is no need to worry about calling `GenericXLogAbort()` during an error exit, either.
- `GenericXLogFinish()` takes care of marking buffers dirty and setting their LSNs. You do not need to do this explicitly.

- For unlogged relations, everything works the same except that no actual WAL record is emitted. Thus, you typically do not need to do any explicit checks for unlogged relations.
- The generic WAL redo function will acquire exclusive locks to buffers in the same order as they were registered. After redoing all changes, the locks will be released in the same order.
- If `GENERIC_XLOG_FULL_IMAGE` is not specified for a registered buffer, the generic WAL record contains a delta between the old and the new page images. This delta is based on byte-by-byte comparison. This is not very compact for the case of moving data within a page, and might be improved in the future.

---

# Chapter 60. B-Tree Indexes

## 60.1. Introduction

LightDB includes an implementation of the standard btree (multi-way balanced tree) index data structure. Any data type that can be sorted into a well-defined linear order can be indexed by a btree index. The only limitation is that an index entry cannot exceed approximately one-third of a page (after TOAST compression, if applicable).

Because each btree operator class imposes a sort order on its data type, btree operator classes (or, really, operator families) have come to be used as LightDB's general representation and understanding of sorting semantics. Therefore, they've acquired some features that go beyond what would be needed just to support btree indexes, and parts of the system that are quite distant from the btree AM make use of them.

## 60.2. Behavior of B-Tree Operator Classes

As shown in Table 36.3, a btree operator class must provide five comparison operators,  $<$ ,  $<=$ ,  $=$ ,  $>=$  and  $>$ . One might expect that  $<>$  should also be part of the operator class, but it is not, because it would almost never be useful to use a  $<>$  WHERE clause in an index search. (For some purposes, the planner treats  $<>$  as associated with a btree operator class; but it finds that operator via the  $=$  operator's negator link, rather than from `pg_amop`.)

When several data types share near-identical sorting semantics, their operator classes can be grouped into an operator family. Doing so is advantageous because it allows the planner to make deductions about cross-type comparisons. Each operator class within the family should contain the single-type operators (and associated support functions) for its input data type, while cross-type comparison operators and support functions are “loose” in the family. It is recommendable that a complete set of cross-type operators be included in the family, thus ensuring that the planner can represent any comparison conditions that it deduces from transitivity.

There are some basic assumptions that a btree operator family must satisfy:

- An  $=$  operator must be an equivalence relation; that is, for all non-null values  $A, B, C$  of the data type:
  - $A = A$  is true (*reflexive law*)
  - if  $A = B$ , then  $B = A$  (*symmetric law*)
  - if  $A = B$  and  $B = C$ , then  $A = C$  (*transitive law*)
- A  $<$  operator must be a strong ordering relation; that is, for all non-null values  $A, B, C$ :
  - $A < A$  is false (*irreflexive law*)
  - if  $A < B$  and  $B < C$ , then  $A < C$  (*transitive law*)
- Furthermore, the ordering is total; that is, for all non-null values  $A, B$ :
  - exactly one of  $A < B$ ,  $A = B$ , and  $B < A$  is true (*trichotomy law*)(The trichotomy law justifies the definition of the comparison support function, of course.)

The other three operators are defined in terms of  $=$  and  $<$  in the obvious way, and must act consistently with them.

For an operator family supporting multiple data types, the above laws must hold when  $A, B, C$  are taken from any data types in the family. The transitive laws are the trickiest to ensure, as in cross-type situations they represent statements that the behaviors of two or three different operators are consistent.



As an example, it would not work to put `float8` and `numeric` into the same operator family, at least not with the current semantics that `numeric` values are converted to `float8` for comparison to a `float8`. Because of the limited accuracy of `float8`, this means there are distinct `numeric` values that will compare equal to the same `float8` value, and thus the transitive law would fail.

Another requirement for a multiple-data-type family is that any implicit or binary-coercion casts that are defined between data types included in the operator family must not change the associated sort ordering.

It should be fairly clear why a btree index requires these laws to hold within a single data type: without them there is no ordering to arrange the keys with. Also, index searches using a comparison key of a different data type require comparisons to behave sanely across two data types. The extensions to three or more data types within a family are not strictly required by the btree index mechanism itself, but the planner relies on them for optimization purposes.

## 60.3. B-Tree Support Functions

As shown in Table 36.7, `btree` defines one required and four optional support functions. The five user-defined methods are:

`order`

For each combination of data types that a btree operator family provides comparison operators for, it must provide a comparison support function, registered in `pg_amproc` with support function number 1 and `amproclefttype/amprocrighttype` equal to the left and right data types for the comparison (i.e., the same data types that the matching operators are registered with in `pg_amop`). The comparison function must take two non-null values *A* and *B* and return an `int32` value that is `< 0`, `0`, or `> 0` when *A* `<` *B*, *A* `=` *B*, or *A* `>` *B*, respectively. A null result is disallowed: all values of the data type must be comparable. See `src/backend/access/nbtree/nbtcompare.c` for examples.

If the compared values are of a collatable data type, the appropriate collation OID will be passed to the comparison support function, using the standard `PG_GET_COLLATION()` mechanism.

`sortsupport`

Optionally, a btree operator family may provide *sort support* function(s), registered under support function number 2. These functions allow implementing comparisons for sorting purposes in a more efficient way than naively calling the comparison support function. The APIs involved in this are defined in `src/include/utils/sortsupport.h`.

`in_range`

Optionally, a btree operator family may provide *in\_range* support function(s), registered under support function number 3. These are not used during btree index operations; rather, they extend the semantics of the operator family so that it can support window clauses containing the `RANGE offset PRECEDING` and `RANGE offset FOLLOWING` frame bound types (see Section 4.2.8). Fundamentally, the extra information provided is how to add or subtract an *offset* value in a way that is compatible with the family's data ordering.

An `in_range` function must have the signature

```
in_range(val type1, base type1, offset type2, sub bool, less
        bool)
returns bool
```

*val* and *base* must be of the same type, which is one of the types supported by the operator family (i.e., a type for which it provides an ordering). However, *offset* could be of a different

type, which might be one otherwise unsupported by the family. An example is that the built-in `time_ops` family provides an `in_range` function that has `offset` of type `interval`. A family can provide `in_range` functions for any of its supported types and one or more `offset` types. Each `in_range` function should be entered in `pg_amproc` with `amproclefttype` equal to `type1` and `amprocrighttype` equal to `type2`.

The essential semantics of an `in_range` function depend on the two Boolean flag parameters. It should add or subtract `base` and `offset`, then compare `val` to the result, as follows:

- if `!sub` and `!less`, return `val >= (base + offset)`
- if `!sub` and `less`, return `val <= (base + offset)`
- if `sub` and `!less`, return `val >= (base - offset)`
- if `sub` and `less`, return `val <= (base - offset)`

Before doing so, the function should check the sign of `offset`: if it is less than zero, raise error `ERRCODE_INVALID_PRECEDING_OR_FOLLOWING_SIZE` (22013) with error text like “invalid preceding or following size in window function”. (This is required by the SQL standard, although nonstandard operator families might perhaps choose to ignore this restriction, since there seems to be little semantic necessity for it.) This requirement is delegated to the `in_range` function so that the core code needn't understand what “less than zero” means for a particular data type.

An additional expectation is that `in_range` functions should, if practical, avoid throwing an error if `base + offset` or `base - offset` would overflow. The correct comparison result can be determined even if that value would be out of the data type's range. Note that if the data type includes concepts such as “infinity” or “NaN”, extra care may be needed to ensure that `in_range`'s results agree with the normal sort order of the operator family.

The results of the `in_range` function must be consistent with the sort ordering imposed by the operator family. To be precise, given any fixed values of `offset` and `sub`, then:

- If `in_range` with `less = true` is true for some `val1` and `base`, it must be true for every `val2 <= val1` with the same `base`.
- If `in_range` with `less = true` is false for some `val1` and `base`, it must be false for every `val2 >= val1` with the same `base`.
- If `in_range` with `less = true` is true for some `val` and `base1`, it must be true for every `base2 >= base1` with the same `val`.
- If `in_range` with `less = true` is false for some `val` and `base1`, it must be false for every `base2 <= base1` with the same `val`.

Analogous statements with inverted conditions hold when `less = false`.

If the type being ordered (`type1`) is collatable, the appropriate collation OID will be passed to the `in_range` function, using the standard `PG_GET_COLLATION()` mechanism.

`in_range` functions need not handle NULL inputs, and typically will be marked strict.

`equalimage`

Optionally, a btree operator family may provide `equalimage` (“equality implies image equality”) support functions, registered under support function number 4. These functions allow the core code to determine when it is safe to apply the btree deduplication optimization. Currently, `equalimage` functions are only called when building or rebuilding an index.

An `equalimage` function must have the signature

`equalimage(opcintype oid)` returns `bool`

The return value is static information about an operator class and collation. Returning `true` indicates that the `order` function for the operator class is guaranteed to only return 0 (“arguments are equal”) when its *A* and *B* arguments are also interchangeable without any loss of semantic information. Not registering an `equalimage` function or returning `false` indicates that this condition cannot be assumed to hold.

The `opcintype` argument is the `pg_type.oid` of the data type that the operator class indexes. This is a convenience that allows reuse of the same underlying `equalimage` function across operator classes. If `opcintype` is a collatable data type, the appropriate collation OID will be passed to the `equalimage` function, using the standard `PG_GET_COLLATION()` mechanism.

As far as the operator class is concerned, returning `true` indicates that deduplication is safe (or safe for the collation whose OID was passed to its `equalimage` function). However, the core code will only deem deduplication safe for an index when *every* indexed column uses an operator class that registers an `equalimage` function, and each function actually returns `true` when called.

Image equality is *almost* the same condition as simple bitwise equality. There is one subtle difference: When indexing a varlena data type, the on-disk representation of two image equal datums may not be bitwise equal due to inconsistent application of TOAST compression on input. Formally, when an operator class's `equalimage` function returns `true`, it is safe to assume that the `datum_image_eq()` C function will always agree with the operator class's `order` function (provided that the same collation OID is passed to both the `equalimage` and `order` functions).

The core code is fundamentally unable to deduce anything about the “equality implies image equality” status of an operator class within a multiple-data-type family based on details from other operator classes in the same family. Also, it is not sensible for an operator family to register a cross-type `equalimage` function, and attempting to do so will result in an error. This is because “equality implies image equality” status does not just depend on sorting/equality semantics, which are more or less defined at the operator family level. In general, the semantics that one particular data type implements must be considered separately.

The convention followed by the operator classes included with the core LightDB distribution is to register a stock, generic `equalimage` function. Most operator classes register `btequalimage()`, which indicates that deduplication is safe unconditionally. Operator classes for collatable data types such as `text` register `btvarstrequalimage()`, which indicates that deduplication is safe with deterministic collations. Best practice for third-party extensions is to register their own custom function to retain control.

## options

Optionally, a B-tree operator family may provide `options` (“operator class specific options”) support functions, registered under support function number 5. These functions define a set of user-visible parameters that control operator class behavior.

An `options` support function must have the signature

`options(relopts local_relopts *)` returns `void`

The function is passed a pointer to a `local_relopts` struct, which needs to be filled with a set of operator class specific options. The options can be accessed from other support functions using the `PG_HAS_OPCLASS_OPTIONS()` and `PG_GET_OPCLASS_OPTIONS()` macros.

Currently, no B-Tree operator class has an `options` support function. B-tree doesn't allow flexible representation of keys like GiST, GIN. So, `options` probably doesn't have much application in the current B-tree index access method. Nevertheless, this support function was

added to B-tree for uniformity, and will probably find uses during further evolution of B-tree in LightDB.

## 60.4. Implementation

This section covers B-Tree index implementation details that may be of use to advanced users. See `src/backend/access/nbtree/README` in the source distribution for a much more detailed, internals-focused description of the B-Tree implementation.

### 60.4.1. B-Tree Structure

LightDB B-Tree indexes are multi-level tree structures, where each level of the tree can be used as a doubly-linked list of pages. A single metapage is stored in a fixed position at the start of the first segment file of the index. All other pages are either leaf pages or internal pages. Leaf pages are the pages on the lowest level of the tree. All other levels consist of internal pages. Each leaf page contains tuples that point to table rows. Each internal page contains tuples that point to the next level down in the tree. Typically, over 99% of all pages are leaf pages. Both internal pages and leaf pages use the standard page format described in Section 64.6.

New leaf pages are added to a B-Tree index when an existing leaf page cannot fit an incoming tuple. A *page split* operation makes room for items that originally belonged on the overflowing page by moving a portion of the items to a new page. Page splits must also insert a new *downlink* to the new page in the parent page, which may cause the parent to split in turn. Page splits “cascade upwards” in a recursive fashion. When the root page finally cannot fit a new downlink, a *root page split* operation takes place. This adds a new level to the tree structure by creating a new root page that is one level above the original root page.

### 60.4.2. Deduplication

A duplicate is a leaf page tuple (a tuple that points to a table row) where *all* indexed key columns have values that match corresponding column values from at least one other leaf page tuple in the same index. Duplicate tuples are quite common in practice. B-Tree indexes can use a special, space-efficient representation for duplicates when an optional technique is enabled: *deduplication*.

Deduplication works by periodically merging groups of duplicate tuples together, forming a single *posting list* tuple for each group. The column key value(s) only appear once in this representation. This is followed by a sorted array of TIDs that point to rows in the table. This significantly reduces the storage size of indexes where each value (or each distinct combination of column values) appears several times on average. The latency of queries can be reduced significantly. Overall query throughput may increase significantly. The overhead of routine index vacuuming may also be reduced significantly.

#### Note

B-Tree deduplication is just as effective with “duplicates” that contain a NULL value, even though NULL values are never equal to each other according to the = member of any B-Tree operator class. As far as any part of the implementation that understands the on-disk B-Tree structure is concerned, NULL is just another value from the domain of indexed values.

The deduplication process occurs lazily, when a new item is inserted that cannot fit on an existing leaf page. This prevents (or at least delays) leaf page splits. Unlike GIN posting list tuples, B-Tree posting list tuples do not need to expand every time a new duplicate is inserted; they are merely an alternative physical representation of the original logical contents of the leaf page. This design prioritizes consistent performance with mixed read-write workloads. Most client applications will

at least see a moderate performance benefit from using deduplication. Deduplication is enabled by default.

`CREATE INDEX` and `REINDEX` apply deduplication to create posting list tuples, though the strategy they use is slightly different. Each group of duplicate ordinary tuples encountered in the sorted input taken from the table is merged into a posting list tuple *before* being added to the current pending leaf page. Individual posting list tuples are packed with as many TIDs as possible. Leaf pages are written out in the usual way, without any separate deduplication pass. This strategy is well-suited to `CREATE INDEX` and `REINDEX` because they are once-off batch operations.

Write-heavy workloads that don't benefit from deduplication due to having few or no duplicate values in indexes will incur a small, fixed performance penalty (unless deduplication is explicitly disabled). The `deduplicate_items` storage parameter can be used to disable deduplication within individual indexes. There is never any performance penalty with read-only workloads, since reading posting list tuples is at least as efficient as reading the standard tuple representation. Disabling deduplication isn't usually helpful.

B-Tree indexes are not directly aware that under MVCC, there might be multiple extant versions of the same logical table row; to an index, each tuple is an independent object that needs its own index entry. “Version duplicates” may sometimes accumulate and adversely affect query latency and throughput. This typically occurs with `UPDATE`-heavy workloads where most individual updates cannot apply the HOT optimization (often because at least one indexed column gets modified, necessitating a new set of index tuple versions — one new tuple for *each and every* index). In effect, B-Tree deduplication ameliorates index bloat caused by version churn. Note that even the tuples from a unique index are not necessarily *physically* unique when stored on disk due to version churn. The deduplication optimization is selectively applied within unique indexes. It targets those pages that appear to have version duplicates. The high level goal is to give `VACUUM` more time to run before an “unnecessary” page split caused by version churn can take place.

### Tip

A special heuristic is applied to determine whether a deduplication pass in a unique index should take place. It can often skip straight to splitting a leaf page, avoiding a performance penalty from wasting cycles on unhelpful deduplication passes. If you're concerned about the overhead of deduplication, consider setting `deduplicate_items = off` selectively. Leaving deduplication enabled in unique indexes has little downside.

Deduplication cannot be used in all cases due to implementation-level restrictions. Deduplication safety is determined when `CREATE INDEX` or `REINDEX` is run.

Note that deduplication is deemed unsafe and cannot be used in the following cases involving semantically significant differences among equal datums:

- `text`, `varchar`, and `char` cannot use deduplication when a *nondeterministic* collation is used. Case and accent differences must be preserved among equal datums.
- `numeric` cannot use deduplication. Numeric display scale must be preserved among equal datums.
- `jsonb` cannot use deduplication, since the `jsonb` B-Tree operator class uses `numeric` internally.
- `float4` and `float8` cannot use deduplication. These types have distinct representations for `-0` and `0`, which are nevertheless considered equal. This difference must be preserved.

There is one further implementation-level restriction that may be lifted in a future version of LightDB:

- Container types (such as composite types, arrays, or range types) cannot use deduplication.

There is one further implementation-level restriction that applies regardless of the operator class or collation used:

- INCLUDE indexes can never use deduplication.

---

# Chapter 61. GiST Indexes

## 61.1. Introduction

GiST stands for Generalized Search Tree. It is a balanced, tree-structured access method, that acts as a base template in which to implement arbitrary indexing schemes. B-trees, R-trees and many other indexing schemes can be implemented in GiST.

One advantage of GiST is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert.

Some of the information here is derived from the University of California at Berkeley's GiST Indexing Project web site<sup>1</sup> and Marcel Kornacker's thesis, Access Methods for Next-Generation Database Systems<sup>2</sup>. The GiST implementation in LightDB is primarily maintained by Teodor Sigaev and Oleg Bartunov, and there is more information on their web site<sup>3</sup>.

## 61.2. Built-in Operator Classes

The core LightDB distribution includes the GiST operator classes shown in Table 61.1. (Some of the optional modules described in Appendix F provide additional GiST operator classes.)

**Table 61.1. Built-in GiST Operator Classes**

Name	Indexed Data Type	Indexable Operators	Ordering Operators
box_ops	box	&& &> &< &<   >> << <<   <@ @> @   &>   >> ~ ~=	<->
circle_ops	circle	&& &> &< &<   >> << <<   <@ @> @   &>   >> ~ ~=	<->
inet_ops	inet, cidr	&& >> >>= > >= <> << <<= < <= =	
point_ops	point	>> >^ << <@ <@ <@ <^ ~=	<->
poly_ops	polygon	&& &> &< &<   >> << <<   <@ @> @   &>   >> ~ ~=	<->
range_ops	any range type	&& &> &< >> << <@ -   - = @> @>	
tsquery_ops	tsquery	<@ @>	
tsvector_ops	tsvector	@@	

For historical reasons, the `inet_ops` operator class is not the default class for types `inet` and `cidr`. To use it, mention the class name in `CREATE INDEX`, for example

```
CREATE INDEX ON my_table USING GIST (my_inet_column inet_ops);
```

---

<sup>1</sup> <http://gist.cs.berkeley.edu/>

<sup>2</sup> <http://www.sai.msu.su/~megeera/postgres/gist/papers/concurrency/access-methods-for-next-generation.pdf.gz>

<sup>3</sup> <http://www.sai.msu.su/~megeera/postgres/gist/>

## 61.3. Extensibility

Traditionally, implementing a new index access method meant a lot of difficult work. It was necessary to understand the inner workings of the database, such as the lock manager and Write-Ahead Log. The GiST interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GiST layer itself takes care of concurrency, logging and searching the tree structure.

This extensibility should not be confused with the extensibility of the other standard search trees in terms of the data they can handle. For example, LightDB supports extensible B-trees and hash indexes. That means that you can use LightDB to build a B-tree or hash over any data type you want. But B-trees only support range predicates ( $<$ ,  $=$ ,  $>$ ), and hash indexes only support equality queries.

So if you index, say, an image collection with a LightDB B-tree, you can only issue queries such as “is imagex equal to imagey”, “is imagex less than imagey” and “is imagex greater than imagey”. Depending on how you define “equals”, “less than” and “greater than” in this context, this could be useful. However, by using a GiST based index, you could create ways to ask domain-specific questions, perhaps “find all images of horses” or “find all over-exposed images”.

All it takes to get a GiST access method up and running is to implement several user-defined methods, which define the behavior of keys in the tree. Of course these methods have to be pretty fancy to support fancy queries, but for all the standard queries (B-trees, R-trees, etc.) they're relatively straightforward. In short, GiST combines extensibility along with generality, code reuse, and a clean interface.

There are five methods that an index operator class for GiST must provide, and five that are optional. Correctness of the index is ensured by proper implementation of the same, `consistent` and `union` methods, while efficiency (size and speed) of the index will depend on the `penalty` and `picksplit` methods. Two optional methods are `compress` and `decompress`, which allow an index to have internal tree data of a different type than the data it indexes. The leaves are to be of the indexed data type, while the other tree nodes can be of any C struct (but you still have to follow LightDB data type rules here, see about `varlena` for variable sized data). If the tree's internal data type exists at the SQL level, the `STORAGE` option of the `CREATE OPERATOR CLASS` command can be used. The optional eighth method is `distance`, which is needed if the operator class wishes to support ordered scans (nearest-neighbor searches). The optional ninth method `fetch` is needed if the operator class wishes to support index-only scans, except when the `compress` method is omitted. The optional tenth method `options` is needed if the operator class provides the user-specified parameters.

`consistent`

Given an index entry `p` and a query value `q`, this function determines whether the index entry is “consistent” with the query; that is, could the predicate “`indexed_column indexable_operator q`” be true for any row represented by the index entry? For a leaf index entry this is equivalent to testing the indexable condition, while for an internal tree node this determines whether it is necessary to scan the subtree of the index represented by the tree node. When the result is `true`, a `recheck` flag must also be returned. This indicates whether the predicate is certainly true or only possibly true. If `recheck = false` then the index has tested the predicate condition exactly, whereas if `recheck = true` the row is only a candidate match. In that case the system will automatically evaluate the `indexable_operator` against the actual row value to see if it is really a match. This convention allows GiST to support both lossless and lossy index structures.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_consistent(internal, data_type,
    smallint, oid, internal)
RETURNS bool
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```



And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_consistent);

Datum
my_consistent(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber)
    PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    bool *recheck = (bool *) PG_GETARG_POINTER(4);
    data_type *key = DatumGetDataTypes(entry->key);
    bool retval;

    /*
     * determine return value as a function of strategy, key and
     * query.
     *
     * Use GIST_LEAF(entry) to know where you're called in the
     * index tree,
     * which comes handy when supporting the = operator for
     * example (you could
     * check for non empty union() in non-leaf nodes and
     * equality in leaf
     * nodes).
     */

    *recheck = true; /* or false if check is exact */

    PG_RETURN_BOOL(retval);
}
```

Here, `key` is an element in the index and `query` the value being looked up in the index. The `StrategyNumber` parameter indicates which operator of your operator class is being applied — it matches one of the operator numbers in the `CREATE OPERATOR CLASS` command.

Depending on which operators you have included in the class, the data type of `query` could vary with the operator, since it will be whatever type is on the righthand side of the operator, which might be different from the indexed data type appearing on the lefthand side. (The above code skeleton assumes that only one type is possible; if not, fetching the `query` argument value would have to depend on the operator.) It is recommended that the SQL declaration of the `consistent` function use the `opclass`'s indexed data type for the `query` argument, even though the actual type might be something else depending on the operator.

`union`

This method consolidates information in the tree. Given a set of entries, this function generates a new index entry that represents all the given entries.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_union(internal, internal)
RETURNS storage_type
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_union);

Datum
my_union(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *)
    PG_GETARG_POINTER(0);
    GISTENTRY *ent = entryvec->vector;
    data_type *out,
               *tmp,
               *old;
    int        numranges,
               i = 0;

    numranges = entryvec->n;
    tmp = DatumGetDataTypes(ent[0].key);
    out = tmp;

    if (numranges == 1)
    {
        out = data_type_deep_copy(tmp);

        PG_RETURN_DATA_TYPE_P(out);
    }

    for (i = 1; i < numranges; i++)
    {
        old = out;
        tmp = DatumGetDataTypes(ent[i].key);
        out = my_union_implementation(out, tmp);
    }

    PG_RETURN_DATA_TYPE_P(out);
}
```

As you can see, in this skeleton we're dealing with a data type where `union(X, Y, Z) = union(union(X, Y), Z)`. It's easy enough to support data types where this is not the case, by implementing the proper union algorithm in this GiST support method.

The result of the union function must be a value of the index's storage type, whatever that is (it might or might not be different from the indexed column's type). The union function should return a pointer to newly `palloc()`ed memory. You can't just return the input value as-is, even if there is no type change.

As shown above, the union function's first internal argument is actually a `GistEntryVector` pointer. The second argument is a pointer to an integer variable, which can be ignored. (It used to be required that the union function store the size of its result value into that variable, but this is no longer necessary.)

#### `compress`

Converts a data item into a format suitable for physical storage in an index page. If the `compress` method is omitted, data items are stored in the index without modification.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_compress(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_compress);

Datum
my_compress(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY *retval;

    if (entry->leafkey)
    {
        /* replace entry->key with a compressed version */
        compressed_data_type *compressed_data =
        palloc(sizeof(compressed_data_type));

        /* fill *compressed_data from entry->key ... */

        retval = palloc(sizeof(GISTENTRY));
        gistentryinit(*retval, PointerGetDatum(compressed_data),
                      entry->rel, entry->page, entry->offset,
FALSE);
    }
    else
    {
        /* typically we needn't do anything with non-leaf
entries */
        retval = entry;
    }

    PG_RETURN_POINTER(retval);
}
```

You have to adapt *compressed\_data\_type* to the specific type you're converting to in order to compress your leaf nodes, of course.

#### decompress

Converts the stored representation of a data item into a format that can be manipulated by the other GiST methods in the operator class. If the `decompress` method is omitted, it is assumed that the other GiST methods can work directly on the stored data format. (`decompress` is not necessarily the reverse of the `compress` method; in particular, if `compress` is lossy then it's impossible for `decompress` to exactly reconstruct the original data. `decompress` is not necessarily equivalent to `fetch`, either, since the other GiST methods might not require full reconstruction of the data.)

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_decompress(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_decompress);

Datum
my_decompress(PG_FUNCTION_ARGS)
{
    PG_RETURN_POINTER(PG_GETARG_POINTER(0));
}
```

The above skeleton is suitable for the case where no decompression is needed. (But, of course, omitting the method altogether is even easier, and is recommended in such cases.)

`penalty`

Returns a value indicating the “cost” of inserting the new entry into a particular branch of the tree. Items will be inserted down the path of least `penalty` in the tree. Values returned by `penalty` should be non-negative. If a negative value is returned, it will be treated as zero.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_penalty(internal, internal,
    internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT; -- in some cases penalty functions need not
    be strict
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_penalty);

Datum
my_penalty(PG_FUNCTION_ARGS)
{
    GISTENTRY *origentry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY *newentry = (GISTENTRY *) PG_GETARG_POINTER(1);
    float *penalty = (float *) PG_GETARG_POINTER(2);
    data_type *orig = DatumGetDataTypes(origentry->key);
    data_type *new = DatumGetDataTypes(newentry->key);

    *penalty = my_penalty_implementation(orig, new);
    PG_RETURN_POINTER(penalty);
}
```

For historical reasons, the `penalty` function doesn't just return a `float` result; instead it has to store the value at the location indicated by the third argument. The return value per se is ignored, though it's conventional to pass back the address of that argument.

The `penalty` function is crucial to good performance of the index. It'll get used at insertion time to determine which branch to follow when choosing where to add the new entry in the tree. At query time, the more balanced the index, the quicker the lookup.

`picksplit`

When an index page split is necessary, this function decides which entries on the page are to stay on the old page, and which are to move to the new page.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_picksplit(internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_picksplit);

Datum
my_picksplit(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *)
PG_GETARG_POINTER(0);
    GIST_SPLITVEC *v = (GIST_SPLITVEC *) PG_GETARG_POINTER(1);
    OffsetNumber maxoff = entryvec->n - 1;
    GISTENTRY *ent = entryvec->vector;
    int i,
        nbytes;
    OffsetNumber *left,
        *right;
    data_type *tmp_union;
    data_type *unionL;
    data_type *unionR;
    GISTENTRY **raw_entryvec;

    maxoff = entryvec->n - 1;
    nbytes = (maxoff + 1) * sizeof(OffsetNumber);

    v->spl_left = (OffsetNumber *) palloc(nbytes);
    left = v->spl_left;
    v->spl_nleft = 0;

    v->spl_right = (OffsetNumber *) palloc(nbytes);
    right = v->spl_right;
    v->spl_nright = 0;

    unionL = NULL;
    unionR = NULL;

    /* Initialize the raw entry vector. */
    raw_entryvec = (GISTENTRY **) malloc(entryvec->n *
sizeof(void *));
    for (i = FirstOffsetNumber; i <= maxoff; i =
OffsetNumberNext(i))
        raw_entryvec[i] = &(entryvec->vector[i]);

    for (i = FirstOffsetNumber; i <= maxoff; i =
OffsetNumberNext(i))
    {
        int real_index = raw_entryvec[i] - entryvec-
>vector;

        tmp_union = DatumGetDataTypes(entryvec-
>vector[real_index].key);
```

```

    Assert(tmp_union != NULL);

    /*
     * Choose where to put the index entries and update
unionL and unionR
     * accordingly. Append the entries to either v->spl_left
or
     * v->spl_right, and care about the counters.
     */

    if (my_choice_is_left(unionL, curl, unionR, curr))
    {
        if (unionL == NULL)
            unionL = tmp_union;
        else
            unionL = my_union_implementation(unionL,
tmp_union);

        *left = real_index;
        ++left;
        ++(v->spl_nleft);
    }
    else
    {
        /*
         * Same on the right
         */
    }
}

v->spl_ldatum = DataTypeGetDatum(unionL);
v->spl_rdatum = DataTypeGetDatum(unionR);
PG_RETURN_POINTER(v);
}

```

Notice that the `picksplit` function's result is delivered by modifying the passed-in `v` structure. The return value per se is ignored, though it's conventional to pass back the address of `v`.

Like `penalty`, the `picksplit` function is crucial to good performance of the index. Designing suitable `penalty` and `picksplit` implementations is where the challenge of implementing well-performing GiST indexes lies.

same

Returns true if two index entries are identical, false otherwise. (An “index entry” is a value of the index's storage type, not necessarily the original indexed column's type.)

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_same(storage_type, storage_type,
    internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_same);

Datum
my_same(PG_FUNCTION_ARGS)
{
    prefix_range *v1 = PG_GETARG_PREFIX_RANGE_P(0);
    prefix_range *v2 = PG_GETARG_PREFIX_RANGE_P(1);
    bool          *result = (bool *) PG_GETARG_POINTER(2);

    *result = my_eq(v1, v2);
    PG_RETURN_POINTER(result);
}

```

For historical reasons, the same function doesn't just return a Boolean result; instead it has to store the flag at the location indicated by the third argument. The return value per se is ignored, though it's conventional to pass back the address of that argument.

#### distance

Given an index entry  $p$  and a query value  $q$ , this function determines the index entry's “distance” from the query value. This function must be supplied if the operator class contains any ordering operators. A query using the ordering operator will be implemented by returning index entries with the smallest “distance” values first, so the results must be consistent with the operator's semantics. For a leaf index entry the result just represents the distance to the index entry; for an internal tree node, the result must be the smallest distance that any child entry could have.

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_distance(internal, data_type,
    smallint, oid, internal)
RETURNS float8
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_distance);

Datum
my_distance(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber)
    PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    /* bool *recheck = (bool *) PG_GETARG_POINTER(4); */
    data_type *key = DatumGetDataTypes(entry->key);
    double     retval;

    /*
     * determine return value as a function of strategy, key and
     * query.
     */

    PG_RETURN_FLOAT8(retval);
}

```

The arguments to the `distance` function are identical to the arguments of the consistent function.

Some approximation is allowed when determining the distance, so long as the result is never greater than the entry's actual distance. Thus, for example, distance to a bounding box is usually sufficient in geometric applications. For an internal tree node, the distance returned must not be greater than the distance to any of the child nodes. If the returned distance is not exact, the function must set `*recheck` to true. (This is not necessary for internal tree nodes; for them, the calculation is always assumed to be inexact.) In this case the executor will calculate the accurate distance after fetching the tuple from the heap, and reorder the tuples if necessary.

If the distance function returns `*recheck = true` for any leaf node, the original ordering operator's return type must be `float8` or `float4`, and the distance function's result values must be comparable to those of the original ordering operator, since the executor will sort using both distance function results and recalculated ordering-operator results. Otherwise, the distance function's result values can be any finite `float8` values, so long as the relative order of the result values matches the order returned by the ordering operator. (Infinity and minus infinity are used internally to handle cases such as nulls, so it is not recommended that distance functions return these values.)

### fetch

Converts the compressed index representation of a data item into the original data type, for index-only scans. The returned data must be an exact, non-lossy copy of the originally indexed value.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_fetch(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

The argument is a pointer to a `GISTENTRY` struct. On entry, its `key` field contains a non-NULL leaf datum in compressed form. The return value is another `GISTENTRY` struct, whose `key` field contains the same datum in its original, uncompressed form. If the opclass's `compress` function does nothing for leaf entries, the `fetch` method can return the argument as-is. Or, if the opclass does not have a `compress` function, the `fetch` method can be omitted as well, since it would necessarily be a no-op.

The matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_fetch);

Datum
my_fetch(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    input_data_type *in = DatumGetPointer(entry->key);
    fetched_data_type *fetched_data;
    GISTENTRY *retval;

    retval = palloc(sizeof(GISTENTRY));
    fetched_data = palloc(sizeof(fetched_data_type));

    /*
     * Convert 'fetched_data' into the a Datum of the original
     * datatype.
     */
}
```



```

    /* fill *retval from fetched_data. */
    gistentryinit(*retval, PointerGetDatum(converted_datum),
                  entry->rel, entry->page, entry->offset,
    FALSE);

    PG_RETURN_POINTER(retval);
}

```

If the compress method is lossy for leaf entries, the operator class cannot support index-only scans, and must not define a fetch function.

#### options

Allows definition of user-visible parameters that control operator class behavior.

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_options(internal)
RETURNS void
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

The function is passed a pointer to a *local\_relopts* struct, which needs to be filled with a set of operator class specific options. The options can be accessed from other support functions using the `PG_HAS_OPCLASS_OPTIONS()` and `PG_GET_OPCLASS_OPTIONS()` macros.

An example implementation of `my_options()` and parameters use from other support functions are given below:

```

typedef enum MyEnumType
{
    MY_ENUM_ON,
    MY_ENUM_OFF,
    MY_ENUM_AUTO
} MyEnumType;

typedef struct
{
    int32   vl_len_;    /* varlena header (do not touch
    directly!) */
    int     int_param;  /* integer parameter */
    double  real_param; /* real parameter */
    MyEnumType enum_param; /* enum parameter */
    int     str_param;  /* string parameter */
} MyOptionsStruct;

/* String representation of enum values */
static relopt_enum_elt_def myEnumValues[] =
{
    {"on", MY_ENUM_ON},
    {"off", MY_ENUM_OFF},
    {"auto", MY_ENUM_AUTO},
    {(const char *) NULL} /* list terminator */
};

static char *str_param_default = "default";

/*

```

---

```

    * Sample validator: checks that string is not longer than 8
    bytes.
    */
static void
validate_my_string_relopt(const char *value)
{
    if (strlen(value) > 8)
        ereport(ERROR,
                (errcode(ERRCODE_INVALID_PARAMETER_VALUE),
                 errmsg("str_param must be at most 8 bytes")));
}

/*
 * Sample filler: switches characters to lower case.
 */
static Size
fill_my_string_relopt(const char *value, void *ptr)
{
    char    *tmp = str_tolower(value, strlen(value),
DEFAULT_COLLATION_OID);
    int     len = strlen(tmp);

    if (ptr)
        strcpy((char *) ptr, tmp);

    pfree(tmp);
    return len + 1;
}

PG_FUNCTION_INFO_V1(my_options);

Datum
my_options(PG_FUNCTION_ARGS)
{
    local_relopts *relopts = (local_relopts *)
PG_GETARG_POINTER(0);

    init_local_reloptions(relopts, sizeof(MyOptionsStruct));
    add_local_int_reloption(relopts, "int_param", "integer
parameter",
                            100, 0, 1000000,
                            offsetof(MyOptionsStruct,
int_param));
    add_local_real_reloption(relopts, "real_param", "real
parameter",
                            1.0, 0.0, 1000000.0,
                            offsetof(MyOptionsStruct,
real_param));
    add_local_enum_reloption(relopts, "enum_param", "enum
parameter",
                            myEnumValues, MY_ENUM_ON,
                            "Valid values are: \"on\", \"off\"
and \"auto\".",
                            offsetof(MyOptionsStruct,
enum_param));
    add_local_string_reloption(relopts, "str_param", "string
parameter",
                               str_param_default,

```

---

```

        &validate_my_string_relopt,
        &fill_my_string_relopt,
        offsetof(MyOptionsStruct,
str_param));

    PG_RETURN_VOID();
}

PG_FUNCTION_INFO_V1(my_compress);

Datum
my_compress(PG_FUNCTION_ARGS)
{
    int    int_param = 100;
    double real_param = 1.0;
    MyEnumType enum_param = MY_ENUM_ON;
    char   *str_param = str_param_default;

    /*
     * Normally, when opclass contains 'options' method, then
     * options are always
     * passed to support functions. However, if you add
     * 'options' method to
     * existing opclass, previously defined indexes have no
     * options, so the
     * check is required.
     */
    if (PG_HAS_OPCLASS_OPTIONS())
    {
        MyOptionsStruct *options = (MyOptionsStruct *)
PG_GET_OPCLASS_OPTIONS();

        int_param = options->int_param;
        real_param = options->real_param;
        enum_param = options->enum_param;
        str_param = GET_STRING_RELOPTION(options, str_param);
    }

    /* the rest implementation of support function */
}

```

Since the representation of the key in GiST is flexible, it may depend on user-specified parameters. For instance, the length of key signature may be specified. See `gtsvector_options()` for example.

All the GiST support methods are normally called in short-lived memory contexts; that is, `CurrentMemoryContext` will get reset after each tuple is processed. It is therefore not very important to worry about pfree'ing everything you palloc. However, in some cases it's useful for a support method to cache data across repeated calls. To do that, allocate the longer-lived data in `fcinfo->flinfo->fn_mcxt`, and keep a pointer to it in `fcinfo->flinfo->fn_extra`. Such data will survive for the life of the index operation (e.g., a single GiST index scan, index build, or index tuple insertion). Be careful to pfree the previous value when replacing a `fn_extra` value, or the leak will accumulate for the duration of the operation.

## 61.4. Implementation

### 61.4.1. GiST Buffering Build

Building large GiST indexes by simply inserting all the tuples tends to be slow, because if the index tuples are scattered across the index and the index is large enough to not fit in cache, the insertions need to perform a lot of random I/O. Beginning in version 9.2, LightDB supports a more efficient method to build GiST indexes based on buffering, which can dramatically reduce the number of random I/Os needed for non-ordered data sets. For well-ordered data sets the benefit is smaller or non-existent, because only a small number of pages receive new tuples at a time, and those pages fit in cache even if the index as whole does not.

However, buffering index build needs to call the `penalty` function more often, which consumes some extra CPU resources. Also, the buffers used in the buffering build need temporary disk space, up to the size of the resulting index. Buffering can also influence the quality of the resulting index, in both positive and negative directions. That influence depends on various factors, like the distribution of the input data and the operator class implementation.

By default, a GiST index build switches to the buffering method when the index size reaches `effective_cache_size`. It can be manually turned on or off by the `buffering` parameter to the `CREATE INDEX` command. The default behavior is good for most cases, but turning buffering off might speed up the build somewhat if the input data is ordered.

## 61.5. Examples

The LightDB source distribution includes several examples of index methods implemented using GiST. The core system currently provides text search support (indexing for `tsvector` and `tsquery`) as well as R-Tree equivalent functionality for some of the built-in geometric data types (see `src/backend/access/gist/gistproc.c`). The following `contrib` modules also contain GiST operator classes:

`btree_gist`

B-tree equivalent functionality for several data types

`cube`

Indexing for multidimensional cubes

`hstore`

Module for storing (key, value) pairs

`intarray`

RD-Tree for one-dimensional array of int4 values

`ltree`

Indexing for tree-like structures

`lt_trgm`

Text similarity using trigram matching

`seg`

Indexing for “float ranges”

---

# Chapter 62. GIN Indexes

## 62.1. Introduction

GIN stands for Generalized Inverted Index. GIN is designed for handling cases where the items to be indexed are composite values, and the queries to be handled by the index need to search for element values that appear within the composite items. For example, the items could be documents, and the queries could be searches for documents containing specific words.

We use the word *item* to refer to a composite value that is to be indexed, and the word *key* to refer to an element value. GIN always stores and searches for keys, not item values per se.

A GIN index stores a set of (key, posting list) pairs, where a *posting list* is a set of row IDs in which the key occurs. The same row ID can appear in multiple posting lists, since an item can contain more than one key. Each key value is stored only once, so a GIN index is very compact for cases where the same key appears many times.

GIN is generalized in the sense that the GIN access method code does not need to know the specific operations that it accelerates. Instead, it uses custom strategies defined for particular data types. The strategy defines how keys are extracted from indexed items and query conditions, and how to determine whether a row that contains some of the key values in a query actually satisfies the query.

One advantage of GIN is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert. This is much the same advantage as using GiST.

The GIN implementation in LightDB is primarily maintained by Teodor Sigaev and Oleg Bartunov. There is more information about GIN on their website<sup>1</sup>.

## 62.2. Built-in Operator Classes

The core LightDB distribution includes the GIN operator classes shown in Table 62.1. (Some of the optional modules described in Appendix F provide additional GIN operator classes.)

**Table 62.1. Built-in GIN Operator Classes**

Name	Indexed Data Type	Indexable Operators
array_ops	anyarray	&& <@ = @>
jsonb_ops	jsonb	? ?& ?   @> @? @@
jsonb_path_ops	jsonb	@> @? @@
tsvector_ops	tsvector	@@ @@@

Of the two operator classes for type `jsonb`, `jsonb_ops` is the default. `jsonb_path_ops` supports fewer operators but offers better performance for those operators. See Section 8.14.4 for details.

## 62.3. Extensibility

The GIN interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GIN layer itself takes care of concurrency, logging and searching the tree structure.

---

<sup>1</sup> <http://www.sai.msu.su/~megeera/wiki/Gin>

All it takes to get a GIN access method working is to implement a few user-defined methods, which define the behavior of keys in the tree and the relationships between keys, indexed items, and indexable queries. In short, GIN combines extensibility with generality, code reuse, and a clean interface.

There are two methods that an operator class for GIN must provide:

```
Datum *extractValue(Datum itemValue, int32 *nkeys, bool **nullFlags)
```

Returns a palloc'd array of keys given an item to be indexed. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys` `bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the item contains no keys.

```
Datum *extractQuery(Datum query, int32 *nkeys, StrategyNumber n, bool
**pmatch, Pointer **extra_data, bool **nullFlags, int32 *searchMode)
```

Returns a palloc'd array of keys given a value to be queried; that is, `query` is the value on the right-hand side of an indexable operator whose left-hand side is the indexed column. `n` is the strategy number of the operator within the operator class (see Section 36.16.2). Often, `extractQuery` will need to consult `n` to determine the data type of `query` and the method it should use to extract key values. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys` `bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the query contains no keys.

`searchMode` is an output argument that allows `extractQuery` to specify details about how the search will be done. If `*searchMode` is set to `GIN_SEARCH_MODE_DEFAULT` (which is the value it is initialized to before call), only items that match at least one of the returned keys are considered candidate matches. If `*searchMode` is set to `GIN_SEARCH_MODE_INCLUDE_EMPTY`, then in addition to items containing at least one matching key, items that contain no keys at all are considered candidate matches. (This mode is useful for implementing is-subset-of operators, for example.) If `*searchMode` is set to `GIN_SEARCH_MODE_ALL`, then all non-null items in the index are considered candidate matches, whether they match any of the returned keys or not. (This mode is much slower than the other two choices, since it requires scanning essentially the entire index, but it may be necessary to implement corner cases correctly. An operator that needs this mode in most cases is probably not a good candidate for a GIN operator class.) The symbols to use for setting this mode are defined in `access/gin.h`.

`pmatch` is an output argument for use when partial match is supported. To use it, `extractQuery` must allocate an array of `*nkeys` `bool`s and store its address at `*pmatch`. Each element of the array should be set to `true` if the corresponding key requires partial match, `false` if not. If `*pmatch` is set to `NULL` then GIN assumes partial match is not required. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not support partial match.

`extra_data` is an output argument that allows `extractQuery` to pass additional data to the `consistent` and `comparePartial` methods. To use it, `extractQuery` must allocate an array of `*nkeys` pointers and store its address at `*extra_data`, then store whatever it wants to into the individual pointers. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not require extra data. If `*extra_data` is set, the whole array is passed to the `consistent` method, and the appropriate element to the `comparePartial` method.

An operator class must also provide a function to check if an indexed item matches the query. It comes in two flavors, a Boolean `consistent` function, and a ternary `triConsistent` function. `triConsistent` covers the functionality of both, so providing `triConsistent` alone is sufficient. However, if the Boolean variant is significantly cheaper to calculate, it can be advantageous

to provide both. If only the Boolean variant is provided, some optimizations that depend on refuting index items before fetching all the keys are disabled.

```
bool consistent(bool check[], StrategyNumber n, Datum query, int32
nkeys, Pointer extra_data[], bool *recheck, Datum queryKeys[], bool
nullFlags[])
```

Returns true if an indexed item satisfies the query operator with strategy number *n* (or might satisfy it, if the *recheck* indication is returned). This function does not have direct access to the indexed item's value, since GIN does not store items explicitly. Rather, what is available is knowledge about which key values extracted from the query appear in a given indexed item. The *check* array has length *nkeys*, which is the same as the number of keys previously returned by *extractQuery* for this query datum. Each element of the *check* array is true if the indexed item contains the corresponding query key, i.e., if (*check*[*i*] == true) the *i*-th key of the *extractQuery* result array is present in the indexed item. The original query datum is passed in case the *consistent* method needs to consult it, and so are the *queryKeys*[ ] and *nullFlags*[ ] arrays previously returned by *extractQuery*. *extra\_data* is the extra-data array returned by *extractQuery*, or NULL if none.

When *extractQuery* returns a null key in *queryKeys*[ ], the corresponding *check*[ ] element is true if the indexed item contains a null key; that is, the semantics of *check*[ ] are like IS NOT DISTINCT FROM. The *consistent* function can examine the corresponding *nullFlags*[ ] element if it needs to tell the difference between a regular value match and a null match.

On success, *\*recheck* should be set to true if the heap tuple needs to be rechecked against the query operator, or false if the index test is exact. That is, a false return value guarantees that the heap tuple does not match the query; a true return value with *\*recheck* set to false guarantees that the heap tuple does match the query; and a true return value with *\*recheck* set to true means that the heap tuple might match the query, so it needs to be fetched and rechecked by evaluating the query operator directly against the originally indexed item.

```
GinTernaryValue      triConsistent(GinTernaryValue      check[],
StrategyNumber n, Datum query, int32 nkeys, Pointer extra_data[],
Datum queryKeys[], bool nullFlags[])
```

*triConsistent* is similar to *consistent*, but instead of Booleans in the *check* vector, there are three possible values for each key: GIN\_TRUE, GIN\_FALSE and GIN\_MAYBE. GIN\_FALSE and GIN\_TRUE have the same meaning as regular Boolean values, while GIN\_MAYBE means that the presence of that key is not known. When GIN\_MAYBE values are present, the function should only return GIN\_TRUE if the item certainly matches whether or not the index item contains the corresponding query keys. Likewise, the function must return GIN\_FALSE only if the item certainly does not match, whether or not it contains the GIN\_MAYBE keys. If the result depends on the GIN\_MAYBE entries, i.e., the match cannot be confirmed or refuted based on the known query keys, the function must return GIN\_MAYBE.

When there are no GIN\_MAYBE values in the *check* vector, a GIN\_MAYBE return value is the equivalent of setting the *recheck* flag in the Boolean *consistent* function.

In addition, GIN must have a way to sort the key values stored in the index. The operator class can define the sort ordering by specifying a comparison method:

```
int compare(Datum a, Datum b)
```

Compares two keys (not indexed items!) and returns an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second. Null keys are never passed to this function.

Alternatively, if the operator class does not provide a *compare* method, GIN will look up the default btree operator class for the index key data type, and use its comparison function. It is recommended to

specify the comparison function in a GIN operator class that is meant for just one data type, as looking up the btree operator class costs a few cycles. However, polymorphic GIN operator classes (such as `array_ops`) typically cannot specify a single comparison function.

An operator class for GIN can optionally supply the following methods:

```
int comparePartial(Datum partial_key, Datum key, StrategyNumber n,
Pointer extra_data)
```

Compare a partial-match query key to an index key. Returns an integer whose sign indicates the result: less than zero means the index key does not match the query, but the index scan should continue; zero means that the index key does match the query; greater than zero indicates that the index scan should stop because no more matches are possible. The strategy number `n` of the operator that generated the partial match query is provided, in case its semantics are needed to determine when to end the scan. Also, `extra_data` is the corresponding element of the extra-data array made by `extractQuery`, or `NULL` if none. Null keys are never passed to this function.

```
void options(local_relopts *relopts)
```

Defines a set of user-visible parameters that control operator class behavior.

The `options` function is passed a pointer to a `local_relopts` struct, which needs to be filled with a set of operator class specific options. The options can be accessed from other support functions using the `PG_HAS_OPCLASS_OPTIONS()` and `PG_GET_OPCLASS_OPTIONS()` macros.

Since both key extraction of indexed values and representation of the key in GIN are flexible, they may depend on user-specified parameters.

To support “partial match” queries, an operator class must provide the `comparePartial` method, and its `extractQuery` method must set the `pmatch` parameter when a partial-match query is encountered. See Section 62.4.2 for details.

The actual data types of the various `Datum` values mentioned above vary depending on the operator class. The item values passed to `extractValue` are always of the operator class's input type, and all key values must be of the class's `STORAGE` type. The type of the `query` argument passed to `extractQuery`, `consistent` and `triConsistent` is whatever is the right-hand input type of the class member operator identified by the strategy number. This need not be the same as the indexed type, so long as key values of the correct type can be extracted from it. However, it is recommended that the SQL declarations of these three support functions use the opclass's indexed data type for the `query` argument, even though the actual type might be something else depending on the operator.

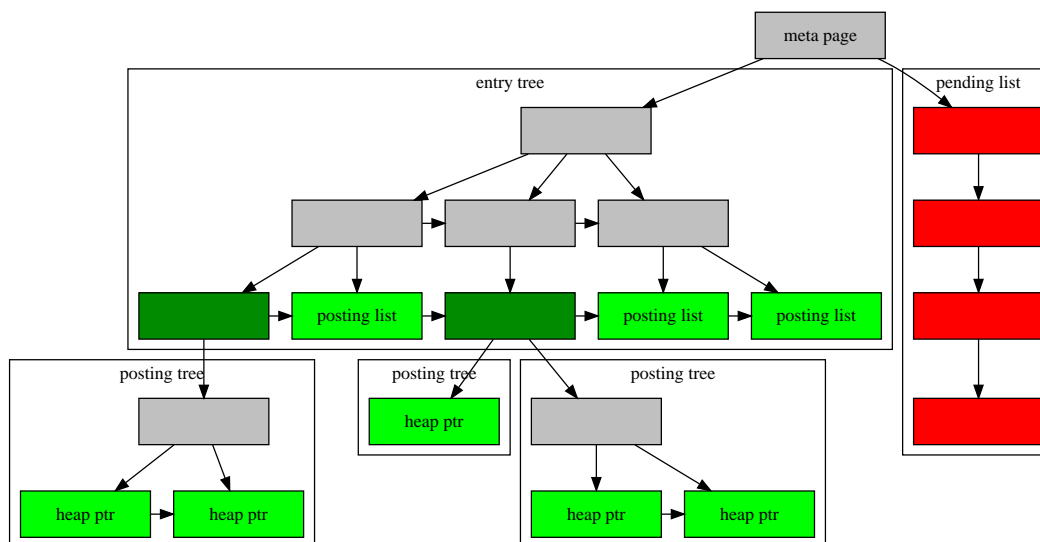
## 62.4. Implementation

Internally, a GIN index contains a B-tree index constructed over keys, where each key is an element of one or more indexed items (a member of an array, for example) and where each tuple in a leaf page contains either a pointer to a B-tree of heap pointers (a “posting tree”), or a simple list of heap pointers (a “posting list”) when the list is small enough to fit into a single index tuple along with the key value. Figure 62.1 illustrates these components of a GIN index.

As of LightDB 9.1, null key values can be included in the index. Also, placeholder nulls are included in the index for indexed items that are null or contain no keys according to `extractValue`. This allows searches that should find empty items to do so.

Multicolumn GIN indexes are implemented by building a single B-tree over composite values (column number, key value). The key values for different columns can be of different types.



**Figure 62.1. GIN Internals**

### 62.4.1. GIN Fast Update Technique

Updating a GIN index tends to be slow because of the intrinsic nature of inverted indexes: inserting or updating one heap row can cause many inserts into the index (one for each key extracted from the indexed item). As of LightDB 8.4, GIN is capable of postponing much of this work by inserting new tuples into a temporary, unsorted list of pending entries. When the table is vacuumed or autoanalyzed, or when `gin_clean_pending_list` function is called, or if the pending list becomes larger than `gin_pending_list_limit`, the entries are moved to the main GIN data structure using the same bulk insert techniques used during initial index creation. This greatly improves GIN index update speed, even counting the additional vacuum overhead. Moreover the overhead work can be done by a background process instead of in foreground query processing.

The main disadvantage of this approach is that searches must scan the list of pending entries in addition to searching the regular index, and so a large list of pending entries will slow searches significantly. Another disadvantage is that, while most updates are fast, an update that causes the pending list to become “too large” will incur an immediate cleanup cycle and thus be much slower than other updates. Proper use of autovacuum can minimize both of these problems.

If consistent response time is more important than update speed, use of pending entries can be disabled by turning off the `fastupdate` storage parameter for a GIN index. See `CREATE INDEX` for details.

### 62.4.2. Partial Match Algorithm

GIN can support “partial match” queries, in which the query does not determine an exact match for one or more keys, but the possible matches fall within a reasonably narrow range of key values (within the key sorting order determined by the `compare` support method). The `extractQuery` method, instead of returning a key value to be matched exactly, returns a key value that is the lower bound of the range to be searched, and sets the `pmatch` flag true. The key range is then scanned using the `comparePartial` method. `comparePartial` must return zero for a matching index key, less than zero for a non-match that is still within the range to be searched, or greater than zero if the index key is past the range that could match.

## 62.5. GIN Tips and Tricks

### Create vs. insert

Insertion into a GIN index can be slow due to the likelihood of many keys being inserted for each item. So, for bulk insertions into a table it is advisable to drop the GIN index and recreate it after finishing bulk insertion.

As of LightDB 8.4, this advice is less necessary since delayed indexing is used (see Section 62.4.1 for details). But for very large updates it may still be best to drop and recreate the index.

### `maintenance_work_mem`

Build time for a GIN index is very sensitive to the `maintenance_work_mem` setting; it doesn't pay to skimp on work memory during index creation.

### `gin_pending_list_limit`

During a series of insertions into an existing GIN index that has `fastupdate` enabled, the system will clean up the pending-entry list whenever the list grows larger than `gin_pending_list_limit`. To avoid fluctuations in observed response time, it's desirable to have pending-list cleanup occur in the background (i.e., via autovacuum). Foreground cleanup operations can be avoided by increasing `gin_pending_list_limit` or making autovacuum more aggressive. However, enlarging the threshold of the cleanup operation means that if a foreground cleanup does occur, it will take even longer.

`gin_pending_list_limit` can be overridden for individual GIN indexes by changing storage parameters, which allows each GIN index to have its own cleanup threshold. For example, it's possible to increase the threshold only for the GIN index which can be updated heavily, and decrease it otherwise.

### `gin_fuzzy_search_limit`

The primary goal of developing GIN indexes was to create support for highly scalable full-text search in LightDB, and there are often situations when a full-text search returns a very large set of results. Moreover, this often happens when the query contains very frequent words, so that the large result set is not even useful. Since reading many tuples from the disk and sorting them could take a lot of time, this is unacceptable for production. (Note that the index search itself is very fast.)

To facilitate controlled execution of such queries, GIN has a configurable soft upper limit on the number of rows returned: the `gin_fuzzy_search_limit` configuration parameter. It is set to 0 (meaning no limit) by default. If a non-zero limit is set, then the returned set is a subset of the whole result set, chosen at random.

“Soft” means that the actual number of returned results could differ somewhat from the specified limit, depending on the query and the quality of the system's random number generator.

From experience, values in the thousands (e.g., 5000 — 20000) work well.

## 62.6. Limitations

GIN assumes that indexable operators are strict. This means that `extractValue` will not be called at all on a null item value (instead, a placeholder index entry is created automatically), and `extractQuery` will not be called on a null query value either (instead, the query is presumed to be unsatisfiable). Note however that null key values contained within a non-null composite item or query value are supported.

## 62.7. Examples

The core LightDB distribution includes the GIN operator classes previously shown in Table 62.1. The following `contrib` modules also contain GIN operator classes:

`btree_gin`

B-tree equivalent functionality for several data types

`hstore`

Module for storing (key, value) pairs

`intarray`

Enhanced support for `int[]`

`lt_trgm`

Text similarity using trigram matching

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# Chapter 63. Hash Indexes

## 63.1. Overview

LightDB includes an implementation of persistent on-disk hash indexes, which are fully crash recoverable. Any data type can be indexed by a hash index, including data types that do not have a well-defined linear ordering. Hash indexes store only the hash value of the data being indexed, thus there are no restrictions on the size of the data column being indexed.

Hash indexes support only single-column indexes and do not allow uniqueness checking.

Hash indexes support only the = operator, so WHERE clauses that specify range operations will not be able to take advantage of hash indexes.

Each hash index tuple stores just the 4-byte hash value, not the actual column value. As a result, hash indexes may be much smaller than B-trees when indexing longer data items such as UUIDs, URLs, etc. The absence of the column value also makes all hash index scans lossy. Hash indexes may take part in bitmap index scans and backward scans.

Hash indexes are best optimized for SELECT and UPDATE-heavy workloads that use equality scans on larger tables. In a B-tree index, searches must descend through the tree until the leaf page is found. In tables with millions of rows, this descent can increase access time to data. The equivalent of a leaf page in a hash index is referred to as a bucket page. In contrast, a hash index allows accessing the bucket pages directly, thereby potentially reducing index access time in larger tables. This reduction in "logical I/O" becomes even more pronounced on indexes/data larger than shared\_buffers/RAM.

Hash indexes have been designed to cope with uneven distributions of hash values. Direct access to the bucket pages works well if the hash values are evenly distributed. When inserts mean that the bucket page becomes full, additional overflow pages are chained to that specific bucket page, locally expanding the storage for index tuples that match that hash value. When scanning a hash bucket during queries, we need to scan through all of the overflow pages. Thus an unbalanced hash index might actually be worse than a B-tree in terms of number of block accesses required, for some data.

As a result of the overflow cases, we can say that hash indexes are most suitable for unique, nearly unique data or data with a low number of rows per hash bucket. One possible way to avoid problems is to exclude highly non-unique values from the index using a partial index condition, but this may not be suitable in many cases.

Like B-Trees, hash indexes perform simple index tuple deletion. This is a deferred maintenance operation that deletes index tuples that are known to be safe to delete (those whose item identifier's LP\_DEAD bit is already set). If an insert finds no space is available on a page we try to avoid creating a new overflow page by attempting to remove dead index tuples. Removal cannot occur if the page is pinned at that time. Deletion of dead index pointers also occurs during VACUUM.

If it can, VACUUM will also try to squeeze the index tuples onto as few overflow pages as possible, minimizing the overflow chain. If an overflow page becomes empty, overflow pages can be recycled for reuse in other buckets, though we never return them to the operating system. There is currently no provision to shrink a hash index, other than by rebuilding it with REINDEX. There is no provision for reducing the number of buckets, either.

Hash indexes may expand the number of bucket pages as the number of rows indexed grows. The hash key-to-bucket-number mapping is chosen so that the index can be incrementally expanded. When a new bucket is to be added to the index, exactly one existing bucket will need to be "split", with some of its tuples being transferred to the new bucket according to the updated key-to-bucket-number mapping.

The expansion occurs in the foreground, which could increase execution time for user inserts. Thus, hash indexes may not be suitable for tables with rapidly increasing number of rows.

## 63.2. Implementation

There are four kinds of pages in a hash index: the meta page (page zero), which contains statically allocated control information; primary bucket pages; overflow pages; and bitmap pages, which keep track of overflow pages that have been freed and are available for re-use. For addressing purposes, bitmap pages are regarded as a subset of the overflow pages.

Both scanning the index and inserting tuples require locating the bucket where a given tuple ought to be located. To do this, we need the bucket count, highmask, and lowmask from the metapage; however, it's undesirable for performance reasons to have to lock and pin the metapage for every such operation. Instead, we retain a cached copy of the metapage in each backend's relcache entry. This will produce the correct bucket mapping as long as the target bucket hasn't been split since the last cache refresh.

Primary bucket pages and overflow pages are allocated independently since any given index might need more or fewer overflow pages relative to its number of buckets. The hash code uses an interesting set of addressing rules to support a variable number of overflow pages while not having to move primary bucket pages around after they are created.

Each row in the table indexed is represented by a single index tuple in the hash index. Hash index tuples are stored in bucket pages, and if they exist, overflow pages. We speed up searches by keeping the index entries in any one index page sorted by hash code, thus allowing binary search to be used within an index page. Note however that there is *\*no\** assumption about the relative ordering of hash codes across different index pages of a bucket.

The bucket splitting algorithms to expand the hash index are too complex to be worthy of mention here, though are described in more detail in `src/backend/access/hash/README`. The split algorithm is crash safe and can be restarted if not completed successfully.

---

# Chapter 64. Database Physical Storage

This chapter provides an overview of the physical storage format used by LightDB databases.

## 64.1. Database File Layout

This section describes the storage format at the level of files and directories.

Traditionally, the configuration and data files used by a database cluster are stored together within the cluster's data directory, commonly referred to as `LTDATA` (after the name of the environment variable that can be used to define it). A common location for `LTDATA` is `/var/lib/lightdb-x/data`. Multiple clusters, managed by different server instances, can exist on the same machine.

The `LTDATA` directory contains several subdirectories and control files, as shown in Table 64.1. In addition to these required items, the cluster configuration files `lightdb.conf`, `lt_hba.conf`, and `lt_ident.conf` are traditionally stored in `LTDATA`, although it is possible to place them elsewhere.

**Table 64.1. Contents of LTDATA**

Item	Description
<code>PG_VERSION</code>	A file containing the major version number of LightDB
<code>base</code>	Subdirectory containing per-database subdirectories
<code>current_logfiles</code>	File recording the log file(s) currently written to by the logging collector
<code>global</code>	Subdirectory containing cluster-wide tables, such as <code>pg_database</code>
<code>lt_commit_ts</code>	Subdirectory containing transaction commit timestamp data
<code>lt_dynshmem</code>	Subdirectory containing files used by the dynamic shared memory subsystem
<code>lt_logical</code>	Subdirectory containing status data for logical decoding
<code>lt_multixact</code>	Subdirectory containing multitransaction status data (used for shared row locks)
<code>lt_notify</code>	Subdirectory containing LISTEN/NOTIFY status data
<code>lt_replslot</code>	Subdirectory containing replication slot data
<code>lt_serial</code>	Subdirectory containing information about committed serializable transactions
<code>lt_snapshots</code>	Subdirectory containing exported snapshots
<code>lt_stat</code>	Subdirectory containing permanent files for the statistics subsystem
<code>lt_stat_tmp</code>	Subdirectory containing temporary files for the statistics subsystem
<code>lt_subtrans</code>	Subdirectory containing subtransaction status data

Item	Description
lt_tblspc	Subdirectory containing symbolic links to tablespaces
lt_twophase	Subdirectory containing state files for prepared transactions
lt_wal	Subdirectory containing WAL (Write Ahead Log) files
lt_xact	Subdirectory containing transaction commit status data
lightdb.auto.conf	A file used for storing configuration parameters that are set by <code>ALTER SYSTEM</code>
lightdb.opts	A file recording the command-line options the server was last started with
lightdb.pid	A lock file recording the current postmaster process ID (PID), cluster data directory path, postmaster start timestamp, port number, Unix-domain socket directory path (could be empty), first valid listen_address (IP address or *, or empty if not listening on TCP), and shared memory segment ID (this file is not present after server shutdown)

For each database in the cluster there is a subdirectory within `LTDATA/base`, named after the database's OID in `pg_database`. This subdirectory is the default location for the database's files; in particular, its system catalogs are stored there.

Note that the following sections describe the behavior of the builtin `heap` table access method, and the builtin index access methods. Due to the extensible nature of LightDB, other access methods might work differently.

Each table and index is stored in a separate file. For ordinary relations, these files are named after the table or index's *filenode* number, which can be found in `pg_class.relfilenode`. But for temporary relations, the file name is of the form `tBBB_FFF`, where *BBB* is the backend ID of the backend which created the file, and *FFF* is the filenode number. In either case, in addition to the main file (a/k/a main fork), each table and index has a *free space map* (see Section 64.3), which stores information about free space available in the relation. The free space map is stored in a file named with the filenode number plus the suffix `_fsm`. Tables also have a *visibility map*, stored in a fork with the suffix `_vm`, to track which pages are known to have no dead tuples. The visibility map is described further in Section 64.4. Unlogged tables and indexes have a third fork, known as the initialization fork, which is stored in a fork with the suffix `_init` (see Section 64.5).

### Caution

Note that while a table's filenode often matches its OID, this is *not* necessarily the case; some operations, like `TRUNCATE`, `REINDEX`, `CLUSTER` and some forms of `ALTER TABLE`, can change the filenode while preserving the OID. Avoid assuming that filenode and table OID are the same. Also, for certain system catalogs including `pg_class` itself, `pg_class.relfilenode` contains zero. The actual filenode number of these catalogs is stored in a lower-level data structure, and can be obtained using the `pg_relation_filenode()` function.

When a table or index exceeds 1 GB, it is divided into gigabyte-sized *segments*. The first segment's file name is the same as the filenode; subsequent segments are named `filenode.1`, `filenode.2`, etc. This arrangement avoids problems on platforms that have file size limitations. (Actually, 1 GB is just the

default segment size. The segment size can be adjusted using the configuration option `--with-segsize` when building LightDB.) In principle, free space map and visibility map forks could require multiple segments as well, though this is unlikely to happen in practice.

A table that has columns with potentially large entries will have an associated *TOAST* table, which is used for out-of-line storage of field values that are too large to keep in the table rows proper. `pg_class.reltoastrelid` links from a table to its TOAST table, if any. See Section 64.2 for more information.

The contents of tables and indexes are discussed further in Section 64.6.

Tablespaces make the scenario more complicated. Each user-defined tablespace has a symbolic link inside the `LTDATA/lt_tblspc` directory, which points to the physical tablespace directory (i.e., the location specified in the tablespace's `CREATE TABLESPACE` command). This symbolic link is named after the tablespace's *OID*. Inside the physical tablespace directory there is a subdirectory with a name that depends on the LightDB server version, such as `PG_9.0_201008051`. (The reason for using this subdirectory is so that successive versions of the database can use the same `CREATE TABLESPACE` location value without conflicts.) Within the version-specific subdirectory, there is a subdirectory for each database that has elements in the tablespace, named after the database's *OID*. Tables and indexes are stored within that directory, using the filenode naming scheme. The `pg_default` tablespace is not accessed through `lt_tblspc`, but corresponds to `LTDATA/base`. Similarly, the `pg_global` tablespace is not accessed through `lt_tblspc`, but corresponds to `LTDATA/global`.

The `pg_relation_filepath()` function shows the entire path (relative to `LTDATA`) of any relation. It is often useful as a substitute for remembering many of the above rules. But keep in mind that this function just gives the name of the first segment of the main fork of the relation — you may need to append a segment number and/or `_fsm`, `_vm`, or `_init` to find all the files associated with the relation.

Temporary files (for operations such as sorting more data than can fit in memory) are created within `LTDATA/base/ltsql_tmp`, or within a `ltsql_tmp` subdirectory of a tablespace directory if a tablespace other than `pg_default` is specified for them. The name of a temporary file has the form `ltsql_tmpPPP.NNN`, where *PPP* is the PID of the owning backend and *NNN* distinguishes different temporary files of that backend.

## 64.2. TOAST

This section provides an overview of TOAST (The Oversized-Attribute Storage Technique).

LightDB uses a fixed page size (commonly 8 kB), and does not allow tuples to span multiple pages. Therefore, it is not possible to store very large field values directly. To overcome this limitation, large field values are compressed and/or broken up into multiple physical rows. This happens transparently to the user, with only small impact on most of the backend code. The technique is affectionately known as TOAST (or “the best thing since sliced bread”). The TOAST infrastructure is also used to improve handling of large data values in-memory.

Only certain data types support TOAST — there is no need to impose the overhead on data types that cannot produce large field values. To support TOAST, a data type must have a variable-length (*varlena*) representation, in which, ordinarily, the first four-byte word of any stored value contains the total length of the value in bytes (including itself). TOAST does not constrain the rest of the data type's representation. The special representations collectively called *TOASTed values* work by modifying or reinterpreting this initial length word. Therefore, the C-level functions supporting a TOAST-able data type must be careful about how they handle potentially TOASTed input values: an input might not actually consist of a four-byte length word and contents until after it's been *detoasted*. (This is normally done by invoking `PG_DETOAST_DATUM` before doing anything with an input value, but in some cases more efficient approaches are possible. See Section 36.13.1 for more detail.)

TOAST usurps two bits of the *varlena* length word (the high-order bits on big-endian machines, the low-order bits on little-endian machines), thereby limiting the logical size of any value of a TOAST-



able data type to 1 GB ( $2^{30}$  - 1 bytes). When both bits are zero, the value is an ordinary un-TOASTed value of the data type, and the remaining bits of the length word give the total datum size (including length word) in bytes. When the highest-order or lowest-order bit is set, the value has only a single-byte header instead of the normal four-byte header, and the remaining bits of that byte give the total datum size (including length byte) in bytes. This alternative supports space-efficient storage of values shorter than 127 bytes, while still allowing the data type to grow to 1 GB at need. Values with single-byte headers aren't aligned on any particular boundary, whereas values with four-byte headers are aligned on at least a four-byte boundary; this omission of alignment padding provides additional space savings that is significant compared to short values. As a special case, if the remaining bits of a single-byte header are all zero (which would be impossible for a self-inclusive length), the value is a pointer to out-of-line data, with several possible alternatives as described below. The type and size of such a *TOAST pointer* are determined by a code stored in the second byte of the datum. Lastly, when the highest-order or lowest-order bit is clear but the adjacent bit is set, the content of the datum has been compressed and must be decompressed before use. In this case the remaining bits of the four-byte length word give the total size of the compressed datum, not the original data. Note that compression is also possible for out-of-line data but the varlena header does not tell whether it has occurred — the content of the TOAST pointer tells that, instead.

As mentioned, there are multiple types of TOAST pointer datums. The oldest and most common type is a pointer to out-of-line data stored in a *TOAST table* that is separate from, but associated with, the table containing the TOAST pointer datum itself. These *on-disk* pointer datums are created by the TOAST management code (in `access/common/toast_internals.c`) when a tuple to be stored on disk is too large to be stored as-is. Further details appear in Section 64.2.1. Alternatively, a TOAST pointer datum can contain a pointer to out-of-line data that appears elsewhere in memory. Such datums are necessarily short-lived, and will never appear on-disk, but they are very useful for avoiding copying and redundant processing of large data values. Further details appear in Section 64.2.2.

The compression technique used for either in-line or out-of-line compressed data is a fairly simple and very fast member of the LZ family of compression techniques. See `src/common/pg_lzcompress.c` for the details.

## 64.2.1. Out-of-Line, On-Disk TOAST Storage

If any of the columns of a table are TOAST-able, the table will have an associated TOAST table, whose OID is stored in the table's `pg_class.reltoastrelid` entry. On-disk TOASTed values are kept in the TOAST table, as described in more detail below.

Out-of-line values are divided (after compression if used) into chunks of at most `TOAST_MAX_CHUNK_SIZE` bytes (by default this value is chosen so that four chunk rows will fit on a page, making it about 2000 bytes). Each chunk is stored as a separate row in the TOAST table belonging to the owning table. Every TOAST table has the columns `chunk_id` (an OID identifying the particular TOASTed value), `chunk_seq` (a sequence number for the chunk within its value), and `chunk_data` (the actual data of the chunk). A unique index on `chunk_id` and `chunk_seq` provides fast retrieval of the values. A pointer datum representing an out-of-line on-disk TOASTed value therefore needs to store the OID of the TOAST table in which to look and the OID of the specific value (its `chunk_id`). For convenience, pointer datums also store the logical datum size (original uncompressed data length) and physical stored size (different if compression was applied). Allowing for the varlena header bytes, the total size of an on-disk TOAST pointer datum is therefore 18 bytes regardless of the actual size of the represented value.

The TOAST management code is triggered only when a row value to be stored in a table is wider than `TOAST_TUPLE_THRESHOLD` bytes (normally 2 kB). The TOAST code will compress and/or move field values out-of-line until the row value is shorter than `TOAST_TUPLE_TARGET` bytes (also normally 2 kB, adjustable) or no more gains can be had. During an UPDATE operation, values of unchanged fields are normally preserved as-is; so an UPDATE of a row with out-of-line values incurs no TOAST costs if none of the out-of-line values change.

The TOAST management code recognizes four different strategies for storing TOAST-able columns on disk:

- `PLAIN` prevents either compression or out-of-line storage; furthermore it disables use of single-byte headers for varlena types. This is the only possible strategy for columns of non-TOAST-able data types.
- `EXTENDED` allows both compression and out-of-line storage. This is the default for most TOAST-able data types. Compression will be attempted first, then out-of-line storage if the row is still too big.
- `EXTERNAL` allows out-of-line storage but not compression. Use of `EXTERNAL` will make substring operations on wide `text` and `bytea` columns faster (at the penalty of increased storage space) because these operations are optimized to fetch only the required parts of the out-of-line value when it is not compressed.
- `MAIN` allows compression but not out-of-line storage. (Actually, out-of-line storage will still be performed for such columns, but only as a last resort when there is no other way to make the row small enough to fit on a page.)

Each TOAST-able data type specifies a default strategy for columns of that data type, but the strategy for a given table column can be altered with `ALTER TABLE ... SET STORAGE`.

`TOAST_TUPLE_TARGET` can be adjusted for each table using `ALTER TABLE ... SET (toast_tuple_target = N)`

This scheme has a number of advantages compared to a more straightforward approach such as allowing row values to span pages. Assuming that queries are usually qualified by comparisons against relatively small key values, most of the work of the executor will be done using the main row entry. The big values of TOASTed attributes will only be pulled out (if selected at all) at the time the result set is sent to the client. Thus, the main table is much smaller and more of its rows fit in the shared buffer cache than would be the case without any out-of-line storage. Sort sets shrink also, and sorts will more often be done entirely in memory. A little test showed that a table containing typical HTML pages and their URLs was stored in about half of the raw data size including the TOAST table, and that the main table contained only about 10% of the entire data (the URLs and some small HTML pages). There was no run time difference compared to an un-TOASTed comparison table, in which all the HTML pages were cut down to 7 kB to fit.

## 64.2.2. Out-of-Line, In-Memory TOAST Storage

TOAST pointers can point to data that is not on disk, but is elsewhere in the memory of the current server process. Such pointers obviously cannot be long-lived, but they are nonetheless useful. There are currently two sub-cases: pointers to *indirect* data and pointers to *expanded* data.

Indirect TOAST pointers simply point at a non-indirect varlena value stored somewhere in memory. This case was originally created merely as a proof of concept, but it is currently used during logical decoding to avoid possibly having to create physical tuples exceeding 1 GB (as pulling all out-of-line field values into the tuple might do). The case is of limited use since the creator of the pointer datum is entirely responsible that the referenced data survives for as long as the pointer could exist, and there is no infrastructure to help with this.

Expanded TOAST pointers are useful for complex data types whose on-disk representation is not especially suited for computational purposes. As an example, the standard varlena representation of a LightDB array includes dimensionality information, a nulls bitmap if there are any null elements, then the values of all the elements in order. When the element type itself is variable-length, the only way to find the *N*th element is to scan through all the preceding elements. This representation is appropriate for on-disk storage because of its compactness, but for computations with the array it's much nicer to have an "expanded" or "deconstructed" representation in which all the element starting locations have been identified. The TOAST pointer mechanism supports this need by allowing a pass-by-reference Datum to point to either a standard varlena value (the on-disk representation) or a TOAST pointer that points to an expanded representation somewhere in memory. The details of this expanded representation are up to the data type, though it must have a standard header and meet the other API requirements given in `src/include/utils/expandeddatum.h`. C-level

functions working with the data type can choose to handle either representation. Functions that do not know about the expanded representation, but simply apply `PG_DETOAST_DATUM` to their inputs, will automatically receive the traditional varlena representation; so support for an expanded representation can be introduced incrementally, one function at a time.

TOAST pointers to expanded values are further broken down into *read-write* and *read-only* pointers. The pointed-to representation is the same either way, but a function that receives a read-write pointer is allowed to modify the referenced value in-place, whereas one that receives a read-only pointer must not; it must first create a copy if it wants to make a modified version of the value. This distinction and some associated conventions make it possible to avoid unnecessary copying of expanded values during query execution.

For all types of in-memory TOAST pointer, the TOAST management code ensures that no such pointer datum can accidentally get stored on disk. In-memory TOAST pointers are automatically expanded to normal in-line varlena values before storage — and then possibly converted to on-disk TOAST pointers, if the containing tuple would otherwise be too big.

## 64.3. Free Space Map

Each heap and index relation, except for hash indexes, has a Free Space Map (FSM) to keep track of available space in the relation. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_fsm` suffix. For example, if the filenode of a relation is 12345, the FSM is stored in a file called `12345_fsm`, in the same directory as the main relation file.

The Free Space Map is organized as a tree of FSM pages. The bottom level FSM pages store the free space available on each heap (or index) page, using one byte to represent each such page. The upper levels aggregate information from the lower levels.

Within each FSM page is a binary tree, stored in an array with one byte per node. Each leaf node represents a heap page, or a lower level FSM page. In each non-leaf node, the higher of its children's values is stored. The maximum value in the leaf nodes is therefore stored at the root.

See `src/backend/storage/freespace/README` for more details on how the FSM is structured, and how it's updated and searched. The `lt_freespacemap` module can be used to examine the information stored in free space maps.

## 64.4. Visibility Map

Each heap relation has a Visibility Map (VM) to keep track of which pages contain only tuples that are known to be visible to all active transactions; it also keeps track of which pages contain only frozen tuples. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_vm` suffix. For example, if the filenode of a relation is 12345, the VM is stored in a file called `12345_vm`, in the same directory as the main relation file. Note that indexes do not have VMs.

The visibility map stores two bits per heap page. The first bit, if set, indicates that the page is all-visible, or in other words that the page does not contain any tuples that need to be vacuumed. This information can also be used by *index-only scans* to answer queries using only the index tuple. The second bit, if set, means that all tuples on the page have been frozen. That means that even an anti-wraparound vacuum need not revisit the page.

The map is conservative in the sense that we make sure that whenever a bit is set, we know the condition is true, but if a bit is not set, it might or might not be true. Visibility map bits are only set by vacuum, but are cleared by any data-modifying operations on a page.

The `lt_visibility` module can be used to examine the information stored in the visibility map.

## 64.5. The Initialization Fork

Each unlogged table, and each index on an unlogged table, has an initialization fork. The initialization fork is an empty table or index of the appropriate type. When an unlogged table must be reset to empty due to a crash, the initialization fork is copied over the main fork, and any other forks are erased (they will be recreated automatically as needed).

## 64.6. Database Page Layout

This section provides an overview of the page format used within LightDB tables and indexes.<sup>1</sup> Sequences and TOAST tables are formatted just like a regular table.

In the following explanation, a *byte* is assumed to contain 8 bits. In addition, the term *item* refers to an individual data value that is stored on a page. In a table, an item is a row; in an index, an item is an index entry.

Every table and index is stored as an array of *pages* of a fixed size (usually 8 kB, although a different page size can be selected when compiling the server). In a table, all the pages are logically equivalent, so a particular item (row) can be stored in any page. In indexes, the first page is generally reserved as a *metapage* holding control information, and there can be different types of pages within the index, depending on the index access method.

Table 64.2 shows the overall layout of a page. There are five parts to each page.

**Table 64.2. Overall Page Layout**

Item	Description
PageHeaderData	24 bytes long. Contains general information about the page, including free space pointers.
ItemIdData	Array of item identifiers pointing to the actual items. Each entry is an (offset,length) pair. 4 bytes per item.
Free space	The unallocated space. New item identifiers are allocated from the start of this area, new items from the end.
Items	The actual items themselves.
Special space	Index access method specific data. Different methods store different data. Empty in ordinary tables.

The first 24 bytes of each page consists of a page header (*PageHeaderData*). Its format is detailed in Table 64.3. The first field tracks the most recent WAL entry related to this page. The second field contains the page checksum if data checksums are enabled. Next is a 2-byte field containing flag bits. This is followed by three 2-byte integer fields (*pd\_lower*, *pd\_upper*, and *pd\_special*). These contain byte offsets from the page start to the start of unallocated space, to the end of unallocated space, and to the start of the special space. The next 2 bytes of the page header, *pd\_pagesize\_version*, store both the page size and a version indicator. Beginning with LightDB 8.3 the version number is 4; LightDB 8.1 and 8.2 used version number 3; LightDB 8.0 used version number 2; LightDB 7.3 and 7.4 used version number 1; prior releases used version number 0. (The basic page layout and header format has not changed in most of these versions, but the layout of heap row headers has.) The page size is basically only present as a cross-check; there is no support for having more than one page size in an installation. The last field is a hint that shows whether pruning the page is likely to be profitable: it tracks the oldest un-pruned XMAX on the page.

<sup>1</sup> Actually, use of this page format is not required for either table or index access methods. The heap table access method always uses this format. All the existing index methods also use the basic format, but the data kept on index metapages usually doesn't follow the item layout rules.

**Table 64.3. PageHeaderData Layout**

Field	Type	Length	Description
pd_lsn	PageXLogRecPtr	8 bytes	LSN: next byte after last byte of WAL record for last change to this page
pd_checksum	uint16	2 bytes	Page checksum
pd_flags	uint16	2 bytes	Flag bits
pd_lower	LocationIndex	2 bytes	Offset to start of free space
pd_upper	LocationIndex	2 bytes	Offset to end of free space
pd_special	LocationIndex	2 bytes	Offset to start of special space
pd_pagesize_version	uint16	2 bytes	Page size and layout version number information
pd_prune_xid	TransactionId	4 bytes	Oldest unpruned XMAX on page, or zero if none

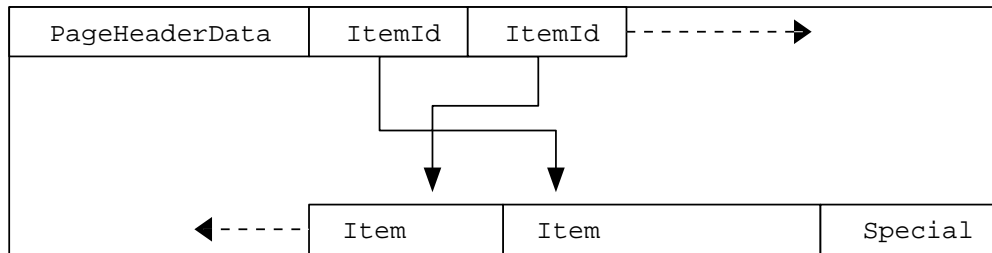
All the details can be found in `src/include/storage/bufpage.h`.

Following the page header are item identifiers (`ItemIdData`), each requiring four bytes. An item identifier contains a byte-offset to the start of an item, its length in bytes, and a few attribute bits which affect its interpretation. New item identifiers are allocated as needed from the beginning of the unallocated space. The number of item identifiers present can be determined by looking at `pd_lower`, which is increased to allocate a new identifier. Because an item identifier is never moved until it is freed, its index can be used on a long-term basis to reference an item, even when the item itself is moved around on the page to compact free space. In fact, every pointer to an item (`ItemPointer`, also known as `CTID`) created by LightDB consists of a page number and the index of an item identifier.

The items themselves are stored in space allocated backwards from the end of unallocated space. The exact structure varies depending on what the table is to contain. Tables and sequences both use a structure named `HeapTupleHeaderData`, described below.

The final section is the “special section” which can contain anything the access method wishes to store. For example, b-tree indexes store links to the page's left and right siblings, as well as some other data relevant to the index structure. Ordinary tables do not use a special section at all (indicated by setting `pd_special` to equal the page size).

Figure 64.1 illustrates how these parts are laid out in a page.

**Figure 64.1. Page Layout**

## 64.6.1. Table Row Layout

All table rows are structured in the same way. There is a fixed-size header (occupying 23 bytes on most machines), followed by an optional null bitmap, an optional object ID field, and the user data. The header is detailed in Table 64.4. The actual user data (columns of the row) begins at the offset indicated by `t_hoff`, which must always be a multiple of the `MAXALIGN` distance for the platform. The null bitmap is only present if the `HEAP_HASNULL` bit is set in `t_infomask`. If it is present it begins just after the fixed header and occupies enough bytes to have one bit per data column (that is, the number of bits that equals the attribute count in `t_infomask2`). In this list of bits, a 1 bit indicates not-null, a 0 bit is a null. When the bitmap is not present, all columns are assumed not-null. The object ID is only present if the `HEAP_HASOID_OLD` bit is set in `t_infomask`. If present, it appears just before the `t_hoff` boundary. Any padding needed to make `t_hoff` a `MAXALIGN` multiple will appear between the null bitmap and the object ID. (This in turn ensures that the object ID is suitably aligned.)

**Table 64.4. HeapTupleHeaderData Layout**

Field	Type	Length	Description
<code>t_xmin</code>	TransactionId	4 bytes	insert XID stamp
<code>t_xmax</code>	TransactionId	4 bytes	delete XID stamp
<code>t_cid</code>	CommandId	4 bytes	insert and/or delete CID stamp (overlays with <code>t_xvac</code> )
<code>t_xvac</code>	TransactionId	4 bytes	XID for VACUUM operation moving a row version
<code>t_ctid</code>	ItemPointerData	6 bytes	current TID of this or newer row version
<code>t_infomask2</code>	uint16	2 bytes	number of attributes, plus various flag bits
<code>t_infomask</code>	uint16	2 bytes	various flag bits
<code>t_hoff</code>	uint8	1 byte	offset to user data

All the details can be found in `src/include/access/htup_details.h`.

Interpreting the actual data can only be done with information obtained from other tables, mostly `pg_attribute`. The key values needed to identify field locations are `attlen` and `attalign`. There is no way to directly get a particular attribute, except when there are only fixed width fields and no null values. All this trickery is wrapped up in the functions `heap_getattr`, `fastgetattr` and `heap_getsysattr`.

To read the data you need to examine each attribute in turn. First check whether the field is NULL according to the null bitmap. If it is, go to the next. Then make sure you have the right alignment. If the field is a fixed width field, then all the bytes are simply placed. If it's a variable length field (`attlen = -1`) then it's a bit more complicated. All variable-length data types share the common header structure `struct varlena`, which includes the total length of the stored value and some flag bits. Depending on the flags, the data can be either inline or in a TOAST table; it might be compressed, too (see Section 64.2).

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# Chapter 65. System Catalog Declarations and Initial Contents

LightDB uses many different system catalogs to keep track of the existence and properties of database objects, such as tables and functions. Physically there is no difference between a system catalog and a plain user table, but the backend C code knows the structure and properties of each catalog, and can manipulate it directly at a low level. Thus, for example, it is inadvisable to attempt to alter the structure of a catalog on-the-fly; that would break assumptions built into the C code about how rows of the catalog are laid out. But the structure of the catalogs can change between major versions.

The structures of the catalogs are declared in specially formatted C header files in the `src/include/catalog/` directory of the source tree. In particular, for each catalog there is a header file named after the catalog (e.g., `pg_class.h` for `pg_class`), which defines the set of columns the catalog has, as well as some other basic properties such as its OID. Other critical files defining the catalog structure include `indexing.h`, which defines the indexes present on all the system catalogs, and `toasting.h`, which defines TOAST tables for catalogs that need one.

Many of the catalogs have initial data that must be loaded into them during the “bootstrap” phase of `initdb`, to bring the system up to a point where it is capable of executing SQL commands. (For example, `pg_class.h` must contain an entry for itself, as well as one for each other system catalog and index.) This initial data is kept in editable form in data files that are also stored in the `src/include/catalog/` directory. For example, `pg_proc.dat` describes all the initial rows that must be inserted into the `pg_proc` catalog.

To create the catalog files and load this initial data into them, a backend running in bootstrap mode reads a BKI (Backend Interface) file containing commands and initial data. The `lightdb.bki` file used in this mode is prepared from the aforementioned header and data files, while building a LightDB distribution, by a Perl script named `genbki.pl`. Although it's specific to a particular LightDB release, `lightdb.bki` is platform-independent and is installed in the `share` subdirectory of the installation tree.

`genbki.pl` also produces a derived header file for each catalog, for example `pg_class_d.h` for the `pg_class` catalog. This file contains automatically-generated macro definitions, and may contain other macros, enum declarations, and so on that can be useful for client C code that reads a particular catalog.

Most LightDB developers don't need to be directly concerned with the BKI file, but almost any nontrivial feature addition in the backend will require modifying the catalog header files and/or initial data files. The rest of this chapter gives some information about that, and for completeness describes the BKI file format.

## 65.1. System Catalog Declaration Rules

The key part of a catalog header file is a C structure definition describing the layout of each row of the catalog. This begins with a `CATALOG` macro, which so far as the C compiler is concerned is just shorthand for `typedef struct FormData_catalogname`. Each field in the struct gives rise to a catalog column. Fields can be annotated using the BKI property macros described in `genbki.h`, for example to define a default value for a field or mark it as nullable or not nullable. The `CATALOG` line can also be annotated, with some other BKI property macros described in `genbki.h`, to define other properties of the catalog as a whole, such as whether it is a shared relation.

The system catalog cache code (and most catalog-munging code in general) assumes that the fixed-length portions of all system catalog tuples are in fact present, because it maps this C struct declaration onto them. Thus, all variable-length fields and nullable fields must be placed at the end, and they cannot be accessed as struct fields. For example, if you tried to set `pg_type.typrelid` to be



NULL, it would fail when some piece of code tried to reference `typetup->typrelid` (or worse, `typetup->typelem`, because that follows `typrelid`). This would result in random errors or even segmentation violations.

As a partial guard against this type of error, variable-length or nullable fields should not be made directly visible to the C compiler. This is accomplished by wrapping them in `#ifdef CATALOG_VARLEN ... #endif` (where `CATALOG_VARLEN` is a symbol that is never defined). This prevents C code from carelessly trying to access fields that might not be there or might be at some other offset. As an independent guard against creating incorrect rows, we require all columns that should be non-nullable to be marked so in `pg_attribute`. The bootstrap code will automatically mark catalog columns as `NOT NULL` if they are fixed-width and are not preceded by any nullable column. Where this rule is inadequate, you can force correct marking by using `BKI_FORCE_NOT_NULL` and `BKI_FORCE_NULL` annotations as needed.

Frontend code should not include any `pg_xxx.h` catalog header file, as these files may contain C code that won't compile outside the backend. (Typically, that happens because these files also contain declarations for functions in `src/backend/catalog/` files.) Instead, frontend code may include the corresponding generated `pg_xxx_d.h` header, which will contain `OID #defines` and any other data that might be of use on the client side. If you want macros or other code in a catalog header to be visible to frontend code, write `#ifdef EXPOSE_TO_CLIENT_CODE ... #endif` around that section to instruct `genbki.pl` to copy that section to the `pg_xxx_d.h` header.

A few of the catalogs are so fundamental that they can't even be created by the `BKI create` command that's used for most catalogs, because that command needs to write information into these catalogs to describe the new catalog. These are called *bootstrap* catalogs, and defining one takes a lot of extra work: you have to manually prepare appropriate entries for them in the pre-loaded contents of `pg_class` and `pg_type`, and those entries will need to be updated for subsequent changes to the catalog's structure. (Bootstrap catalogs also need pre-loaded entries in `pg_attribute`, but fortunately `genbki.pl` handles that chore nowadays.) Avoid making new catalogs be bootstrap catalogs if at all possible.

## 65.2. System Catalog Initial Data

Each catalog that has any manually-created initial data (some do not) has a corresponding `.dat` file that contains its initial data in an editable format.

### 65.2.1. Data File Format

Each `.dat` file contains Perl data structure literals that are simply eval'd to produce an in-memory data structure consisting of an array of hash references, one per catalog row. A slightly modified excerpt from `pg_database.dat` will demonstrate the key features:

```
[
# A comment could appear here.
{ oid => '1', oid_symbol => 'TemplateDbOid',
  descr => 'database\'s default template',
  datname => 'template1', encoding => 'ENCODING', datcollate =>
'LC_COLLATE',
  datatype => 'LC_CTYPE', datistemplate => 't', datallowconn =>
't',
  datconnlimit => '-1', datlastsysoid => '0', datfrozenxid => '0',
  datminmxid => '1', dattablespace => 'pg_default', datacl =>
'_null_' },
]
```

Points to note:

- The overall file layout is: open square bracket, one or more sets of curly braces each of which represents a catalog row, close square bracket. Write a comma after each closing curly brace.
- Within each catalog row, write comma-separated *key => value* pairs. The allowed *keys* are the names of the catalog's columns, plus the metadata keys `oid`, `oid_symbol`, `array_type_oid`, and `descr`. (The use of `oid` and `oid_symbol` is described in Section 65.2.2 below, while `array_type_oid` is described in Section 65.2.4. `descr` supplies a description string for the object, which will be inserted into `pg_description` or `pg_shdescription` as appropriate.) While the metadata keys are optional, the catalog's defined columns must all be provided, except when the catalog's `.h` file specifies a default value for the column. (In the example above, the `datdba` field has been omitted because `pg_database.h` supplies a suitable default value for it.)
- All values must be single-quoted. Escape single quotes used within a value with a backslash. Backslashes meant as data can, but need not, be doubled; this follows Perl's rules for simple quoted literals. Note that backslashes appearing as data will be treated as escapes by the bootstrap scanner, according to the same rules as for escape string constants (see Section 4.1.2.2); for example `\t` converts to a tab character. If you actually want a backslash in the final value, you will need to write four of them: Perl strips two, leaving `\\` for the bootstrap scanner to see.
- Null values are represented by `_null_`. (Note that there is no way to create a value that is just that string.)
- Comments are preceded by `#`, and must be on their own lines.
- Field values that are OIDs of other catalog entries should be represented by symbolic names rather than actual numeric OIDs. (In the example above, `dattablespace` contains such a reference.) This is described in Section 65.2.3 below.
- Since hashes are unordered data structures, field order and line layout aren't semantically significant. However, to maintain a consistent appearance, we set a few rules that are applied by the formatting script `reformat_dat_file.pl`:
  - Within each pair of curly braces, the metadata fields `oid`, `oid_symbol`, `array_type_oid`, and `descr` (if present) come first, in that order, then the catalog's own fields appear in their defined order.
  - Newlines are inserted between fields as needed to limit line length to 80 characters, if possible. A newline is also inserted between the metadata fields and the regular fields.
  - If the catalog's `.h` file specifies a default value for a column, and a data entry has that same value, `reformat_dat_file.pl` will omit it from the data file. This keeps the data representation compact.
  - `reformat_dat_file.pl` preserves blank lines and comment lines as-is. It's recommended to run `reformat_dat_file.pl` before submitting catalog data patches. For convenience, you can simply change to `src/include/catalog/` and run `make reformat-dat-files`.
- If you want to add a new method of making the data representation smaller, you must implement it in `reformat_dat_file.pl` and also teach `Catalog::ParseData()` how to expand the data back into the full representation.

## 65.2.2. OID Assignment

A catalog row appearing in the initial data can be given a manually-assigned OID by writing an `oid => nnnn` metadata field. Furthermore, if an OID is assigned, a C macro for that OID can be created by writing an `oid_symbol => name` metadata field.

Pre-loaded catalog rows must have preassigned OIDs if there are OID references to them in other pre-loaded rows. A preassigned OID is also needed if the row's OID must be referenced from C code. If neither case applies, the `oid` metadata field can be omitted, in which case the bootstrap code assigns an OID automatically. In practice we usually preassign OIDs for all or none of the pre-loaded rows in a given catalog, even if only some of them are actually cross-referenced.

Writing the actual numeric value of any OID in C code is considered very bad form; always use a macro, instead. Direct references to `pg_proc` OIDs are common enough that there's a special mechanism to create the necessary macros automatically; see `src/backend/utils/Gen_fmgrtab.pl`. Similarly — but, for historical reasons, not done the same way — there's an automatic method for creating macros for `pg_type` OIDs. `oid_symbol` entries are therefore not necessary in those two catalogs. Likewise, macros for the `pg_class` OIDs of system catalogs and indexes are set up automatically. For all other system catalogs, you have to manually specify any macros you need via `oid_symbol` entries.

To find an available OID for a new pre-loaded row, run the script `src/include/catalog/unused_oids`. It prints inclusive ranges of unused OIDs (e.g., the output line `45-900` means OIDs 45 through 900 have not been allocated yet). Currently, OIDs 1–9999 are reserved for manual assignment; the `unused_oids` script simply looks through the catalog headers and `.dat` files to see which ones do not appear. You can also use the `duplicate_oids` script to check for mistakes. (`genbki.pl` will assign OIDs for any rows that didn't get one hand-assigned to them, and it will also detect duplicate OIDs at compile time.)

When choosing OIDs for a patch that is not expected to be committed immediately, best practice is to use a group of more-or-less consecutive OIDs starting with some random choice in the range 8000–9999. This minimizes the risk of OID collisions with other patches being developed concurrently. To keep the 8000–9999 range free for development purposes, after a patch has been committed to the master git repository its OIDs should be renumbered into available space below that range. Typically, this will be done near the end of each development cycle, moving all OIDs consumed by patches committed in that cycle at the same time. The script `renumber_oids.pl` can be used for this purpose. If an uncommitted patch is found to have OID conflicts with some recently-committed patch, `renumber_oids.pl` may also be useful for recovering from that situation.

Because of this convention of possibly renumbering OIDs assigned by patches, the OIDs assigned by a patch should not be considered stable until the patch has been included in an official release. We do not change manually-assigned object OIDs once released, however, as that would create assorted compatibility problems.

If `genbki.pl` needs to assign an OID to a catalog entry that does not have a manually-assigned OID, it will use a value in the range 10000–11999. The server's OID counter is set to 12000 at the start of a bootstrap run. Thus objects created by regular SQL commands during the later phases of bootstrap, such as objects created while running the `information_schema.sql` script, receive OIDs of 12000 or above.

OIDs assigned during normal database operation are constrained to be 16384 or higher. This ensures that the range 10000–16383 is free for OIDs assigned automatically by `genbki.pl` or during bootstrap. These automatically-assigned OIDs are not considered stable, and may change from one installation to another.

## 65.2.3. OID Reference Lookup

In principle, cross-references from one initial catalog row to another could be written just by writing the preassigned OID of the referenced row in the referencing field. However, that is against project policy, because it is error-prone, hard to read, and subject to breakage if a newly-assigned OID is renumbered. Therefore `genbki.pl` provides mechanisms to write symbolic references instead. The rules are as follows:

- Use of symbolic references is enabled in a particular catalog column by attaching `BKI_LOOKUP(lookuprule)` to the column's definition, where *lookuprule* is the name of

the referenced catalog, e.g., `pg_proc`. `BKI_LOOKUP` can be attached to columns of type `Oid`, `regproc`, `oidvector`, or `Oid[ ]`; in the latter two cases it implies performing a lookup on each element of the array.

- It's also permissible to attach `BKI_LOOKUP(encoding)` to integer columns to reference character set encodings, which are not currently represented as catalog OIDs, but have a set of values known to `genbki.pl`.
- In such a column, all entries must use the symbolic format except when writing 0 for `InvalidOid`. (If the column is declared `regproc`, you can optionally write `-` instead of 0.) `genbki.pl` will warn about unrecognized names.
- Most kinds of catalog objects are simply referenced by their names. Note that type names must exactly match the referenced `pg_type` entry's `typname`; you do not get to use any aliases such as `integer` for `int4`.
- A function can be represented by its `proname`, if that is unique among the `pg_proc.dat` entries (this works like `regproc input`). Otherwise, write it as `proname(argtypename, argtypename, ...)`, like `regprocedure`. The argument type names must be spelled exactly as they are in the `pg_proc.dat` entry's `proargtypes` field. Do not insert any spaces.
- Operators are represented by `oprname(lefttype, righttype)`, writing the type names exactly as they appear in the `pg_operator.dat` entry's `oprleft` and `oprright` fields. (Write 0 for the omitted operand of a unary operator.)
- The names of `opclasses` and `opfamilies` are only unique within an access method, so they are represented by `access_method_name/object_name`.
- In none of these cases is there any provision for schema-qualification; all objects created during bootstrap are expected to be in the `pg_catalog` schema.
- In addition to the generic lookup mechanisms, there is a special convention that `PGNSP` is replaced by the OID of the `pg_catalog` schema, and `PGUID` is replaced by the OID of the bootstrap superuser role. These usages are somewhat historical but so far there hasn't been a need to generalize them.

`genbki.pl` resolves all symbolic references while it runs, and puts simple numeric OIDs into the emitted BKI file. There is therefore no need for the bootstrap backend to deal with symbolic references.

## 65.2.4. Automatic Creation of Array Types

Most scalar data types should have a corresponding array type (that is, a standard varlena array type whose element type is the scalar type, and which is referenced by the `typarray` field of the scalar type's `pg_type` entry). `genbki.pl` is able to generate the `pg_type` entry for the array type automatically in most cases.

To use this facility, just write an `array_type_oid => nnnn` metadata field in the scalar type's `pg_type` entry, specifying the OID to use for the array type. You may then omit the `typarray` field, since it will be filled automatically with that OID.

The generated array type's name is the scalar type's name with an underscore prepended. The array entry's other fields are filled from `BKI_ARRAY_DEFAULT(value)` annotations in `pg_type.h`, or if there isn't one, copied from the scalar type. (There's also a special case for `typalign`.) Then the `typelem` and `typarray` fields of the two entries are set to cross-reference each other.

## 65.2.5. Recipes for Editing Data Files

Here are some suggestions about the easiest ways to perform common tasks when updating catalog data files.

**Add a new column with a default to a catalog:** Add the column to the header file with a `BKI_DEFAULT(value)` annotation. The data file need only be adjusted by adding the field in existing rows where a non-default value is needed.

**Add a default value to an existing column that doesn't have one:** Add a `BKI_DEFAULT` annotation to the header file, then run `make reformat-dat-files` to remove now-redundant field entries.

**Remove a column, whether it has a default or not:** Remove the column from the header, then run `make reformat-dat-files` to remove now-useless field entries.

**Change or remove an existing default value:** You cannot simply change the header file, since that will cause the current data to be interpreted incorrectly. First run `make expand-dat-files` to rewrite the data files with all default values inserted explicitly, then change or remove the `BKI_DEFAULT` annotation, then run `make reformat-dat-files` to remove superfluous fields again.

**Ad-hoc bulk editing:** `reformat_dat_file.pl` can be adapted to perform many kinds of bulk changes. Look for its block comments showing where one-off code can be inserted. In the following example, we are going to consolidate two boolean fields in `pg_proc` into a char field:

1. Add the new column, with a default, to `pg_proc.h`:

```
+ /* see PROKIND_ categories below */  
+ char          prokind BKI_DEFAULT(f);
```

2. Create a new script based on `reformat_dat_file.pl` to insert appropriate values on-the-fly:

```
-          # At this point we have the full row in memory as a  
hash  
-          # and can do any operations we want. As written, it  
only  
-          # removes default values, but this script can be  
adapted to  
-          # do one-off bulk-editing.  
+          # One-off change to migrate to prokind  
+          # Default has already been filled in by now, so  
change to other  
+          # values as appropriate  
+          if ($values{proisagg} eq 't')  
+          {  
+              $values{prokind} = 'a';  
+          }  
+          elsif ($values{proiswindow} eq 't')  
+          {  
+              $values{prokind} = 'w';  
+          }
```

3. Run the new script:

```
$ cd src/include/catalog  
$ perl rewrite_dat_with_prokind.pl pg_proc.dat
```

At this point `pg_proc.dat` has all three columns, `prokind`, `proisagg`, and `proiswindow`, though they will appear only in rows where they have non-default values.

4. Remove the old columns from `pg_proc.h`:

```
- /* is it an aggregate? */  
- bool      proisagg BKI_DEFAULT(f);  
-  
- /* is it a window function? */  
- bool      proiswindow BKI_DEFAULT(f);
```

5. Finally, run `make reformat-dat-files` to remove the useless old entries from `pg_proc.dat`.

For further examples of scripts used for bulk editing, see `convert_oid2name.pl` and `remove_pg_type_oid_symbols.pl` attached to this message: [www.hs.net/lightdb/message-id/CAJVSX8gXnPm+Xa=DxR7kFYprcQ1tNcCT5D003ShfnM6jehA@mail.gmail.com](http://www.hs.net/lightdb/message-id/CAJVSX8gXnPm+Xa=DxR7kFYprcQ1tNcCT5D003ShfnM6jehA@mail.gmail.com)

## 65.3. BKI File Format

This section describes how the LightDB backend interprets BKI files. This description will be easier to understand if the `lightdb.bki` file is at hand as an example.

BKI input consists of a sequence of commands. Commands are made up of a number of tokens, depending on the syntax of the command. Tokens are usually separated by whitespace, but need not be if there is no ambiguity. There is no special command separator; the next token that syntactically cannot belong to the preceding command starts a new one. (Usually you would put a new command on a new line, for clarity.) Tokens can be certain key words, special characters (parentheses, commas, etc.), numbers, or double-quoted strings. Everything is case sensitive.

Lines starting with `#` are ignored.

## 65.4. BKI Commands

```
create tablename tableoid [bootstrap] [shared_relation] [rowtype_oid oid]  
(name1 = type1 [FORCE NOT NULL | FORCE NULL ], name2 = type2 [FORCE NOT NULL  
| FORCE NULL ], ...)
```

Create a table named *tablename*, and having the OID *tableoid*, with the columns given in parentheses.

The following column types are supported directly by `bootstrap.c`: `bool`, `bytea`, `char` (1 byte), `name`, `int2`, `int4`, `regproc`, `regclass`, `regtype`, `text`, `oid`, `tid`, `xid`, `cid`, `int2vector`, `oidvector`, `_int4` (array), `_text` (array), `_oid` (array), `_char` (array), `_aclitem` (array). Although it is possible to create tables containing columns of other types, this cannot be done until after `pg_type` has been created and filled with appropriate entries. (That effectively means that only these column types can be used in bootstrap catalogs, but non-bootstrap catalogs can contain any built-in type.)

When `bootstrap` is specified, the table will only be created on disk; nothing is entered into `pg_class`, `pg_attribute`, etc, for it. Thus the table will not be accessible by ordinary SQL operations until such entries are made the hard way (with `insert` commands). This option is used for creating `pg_class` etc themselves.

The table is created as shared if `shared_relation` is specified. The table's row type OID (`pg_type` OID) can optionally be specified via the `rowtype_oid` clause; if not specified, an OID is automatically generated for it. (The `rowtype_oid` clause is useless if `bootstrap` is specified, but it can be provided anyway for documentation.)

```
open tablename
```

Open the table named *tablename* for insertion of data. Any currently open table is closed.

`close tablename`

Close the open table. The name of the table must be given as a cross-check.

`insert ( [oid_value] value1 value2 ... )`

Insert a new row into the open table using *value1*, *value2*, etc., for its column values.

NULL values can be specified using the special key word `_null_`. Values that do not look like identifiers or digit strings must be double quoted.

`declare [unique] index indexname indexoid on tablename using amname ( opclass1 name1 [, ...] )`

Create an index named *indexname*, having OID *indexoid*, on the table named *tablename*, using the *amname* access method. The fields to index are called *name1*, *name2* etc., and the operator classes to use are *opclass1*, *opclass2* etc., respectively. The index file is created and appropriate catalog entries are made for it, but the index contents are not initialized by this command.

`declare toast toasttableoid toastindexoid on tablename`

Create a TOAST table for the table named *tablename*. The TOAST table is assigned OID *toasttableoid* and its index is assigned OID *toastindexoid*. As with `declare index`, filling of the index is postponed.

`build indices`

Fill in the indices that have previously been declared.

## 65.5. Structure of the Bootstrap BKI File

The `open` command cannot be used until the tables it uses exist and have entries for the table that is to be opened. (These minimum tables are `pg_class`, `pg_attribute`, `pg_proc`, and `pg_type`.) To allow those tables themselves to be filled, `create` with the `bootstrap` option implicitly opens the created table for data insertion.

Also, the `declare index` and `declare toast` commands cannot be used until the system catalogs they need have been created and filled in.

Thus, the structure of the `lightdb.bki` file has to be:

1. `create bootstrap` one of the critical tables
2. `insert` data describing at least the critical tables
3. `close`
4. Repeat for the other critical tables.
5. `create` (without `bootstrap`) a noncritical table
6. `open`
7. `insert` desired data
8. `close`
9. Repeat for the other noncritical tables.
10. Define indexes and toast tables.

11. build indices

There are doubtless other, undocumented ordering dependencies.

## 65.6. BKI Example

The following sequence of commands will create the table `test_table` with OID 420, having three columns `oid`, `cola` and `colb` of type `oid`, `int4` and `text`, respectively, and insert two rows into the table:

```
create test_table 420 (oid = oid, cola = int4, colb = text)
open test_table
insert ( 421 1 "value1" )
insert ( 422 2 _null_ )
close test_table
```



---

# Chapter 66. How the Planner Uses Statistics

This chapter builds on the material covered in Section 14.1 and Section 14.2 to show some additional details about how the planner uses the system statistics to estimate the number of rows each part of a query might return. This is a significant part of the planning process, providing much of the raw material for cost calculation.

The intent of this chapter is not to document the code in detail, but to present an overview of how it works. This will perhaps ease the learning curve for someone who subsequently wishes to read the code.

## 66.1. Row Estimation Examples

The examples shown below use tables in the LightDB regression test database. The outputs shown are taken from version 8.3. The behavior of earlier (or later) versions might vary. Note also that since ANALYZE uses random sampling while producing statistics, the results will change slightly after any new ANALYZE.

Let's start with a very simple query:

```
EXPLAIN SELECT * FROM tenk1;
```

QUERY PLAN

```
-----  
Seq Scan on tenk1 (cost=0.00..458.00 rows=10000 width=244)
```

How the planner determines the cardinality of tenk1 is covered in Section 14.2, but is repeated here for completeness. The number of pages and rows is looked up in pg\_class:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';
```

```
relpages | reltuples  
-----+-----  
      358 |      10000
```

These numbers are current as of the last VACUUM or ANALYZE on the table. The planner then fetches the actual current number of pages in the table (this is a cheap operation, not requiring a table scan). If that is different from relpages then reltuples is scaled accordingly to arrive at a current number-of-rows estimate. In the example above, the value of relpages is up-to-date so the rows estimate is the same as reltuples.

Let's move on to an example with a range condition in its WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000;
```

QUERY PLAN

```
-----  
Bitmap Heap Scan on tenk1 (cost=24.06..394.64 rows=1007  
width=244)  
  Recheck Cond: (unique1 < 1000)
```

```
-> Bitmap Index Scan on tenk1_unique1 (cost=0.00..23.80
rows=1007 width=0)
      Index Cond: (unique1 < 1000)
```

The planner examines the WHERE clause condition and looks up the selectivity function for the operator < in pg\_operator. This is held in the column oprrest, and the entry in this case is scalarltsel. The scalarltsel function retrieves the histogram for unique1 from pg\_statistic. For manual queries it is more convenient to look in the simpler pg\_stats view:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='unique1';
```

```
          histogram_bounds
-----
{0,993,1997,3050,4040,5036,5957,7057,8029,9016,9995}
```

Next the fraction of the histogram occupied by “< 1000” is worked out. This is the selectivity. The histogram divides the range into equal frequency buckets, so all we have to do is locate the bucket that our value is in and count *part* of it and *all* of the ones before. The value 1000 is clearly in the second bucket (993–1997). Assuming a linear distribution of values inside each bucket, we can calculate the selectivity as:

```
selectivity = (1 + (1000 - bucket[2].min)/(bucket[2].max -
bucket[2].min))/num_buckets
             = (1 + (1000 - 993)/(1997 - 993))/10
             = 0.100697
```

that is, one whole bucket plus a linear fraction of the second, divided by the number of buckets. The estimated number of rows can now be calculated as the product of the selectivity and the cardinality of tenk1:

```
rows = rel_cardinality * selectivity
      = 10000 * 0.100697
      = 1007 (rounding off)
```

Next let's consider an example with an equality condition in its WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul = 'CRAAAA';
```

```
          QUERY PLAN
-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=30 width=244)
  Filter: (stringul = 'CRAAAA'::name)
```

Again the planner examines the WHERE clause condition and looks up the selectivity function for =, which is eqsel. For equality estimation the histogram is not useful; instead the list of *most common values* (MCVs) is used to determine the selectivity. Let's have a look at the MCVs, with some additional columns that will be useful later:

```
SELECT null_frac, n_distinct, most_common_vals, most_common_freqs
FROM pg_stats
WHERE tablename='tenk1' AND attname='stringul';
```

```
null_frac          | 0
```

```
n_distinct          | 676
most_common_vals    | {EJAAAA, BBAAAA, CRAAAA, FCAAAA, FEAAAA, GSAAAA,
JOAAAA, MCAAAA, NAAAAA, WGAAAA}
most_common_freqs   | {0.00333333, 0.003, 0.003, 0.003, 0.003, 0.003,
0.003, 0.003, 0.003, 0.003}
```

Since CRAAAA appears in the list of MCVs, the selectivity is merely the corresponding entry in the list of most common frequencies (MCFs):

```
selectivity = mcf[3]
            = 0.003
```

As before, the estimated number of rows is just the product of this with the cardinality of tenk1:

```
rows = 10000 * 0.003
      = 30
```

Now consider the same query, but with a constant that is not in the MCV list:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul = 'xxx';
```

QUERY PLAN

```
-----
Seq Scan on tenk1  (cost=0.00..483.00 rows=15 width=244)
  Filter: (stringul = 'xxx'::name)
```

This is quite a different problem: how to estimate the selectivity when the value is *not* in the MCV list. The approach is to use the fact that the value is not in the list, combined with the knowledge of the frequencies for all of the MCVs:

```
selectivity = (1 - sum(mvf))/(num_distinct - num_mcv)
            = (1 - (0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 +
0.003 +
                    0.003 + 0.003 + 0.003 + 0.003))/(676 - 10)
            = 0.0014559
```

That is, add up all the frequencies for the MCVs and subtract them from one, then divide by the number of *other* distinct values. This amounts to assuming that the fraction of the column that is not any of the MCVs is evenly distributed among all the other distinct values. Notice that there are no null values so we don't have to worry about those (otherwise we'd subtract the null fraction from the numerator as well). The estimated number of rows is then calculated as usual:

```
rows = 10000 * 0.0014559
      = 15 (rounding off)
```

The previous example with `unique1 < 1000` was an oversimplification of what `scalarltsetl` really does; now that we have seen an example of the use of MCVs, we can fill in some more detail. The example was correct as far as it went, because since `unique1` is a unique column it has no MCVs (obviously, no value is any more common than any other value). For a non-unique column, there will normally be both a histogram and an MCV list, and *the histogram does not include the portion of the column population represented by the MCVs*. We do things this way because it allows more precise estimation. In this situation `scalarltsetl` directly applies the condition (e.g., “< 1000”) to each value of the MCV list, and adds up the frequencies of the MCVs for which the condition is true. This gives an exact estimate of the selectivity within the portion of the table that is MCVs. The histogram

is then used in the same way as above to estimate the selectivity in the portion of the table that is not MCVs, and then the two numbers are combined to estimate the overall selectivity. For example, consider

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul < 'IAAAAA';
```

```
QUERY PLAN
```

```
-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=3077 width=244)
  Filter: (stringul < 'IAAAAA'::name)
```

We already saw the MCV information for stringul, and here is its histogram:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='stringul';
```

```
          histogram_bounds
```

```
-----
{AAAAAA, CQAAAA, FRAAAA, IBAAAA, KRAAAA, NFAAAA, PSAAAA, SGAAAA, VAAAAA,
XLAAAA, ZZAAAA}
```

Checking the MCV list, we find that the condition `stringul < 'IAAAAA'` is satisfied by the first six entries and not the last four, so the selectivity within the MCV part of the population is

```
selectivity = sum(relevant mvfs)
             = 0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003
             = 0.01833333
```

Summing all the MCFs also tells us that the total fraction of the population represented by MCVs is 0.03033333, and therefore the fraction represented by the histogram is 0.96966667 (again, there are no nulls, else we'd have to exclude them here). We can see that the value `IAAAAA` falls nearly at the end of the third histogram bucket. Using some rather cheesy assumptions about the frequency of different characters, the planner arrives at the estimate 0.298387 for the portion of the histogram population that is less than `IAAAAA`. We then combine the estimates for the MCV and non-MCV populations:

```
selectivity = mcv_selectivity + histogram_selectivity *
             histogram_fraction
             = 0.01833333 + 0.298387 * 0.96966667
             = 0.307669

rows       = 10000 * 0.307669
           = 3077 (rounding off)
```

In this particular example, the correction from the MCV list is fairly small, because the column distribution is actually quite flat (the statistics showing these particular values as being more common than others are mostly due to sampling error). In a more typical case where some values are significantly more common than others, this complicated process gives a useful improvement in accuracy because the selectivity for the most common values is found exactly.

Now let's consider a case with more than one condition in the `WHERE` clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000 AND stringul =
'xxx';
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=23.80..396.91 rows=1 width=244)
  Recheck Cond: (unique1 < 1000)
  Filter: (stringul = 'xxx'::name)
  -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..23.80
rows=1007 width=0)
      Index Cond: (unique1 < 1000)
```

The planner assumes that the two conditions are independent, so that the individual selectivities of the clauses can be multiplied together:

```
selectivity = selectivity(unique1 < 1000) * selectivity(stringul =
'xxx')
              = 0.100697 * 0.0014559
              = 0.0001466

rows         = 10000 * 0.0001466
              = 1 (rounding off)
```

Notice that the number of rows estimated to be returned from the bitmap index scan reflects only the condition used with the index; this is important since it affects the cost estimate for the subsequent heap fetches.

Finally we will examine a query that involves a join:

```
EXPLAIN SELECT * FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 50 AND t1.unique2 = t2.unique2;
```

QUERY PLAN

```
-----
Nested Loop (cost=4.64..456.23 rows=50 width=488)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.64..142.17 rows=50
width=244)
      Recheck Cond: (unique1 < 50)
      -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.63
rows=50 width=0)
          Index Cond: (unique1 < 50)
  -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.00..6.27
rows=1 width=244)
      Index Cond: (unique2 = t1.unique2)
```

The restriction on `tenk1, unique1 < 50`, is evaluated before the nested-loop join. This is handled analogously to the previous range example. This time the value 50 falls into the first bucket of the `unique1` histogram:

```
selectivity = (0 + (50 - bucket[1].min)/(bucket[1].max -
bucket[1].min))/num_buckets
              = (0 + (50 - 0)/(993 - 0))/10
              = 0.005035

rows         = 10000 * 0.005035
              = 50 (rounding off)
```

The restriction for the join is `t2.unique2 = t1.unique2`. The operator is just our familiar `=`, however the selectivity function is obtained from the `oprjoin` column of `pg_operator`, and is `eqjoinsel`. `eqjoinsel` looks up the statistical information for both `tenk2` and `tenk1`:

```
SELECT tablename, null_frac, n_distinct, most_common_vals FROM
   pg_stats
WHERE tablename IN ('tenk1', 'tenk2') AND attname='unique2';
```

tablename	null_frac	n_distinct	most_common_vals
tenk1	0	-1	
tenk2	0	-1	

In this case there is no MCV information for `unique2` because all the values appear to be unique, so we use an algorithm that relies only on the number of distinct values for both relations together with their null fractions:

```
selectivity = (1 - null_frac1) * (1 - null_frac2) * min(1/
num_distinct1, 1/num_distinct2)
             = (1 - 0) * (1 - 0) / max(10000, 10000)
             = 0.0001
```

This is, subtract the null fraction from one for each of the relations, and divide by the maximum of the numbers of distinct values. The number of rows that the join is likely to emit is calculated as the cardinality of the Cartesian product of the two inputs, multiplied by the selectivity:

```
rows = (outer_cardinality * inner_cardinality) * selectivity
      = (50 * 10000) * 0.0001
      = 50
```

Had there been MCV lists for the two columns, `eqjoinsel` would have used direct comparison of the MCV lists to determine the join selectivity within the part of the column populations represented by the MCVs. The estimate for the remainder of the populations follows the same approach shown here.

Notice that we showed `inner_cardinality` as 10000, that is, the unmodified size of `tenk2`. It might appear from inspection of the `EXPLAIN` output that the estimate of join rows comes from `50 * 1`, that is, the number of outer rows times the estimated number of rows obtained by each inner index scan on `tenk2`. But this is not the case: the join relation size is estimated before any particular join plan has been considered. If everything is working well then the two ways of estimating the join size will produce about the same answer, but due to round-off error and other factors they sometimes diverge significantly.

For those interested in further details, estimation of the size of a table (before any `WHERE` clauses) is done in `src/backend/optimizer/util/plancat.c`. The generic logic for clause selectivities is in `src/backend/optimizer/path/clausesel.c`. The operator-specific selectivity functions are mostly found in `src/backend/utils/adt/selfuncs.c`.

## 66.2. Multivariate Statistics Examples

### 66.2.1. Functional Dependencies

Multivariate correlation can be demonstrated with a very simple data set — a table with two columns, both containing the same values:

```
CREATE TABLE t (a INT, b INT);
INSERT INTO t SELECT i % 100, i % 100 FROM generate_series(1,
  10000) s(i);
ANALYZE t;
```

As explained in Section 14.2, the planner can determine cardinality of `t` using the number of pages and rows obtained from `pg_class`:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 't';
```

relpages	reltuples
45	10000

The data distribution is very simple; there are only 100 distinct values in each column, uniformly distributed.

The following example shows the result of estimating a `WHERE` condition on the `a` column:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1;
QUERY PLAN
```

```
-----
Seq Scan on t (cost=0.00..170.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: (a = 1)
  Rows Removed by Filter: 9900
```

The planner examines the condition and determines the selectivity of this clause to be 1%. By comparing this estimate and the actual number of rows, we see that the estimate is very accurate (in fact exact, as the table is very small). Changing the `WHERE` condition to use the `b` column, an identical plan is generated. But observe what happens if we apply the same condition on both columns, combining them with `AND`:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
  1;
QUERY PLAN
```

```
-----
Seq Scan on t (cost=0.00..195.00 rows=1 width=8) (actual rows=100
loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

The planner estimates the selectivity for each condition individually, arriving at the same 1% estimates as above. Then it assumes that the conditions are independent, and so it multiplies their selectivities, producing a final selectivity estimate of just 0.01%. This is a significant underestimate, as the actual number of rows matching the conditions (100) is two orders of magnitude higher.

This problem can be fixed by creating a statistics object that directs `ANALYZE` to calculate functional-dependency multivariate statistics on the two columns:

```
CREATE STATISTICS stts (dependencies) ON a, b FROM t;
```

```
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
1;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

## 66.2.2. Multivariate N-Distinct Counts

A similar problem occurs with estimation of the cardinality of sets of multiple columns, such as the number of groups that would be generated by a `GROUP BY` clause. When `GROUP BY` lists a single column, the n-distinct estimate (which is visible as the estimated number of rows returned by the HashAggregate node) is very accurate:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a;
```

QUERY PLAN

```
-----
HashAggregate (cost=195.00..196.00 rows=100 width=12) (actual
rows=100 loops=1)
  Group Key: a
    -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=4)
    (actual rows=10000 loops=1)
```

But without multivariate statistics, the estimate for the number of groups in a query with two columns in `GROUP BY`, as in the following example, is off by an order of magnitude:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a, b;
```

QUERY PLAN

```
-----
HashAggregate (cost=220.00..230.00 rows=1000 width=16) (actual
rows=100 loops=1)
  Group Key: a, b
    -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=8)
    (actual rows=10000 loops=1)
```

By redefining the statistics object to include n-distinct counts for the two columns, the estimate is much improved:

```
DROP STATISTICS stts;
CREATE STATISTICS stts (dependencies, ndistinct) ON a, b FROM t;
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a, b;
```

QUERY PLAN



```
HashAggregate (cost=220.00..221.00 rows=100 width=16) (actual
rows=100 loops=1)
  Group Key: a, b
  -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=8)
(actual rows=10000 loops=1)
```

### 66.2.3. MCV Lists

As explained in Section 66.2.1, functional dependencies are very cheap and efficient type of statistics, but their main limitation is their global nature (only tracking dependencies at the column level, not between individual column values).

This section introduces multivariate variant of MCV (most-common values) lists, a straightforward extension of the per-column statistics described in Section 66.1. These statistics address the limitation by storing individual values, but it is naturally more expensive, both in terms of building the statistics in ANALYZE, storage and planning time.

Let's look at the query from Section 66.2.1 again, but this time with a MCV list created on the same set of columns (be sure to drop the functional dependencies, to make sure the planner uses the newly created statistics).

```
DROP STATISTICS stts;
CREATE STATISTICS stts2 (mcv) ON a, b FROM t;
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
1;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

The estimate is as accurate as with the functional dependencies, mostly thanks to the table being fairly small and having a simple distribution with a low number of distinct values. Before looking at the second query, which was not handled by functional dependencies particularly well, let's inspect the MCV list a bit.

Inspecting the MCV list is possible using `pg_mcv_list_items` set-returning function.

```
SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
          pg_mcv_list_items(stxdmcv) m WHERE stxname =
'stts2';
index | values | nulls | frequency | base_frequency
-----+-----+-----+-----+-----
      0 | {0, 0} | {f,f} |      0.01 |          0.0001
      1 | {1, 1} | {f,f} |      0.01 |          0.0001
      ...
     49 | {49, 49} | {f,f} |      0.01 |          0.0001
     50 | {50, 50} | {f,f} |      0.01 |          0.0001
      ...
     97 | {97, 97} | {f,f} |      0.01 |          0.0001
     98 | {98, 98} | {f,f} |      0.01 |          0.0001
     99 | {99, 99} | {f,f} |      0.01 |          0.0001
(100 rows)
```

This confirms there are 100 distinct combinations in the two columns, and all of them are about equally likely (1% frequency for each one). The base frequency is the frequency computed from per-column statistics, as if there were no multi-column statistics. Had there been any null values in either of the columns, this would be identified in the `nulls` column.

When estimating the selectivity, the planner applies all the conditions on items in the MCV list, and then sums the frequencies of the matching ones. See `mcv_clauselist_selectivity` in `src/backend/statistics/mcv.c` for details.

Compared to functional dependencies, MCV lists have two major advantages. Firstly, the list stores actual values, making it possible to decide which combinations are compatible.

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
10;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=1 width=8) (actual rows=0
loops=1)
  Filter: ((a = 1) AND (b = 10))
  Rows Removed by Filter: 10000
```

Secondly, MCV lists handle a wider range of clause types, not just equality clauses like functional dependencies. For example, consider the following range query for the same table:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a <= 49 AND b >
49;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=1 width=8) (actual rows=0
loops=1)
  Filter: ((a <= 49) AND (b > 49))
  Rows Removed by Filter: 10000
```

## 66.3. Planner Statistics and Security

Access to the table `pg_statistic` is restricted to superusers, so that ordinary users cannot learn about the contents of the tables of other users from it. Some selectivity estimation functions will use a user-provided operator (either the operator appearing in the query or a related operator) to analyze the stored statistics. For example, in order to determine whether a stored most common value is applicable, the selectivity estimator will have to run the appropriate `=` operator to compare the constant in the query to the stored value. Thus the data in `pg_statistic` is potentially passed to user-defined operators. An appropriately crafted operator can intentionally leak the passed operands (for example, by logging them or writing them to a different table), or accidentally leak them by showing their values in error messages, in either case possibly exposing data from `pg_statistic` to a user who should not be able to see it.

In order to prevent this, the following applies to all built-in selectivity estimation functions. When planning a query, in order to be able to use stored statistics, the current user must either have `SELECT` privilege on the table or the involved columns, or the operator used must be `LEAKPROOF` (more accurately, the function that the operator is based on). If not, then the selectivity estimator will behave as if no statistics are available, and the planner will proceed with default or fall-back assumptions.

If a user does not have the required privilege on the table or columns, then in many cases the query will ultimately receive a permission-denied error, in which case this mechanism is invisible in practice. But if the user is reading from a security-barrier view, then the planner might wish to check the statistics

of an underlying table that is otherwise inaccessible to the user. In that case, the operator should be leak-proof or the statistics will not be used. There is no direct feedback about that, except that the plan might be suboptimal. If one suspects that this is the case, one could try running the query as a more privileged user, to see if a different plan results.

This restriction applies only to cases where the planner would need to execute a user-defined operator on one or more values from `pg_statistic`. Thus the planner is permitted to use generic statistical information, such as the fraction of null values or the number of distinct values in a column, regardless of access privileges.

Selectivity estimation functions contained in third-party extensions that potentially operate on statistics with user-defined operators should follow the same security rules. Consult the LightDB source code for guidance.

---

# Chapter 67. Backup Manifest Format

The backup manifest generated by `lt_basebackup` is primarily intended to permit the backup to be verified using `lt_verifybackup`. However, it is also possible for other tools to read the backup manifest file and use the information contained therein for their own purposes. To that end, this chapter describes the format of the backup manifest file.

A backup manifest is a JSON document encoded as UTF-8. (Although in general JSON documents are required to be Unicode, `LightDB` permits the `json` and `jsonb` data types to be used with any supported server encoding. There is no similar exception for backup manifests.) The JSON document is always an object; the keys that are present in this object are described in the next section.

## 67.1. Backup Manifest Top-level Object

The backup manifest JSON document contains the following keys.

`LightDB-Backup-Manifest-Version`

The associated value is always the integer 1.

`Files`

The associated value is always a list of objects, each describing one file that is present in the backup. No entries are present in this list for the WAL files that are needed in order to use the backup, or for the backup manifest itself. The structure of each object in the list is described in Section 67.2.

`WAL-Ranges`

The associated value is always a list of objects, each describing a range of WAL records that must be readable from a particular timeline in order to make use of the backup. The structure of these objects is further described in Section 67.3.

`Manifest-Checksum`

This key is always present on the last line of the backup manifest file. The associated value is a SHA256 checksum of all the preceding lines. We use a fixed checksum method here to make it possible for clients to do incremental parsing of the manifest. While a SHA256 checksum is significantly more expensive than a CRC32C checksum, the manifest should normally be small enough that the extra computation won't matter very much.

## 67.2. Backup Manifest File Object

The object which describes a single file contains either a `Path` key or an `Encoded-Path` key. Normally, the `Path` key will be present. The associated string value is the path of the file relative to the root of the backup directory. Files located in a user-defined tablespace will have paths whose first two components are `lt_tblspc` and the OID of the tablespace. If the path is not a string that is legal in UTF-8, or if the user requests that encoded paths be used for all files, then the `Encoded-Path` key will be present instead. This stores the same data, but it is encoded as a string of hexadecimal digits. Each pair of hexadecimal digits in the string represents a single octet.

The following two keys are always present:

`Size`

The expected size of this file, as an integer.

#### Last-Modified

The last modification time of the file as reported by the server at the time of the backup. Unlike the other fields stored in the backup, this field is not used by `lt_verifybackup`. It is included only for informational purposes.

If the backup was taken with file checksums enabled, the following keys will be present:

#### Checksum-Algorithm

The checksum algorithm used to compute a checksum for this file. Currently, this will be the same for every file in the backup manifest, but this may change in future releases. At present, the supported checksum algorithms are `CRC32C`, `SHA224`, `SHA256`, `SHA384`, and `SHA512`.

#### Checksum

The checksum computed for this file, stored as a series of hexadecimal characters, two for each byte of the checksum.

## 67.3. Backup Manifest WAL Range Object

The object which describes a WAL range always has three keys:

#### Timeline

The timeline for this range of WAL records, as an integer.

#### Start-LSN

The LSN at which replay must begin on the indicated timeline in order to make use of this backup. The LSN is stored in the format normally used by `LightDB`; that is, it is a string consisting of two strings of hexadecimal characters, each with a length of between 1 and 8, separated by a slash.

#### End-LSN

The earliest LSN at which replay on the indicated timeline may end when making use of this backup. This is stored in the same format as `Start-LSN`.

Ordinarily, there will be only a single WAL range. However, if a backup is taken from a standby which switches timelines during the backup due to an upstream promotion, it is possible for multiple ranges to be present, each with a different timeline. There will never be multiple WAL ranges present for the same timeline.

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# Part VIII. Appendixes

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# Appendix A. LightDB Error Codes

All messages emitted by the LightDB server are assigned five-character error codes that follow the SQL standard's conventions for "SQLSTATE" codes. Applications that need to know which error condition has occurred should usually test the error code, rather than looking at the textual error message. The error codes are less likely to change across LightDB releases, and also are not subject to change due to localization of error messages. Note that some, but not all, of the error codes produced by LightDB are defined by the SQL standard; some additional error codes for conditions not defined by the standard have been invented or borrowed from other databases.

According to the standard, the first two characters of an error code denote a class of errors, while the last three characters indicate a specific condition within that class. Thus, an application that does not recognize the specific error code might still be able to infer what to do from the error class.

Table A.1 lists all the error codes defined in LightDB 13.8-23.4. (Some are not actually used at present, but are defined by the SQL standard.) The error classes are also shown. For each error class there is a "standard" error code having the last three characters 000. This code is used only for error conditions that fall within the class but do not have any more-specific code assigned.

The symbol shown in the column "Condition Name" is the condition name to use in PL/pgSQL. Condition names can be written in either upper or lower case. (Note that PL/pgSQL does not recognize warning, as opposed to error, condition names; those are classes 00, 01, and 02.)

For some types of errors, the server reports the name of a database object (a table, table column, data type, or constraint) associated with the error; for example, the name of the unique constraint that caused a `unique_violation` error. Such names are supplied in separate fields of the error report message so that applications need not try to extract them from the possibly-localized human-readable text of the message. As of LightDB 9.3, complete coverage for this feature exists only for errors in SQLSTATE class 23 (integrity constraint violation), but this is likely to be expanded in future.

**Table A.1. LightDB Error Codes**

Error Code	Condition Name
<b>Class 00 — Successful Completion</b>	
00000	successful_completion
<b>Class 01 — Warning</b>	
01000	warning
0100C	dynamic_result_sets_returned
01008	implicit_zero_bit_padding
01003	null_value_eliminated_in_set_function
01007	privilege_not_granted
01006	privilege_not_revoked
01004	string_data_right_truncation
01P01	deprecated_feature
<b>Class 02 — No Data (this is also a warning class per the SQL standard)</b>	
02000	no_data
02001	no_additional_dynamic_result_sets_returned
<b>Class 03 — SQL Statement Not Yet Complete</b>	
03000	sql_statement_not_yet_complete
<b>Class 08 — Connection Exception</b>	

<b>Error Code</b>	<b>Condition Name</b>
08000	connection_exception
08003	connection_does_not_exist
08006	connection_failure
08001	sqlclient_unable_to_establish_sqlconnection
08004	sqlserver_rejected_establishment_of_sqlconnection
08007	transaction_resolution_unknown
08P01	protocol_violation
<b>Class 09 — Triggered Action Exception</b>	
09000	triggered_action_exception
<b>Class 0A — Feature Not Supported</b>	
0A000	feature_not_supported
<b>Class 0B — Invalid Transaction Initiation</b>	
0B000	invalid_transaction_initiation
<b>Class 0F — Locator Exception</b>	
0F000	locator_exception
0F001	invalid_locator_specification
<b>Class 0L — Invalid Grantor</b>	
0L000	invalid_grantor
0LP01	invalid_grant_operation
<b>Class 0P — Invalid Role Specification</b>	
0P000	invalid_role_specification
<b>Class 0Z — Diagnostics Exception</b>	
0Z000	diagnostics_exception
0Z002	stacked_diagnostics_accessed_without_active_handler
<b>Class 20 — Case Not Found</b>	
20000	case_not_found
<b>Class 21 — Cardinality Violation</b>	
21000	cardinality_violation
<b>Class 22 — Data Exception</b>	
22000	data_exception
2202E	array_subscript_error
22021	character_not_in_repertoire
22008	datetime_field_overflow
22012	division_by_zero
22005	error_in_assignment
2200B	escape_character_conflict
22022	indicator_overflow
22015	interval_field_overflow
2201E	invalid_argument_for_logarithm
22014	invalid_argument_for_ntile_function



LightDB Error Codes

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<b>Error Code</b>	<b>Condition Name</b>
22016	invalid_argument_for_nth_value_function
2201F	invalid_argument_for_power_function
2201G	invalid_argument_for_width_bucket_function
22018	invalid_character_value_for_cast
22007	invalid_datetime_format
22019	invalid_escape_character
2200D	invalid_escape_octet
22025	invalid_escape_sequence
22P06	nonstandard_use_of_escape_character
22010	invalid_indicator_parameter_value
22023	invalid_parameter_value
22013	invalid_preceding_or_following_size
2201B	invalid_regular_expression
2201W	invalid_row_count_in_limit_clause
2201X	invalid_row_count_in_result_offset_clause
2202H	invalid_tablesample_argument
2202G	invalid_tablesample_repeat
22009	invalid_time_zone_displacement_value
2200C	invalid_use_of_escape_character
2200G	most_specific_type_mismatch
22004	null_value_not_allowed
22002	null_value_no_indicator_parameter
22003	numeric_value_out_of_range
2200H	sequence_generator_limit_exceeded
22026	string_data_length_mismatch
22001	string_data_right_truncation
22011	substring_error
22027	trim_error
22024	unterminated_c_string
2200F	zero_length_character_string
22P01	floating_point_exception
22P02	invalid_text_representation
22P03	invalid_binary_representation
22P04	bad_copy_file_format
22P05	untranslatable_character
2200L	not_an_xml_document
2200M	invalid_xml_document
2200N	invalid_xml_content
2200S	invalid_xml_comment
2200T	invalid_xml_processing_instruction

<b>Error Code</b>	<b>Condition Name</b>
22030	duplicate_json_object_key_value
22031	invalid_argument_for_sql_json_datetime_function
22032	invalid_json_text
22033	invalid_sql_json_subscript
22034	more_than_one_sql_json_item
22035	no_sql_json_item
22036	non_numeric_sql_json_item
22037	non_unique_keys_in_a_json_object
22038	singleton_sql_json_item_required
22039	sql_json_array_not_found
2203A	sql_json_member_not_found
2203B	sql_json_number_not_found
2203C	sql_json_object_not_found
2203D	too_many_json_array_elements
2203E	too_many_json_object_members
2203F	sql_json_scalar_required
<b>Class 23 — Integrity Constraint Violation</b>	
23000	integrity_constraint_violation
23001	restrict_violation
23502	not_null_violation
23503	foreign_key_violation
23505	unique_violation
23514	check_violation
23P01	exclusion_violation
<b>Class 24 — Invalid Cursor State</b>	
24000	invalid_cursor_state
<b>Class 25 — Invalid Transaction State</b>	
25000	invalid_transaction_state
25001	active_sql_transaction
25002	branch_transaction_already_active
25008	held_cursor_requires_same_isolation_level
25003	inappropriate_access_mode_for_branch_transaction
25004	inappropriate_isolation_level_for_branch_transaction
25005	no_active_sql_transaction_for_branch_transaction
25006	read_only_sql_transaction
25007	schema_and_data_statement_mixing_not_supported
25P01	no_active_sql_transaction
25P02	in_failed_sql_transaction
25P03	idle_in_transaction_session_timeout
<b>Class 29 — Invalid or Unexpected Status</b>	

<b>Error Code</b>	<b>Condition Name</b>
29000	invalid_status
29003	assert_failed
29P01	cache_lookup_failed
29P02	fetch_data_failed
29P03	flush_data_size_mismatch
29P04	relation_open_error
29P05	relation_close_error
29P06	invalid_cache_plan
<b>Class 26 — Invalid SQL Statement Name</b>	
26000	invalid_sql_statement_name
<b>Class 27 — Triggered Data Change Violation</b>	
27000	triggered_data_change_violation
<b>Class 28 — Invalid Authorization Specification</b>	
28000	invalid_authorization_specification
28P01	invalid_password
<b>Class 2B — Dependent Privilege Descriptors Still Exist</b>	
2B000	dependent_privilege_descriptors_still_exist
2BP01	dependent_objects_still_exist
<b>Class 2D — Invalid Transaction Termination</b>	
2D000	invalid_transaction_termination
<b>Class 2F — SQL Routine Exception</b>	
2F000	sql_routine_exception
2F005	function_executed_no_return_statement
2F002	modifying_sql_data_not_permitted
2F003	prohibited_sql_statement_attempted
2F004	reading_sql_data_not_permitted
<b>Class 34 — Invalid Cursor Name</b>	
34000	invalid_cursor_name
<b>Class 38 — External Routine Exception</b>	
38000	external_routine_exception
38001	containing_sql_not_permitted
38002	modifying_sql_data_not_permitted
38003	prohibited_sql_statement_attempted
38004	reading_sql_data_not_permitted
<b>Class 39 — External Routine Invocation Exception</b>	
39000	external_routine_invocation_exception
39001	invalid_sqlstate_returned
39004	null_value_not_allowed
39P01	trigger_protocol_violated
39P02	srf_protocol_violated

<b>Error Code</b>	<b>Condition Name</b>
39P03	event_trigger_protocol_violated
<b>Class 3B — Savepoint Exception</b>	
3B000	savepoint_exception
3B001	invalid_savepoint_specification
<b>Class 3D — Invalid Catalog Name</b>	
3D000	invalid_catalog_name
<b>Class 3F — Invalid Schema Name</b>	
3F000	invalid_schema_name
<b>Class 40 — Transaction Rollback</b>	
40000	transaction_rollback
40002	transaction_integrity_constraint_violation
40001	serialization_failure
40003	statement_completion_unknown
40P01	deadlock_detected
<b>Class 42 — Syntax Error or Access Rule Violation</b>	
42000	syntax_error_or_access_rule_violation
42601	syntax_error
42501	insufficient_privilege
42846	cannot_coerce
42803	grouping_error
42P20	windowing_error
42P19	invalid_recursion
42830	invalid_foreign_key
42602	invalid_name
42622	name_too_long
42939	reserved_name
42804	datatype_mismatch
42P18	indeterminate_datatype
42P21	collation_mismatch
42P22	indeterminate_collation
42809	wrong_object_type
428C9	generated_always
42703	undefined_column
42883	undefined_function
42P01	undefined_table
42P02	undefined_parameter
42704	undefined_object
42701	duplicate_column
42P03	duplicate_cursor
42P04	duplicate_database

<b>Error Code</b>	<b>Condition Name</b>
42723	duplicate_function
42P05	duplicate_prepared_statement
42P06	duplicate_schema
42P07	duplicate_table
42712	duplicate_alias
42710	duplicate_object
42702	ambiguous_column
42725	ambiguous_function
42P08	ambiguous_parameter
42P09	ambiguous_alias
42P10	invalid_column_reference
42611	invalid_column_definition
42P11	invalid_cursor_definition
42P12	invalid_database_definition
42P13	invalid_function_definition
42P14	invalid_prepared_statement_definition
42P15	invalid_schema_definition
42P16	invalid_table_definition
42P17	invalid_object_definition
<b>Class 44 — WITH CHECK OPTION Violation</b>	
44000	with_check_option_violation
<b>Class 53 — Insufficient Resources</b>	
53000	insufficient_resources
53100	disk_full
53200	out_of_memory
53300	too_many_connections
53400	configuration_limit_exceeded
<b>Class 54 — Program Limit Exceeded</b>	
54000	program_limit_exceeded
54001	statement_too_complex
54011	too_many_columns
54023	too_many_arguments
<b>Class 55 — Object Not In Prerequisite State</b>	
55000	object_not_in_prerequisite_state
55006	object_in_use
55P02	cant_change_runtime_param
55P03	lock_not_available
55P04	unsafe_new_enum_value_usage
<b>Class 57 — Operator Intervention</b>	
57000	operator_intervention

<b>Error Code</b>	<b>Condition Name</b>
57014	query_canceled
57P01	admin_shutdown
57P02	crash_shutdown
57P03	cannot_connect_now
57P04	database_dropped
<b>Class 58 — System Error (errors external to PostgreSQL itself)</b>	
58000	system_error
58030	io_error
58P01	undefined_file
58P02	duplicate_file
<b>Class 72 — Snapshot Failure</b>	
72000	snapshot_too_old
<b>Class F0 — Configuration File Error</b>	
F0000	config_file_error
F0001	lock_file_exists
<b>Class HV — Foreign Data Wrapper Error (SQL/MED)</b>	
HV000	fdw_error
HV005	fdw_column_name_not_found
HV002	fdw_dynamic_parameter_value_needed
HV010	fdw_function_sequence_error
HV021	fdw_inconsistent_descriptor_information
HV024	fdw_invalid_attribute_value
HV007	fdw_invalid_column_name
HV008	fdw_invalid_column_number
HV004	fdw_invalid_data_type
HV006	fdw_invalid_data_type_descriptors
HV091	fdw_invalid_descriptor_field_identifier
HV00B	fdw_invalid_handle
HV00C	fdw_invalid_option_index
HV00D	fdw_invalid_option_name
HV090	fdw_invalid_string_length_or_buffer_length
HV00A	fdw_invalid_string_format
HV009	fdw_invalid_use_of_null_pointer
HV014	fdw_too_many_handles
HV001	fdw_out_of_memory
HV00P	fdw_no_schemas
HV00J	fdw_option_name_not_found
HV00K	fdw_reply_handle
HV00Q	fdw_schema_not_found
HV00R	fdw_table_not_found

<b>Error Code</b>	<b>Condition Name</b>
HV00L	fdw_unable_to_create_execution
HV00M	fdw_unable_to_create_reply
HV00N	fdw_unable_to_establish_connection
<b>Class P0 — PL/pgSQL Error</b>	
P0000	plpgsql_error
P0001	raise_exception
P0002	no_data_found
P0003	too_many_rows
P0004	assert_failure
P0005	forall_need_dml
<b>Class XX — Internal Error</b>	
XX000	internal_error
XX001	data_corrupted
XX002	index_corrupted
<b>Class LT — DDL Standard Check Failure</b>	
LT000	keyword_not_allowed
LT001	bad_datatype
LT002	must_have_pk
LT003	must_have_gmt
LT004	no_more_100cols
LT005	invalid_procedure_definition
LT006	no_paging
LT007	high_risk_ddl
LT008	hint_need_index
LT009	index_invalid_in_hint
LT010	multi_index_in_hint
LT011	hint_disallowed
22012	zero_divide
24000	invalid_cursor
28P01	login_denied
23505	dup_val_on_index

---

# Appendix B. Date/Time Support

LightDB uses an internal heuristic parser for all date/time input support. Dates and times are input as strings, and are broken up into distinct fields with a preliminary determination of what kind of information can be in the field. Each field is interpreted and either assigned a numeric value, ignored, or rejected. The parser contains internal lookup tables for all textual fields, including months, days of the week, and time zones.

This appendix includes information on the content of these lookup tables and describes the steps used by the parser to decode dates and times.

## B.1. Date/Time Input Interpretation

Date/time input strings are decoded using the following procedure.

1. Break the input string into tokens and categorize each token as a string, time, time zone, or number.
  - a. If the numeric token contains a colon (:), this is a time string. Include all subsequent digits and colons.
  - b. If the numeric token contains a dash (-), slash (/), or two or more dots (.), this is a date string which might have a text month. If a date token has already been seen, it is instead interpreted as a time zone name (e.g., `America/New_York`).
  - c. If the token is numeric only, then it is either a single field or an ISO 8601 concatenated date (e.g., `19990113` for January 13, 1999) or time (e.g., `141516` for 14:15:16).
  - d. If the token starts with a plus (+) or minus (-), then it is either a numeric time zone or a special field.
2. If the token is an alphabetic string, match up with possible strings:
  - a. See if the token matches any known time zone abbreviation. These abbreviations are supplied by the configuration file described in Section B.4.
  - b. If not found, search an internal table to match the token as either a special string (e.g., `today`), day (e.g., `Thursday`), month (e.g., `January`), or noise word (e.g., `at`, `on`).
  - c. If still not found, throw an error.
3. When the token is a number or number field:
  - a. If there are eight or six digits, and if no other date fields have been previously read, then interpret as a “concatenated date” (e.g., `19990118` or `990118`). The interpretation is `YYYYMMDD` or `YYMMDD`.
  - b. If the token is three digits and a year has already been read, then interpret as day of year.
  - c. If four or six digits and a year has already been read, then interpret as a time (`HHMM` or `HHMMSS`).
  - d. If three or more digits and no date fields have yet been found, interpret as a year (this forces `yy-mm-dd` ordering of the remaining date fields).
  - e. Otherwise the date field ordering is assumed to follow the `DateStyle` setting: `mm-dd-yy`, `dd-mm-yy`, or `yy-mm-dd`. Throw an error if a month or day field is found to be out of range.
4. If BC has been specified, negate the year and add one for internal storage. (There is no year zero in the Gregorian calendar, so numerically 1 BC becomes year zero.)



- If BC was not specified, and if the year field was two digits in length, then adjust the year to four digits. If the field is less than 70, then add 2000, otherwise add 1900.

### Tip

Gregorian years AD 1–99 can be entered by using 4 digits with leading zeros (e.g., 0099 is AD 99).

## B.2. Handling of Invalid or Ambiguous Timestamps

Ordinarily, if a date/time string is syntactically valid but contains out-of-range field values, an error will be thrown. For example, input specifying the 31st of February will be rejected.

During a daylight-savings-time transition, it is possible for a seemingly valid timestamp string to represent a nonexistent or ambiguous timestamp. Such cases are not rejected; the ambiguity is resolved by determining which UTC offset to apply. For example, supposing that the `TimeZone` parameter is set to `America/New_York`, consider

```
=> SELECT '2018-03-11 02:30'::timestampz;
       timestampz
-----
2018-03-11 03:30:00-04
(1 row)
```

Because that day was a spring-forward transition date in that time zone, there was no civil time instant 2:30AM; clocks jumped forward from 2AM EST to 3AM EDT. LightDB interprets the given time as if it were standard time (UTC-5), which then renders as 3:30AM EDT (UTC-4).

Conversely, consider the behavior during a fall-back transition:

```
=> SELECT '2018-11-04 01:30'::timestampz;
       timestampz
-----
2018-11-04 01:30:00-05
(1 row)
```

On that date, there were two possible interpretations of 1:30AM; there was 1:30AM EDT, and then an hour later after clocks jumped back from 2AM EDT to 1AM EST, there was 1:30AM EST. Again, LightDB interprets the given time as if it were standard time (UTC-5). We can force the other interpretation by specifying daylight-savings time:

```
=> SELECT '2018-11-04 01:30 EDT'::timestampz;
       timestampz
-----
2018-11-04 01:30:00-04
(1 row)
```

The precise rule that is applied in such cases is that an invalid timestamp that appears to fall within a jump-forward daylight savings transition is assigned the UTC offset that prevailed in the time zone just before the transition, while an ambiguous timestamp that could fall on either side of a jump-back transition is assigned the UTC offset that prevailed just after the transition. In most time zones this is equivalent to saying that “the standard-time interpretation is preferred when in doubt”.

In all cases, the UTC offset associated with a timestamp can be specified explicitly, using either a numeric UTC offset or a time zone abbreviation that corresponds to a fixed UTC offset. The rule just given applies only when it is necessary to infer a UTC offset for a time zone in which the offset varies.

## B.3. Date/Time Key Words

Table B.1 shows the tokens that are recognized as names of months.

**Table B.1. Month Names**

Month	Abbreviations
January	Jan
February	Feb
March	Mar
April	Apr
May	
June	Jun
July	Jul
August	Aug
September	Sep, Sept
October	Oct
November	Nov
December	Dec

Table B.2 shows the tokens that are recognized as names of days of the week.

**Table B.2. Day of the Week Names**

Day	Abbreviations
Sunday	Sun
Monday	Mon
Tuesday	Tue, Tues
Wednesday	Wed, Weds
Thursday	Thu, Thur, Thurs
Friday	Fri
Saturday	Sat

Table B.3 shows the tokens that serve various modifier purposes.

**Table B.3. Date/Time Field Modifiers**

Identifier	Description
AM	Time is before 12:00
AT	Ignored
JULIAN, JD, J	Next field is Julian Date
ON	Ignored
PM	Time is on or after 12:00
T	Next field is time

## B.4. Date/Time Configuration Files

Since timezone abbreviations are not well standardized, LightDB provides a means to customize the set of abbreviations accepted by the server. The `timezone_abbreviations` run-time parameter determines the active set of abbreviations. While this parameter can be altered by any database user, the possible values for it are under the control of the database administrator — they are in fact names of configuration files stored in `.../share/timezonesets/` of the installation directory. By adding or altering files in that directory, the administrator can set local policy for timezone abbreviations.

`timezone_abbreviations` can be set to any file name found in `.../share/timezonesets/`, if the file's name is entirely alphabetic. (The prohibition against non-alphabetic characters in `timezone_abbreviations` prevents reading files outside the intended directory, as well as reading editor backup files and other extraneous files.)

A timezone abbreviation file can contain blank lines and comments beginning with `#`. Non-comment lines must have one of these formats:

```
zone_abbreviation offset
zone_abbreviation offset D
zone_abbreviation time_zone_name
@INCLUDE file_name
@OVERRIDE
```

A *zone\_abbreviation* is just the abbreviation being defined. An *offset* is an integer giving the equivalent offset in seconds from UTC, positive being east from Greenwich and negative being west. For example, `-18000` would be five hours west of Greenwich, or North American east coast standard time. `D` indicates that the zone name represents local daylight-savings time rather than standard time.

Alternatively, a *time\_zone\_name* can be given, referencing a zone name defined in the IANA timezone database. The zone's definition is consulted to see whether the abbreviation is or has been in use in that zone, and if so, the appropriate meaning is used — that is, the meaning that was currently in use at the timestamp whose value is being determined, or the meaning in use immediately before that if it wasn't current at that time, or the oldest meaning if it was used only after that time. This behavior is essential for dealing with abbreviations whose meaning has historically varied. It is also allowed to define an abbreviation in terms of a zone name in which that abbreviation does not appear; then using the abbreviation is just equivalent to writing out the zone name.

### Tip

Using a simple integer *offset* is preferred when defining an abbreviation whose offset from UTC has never changed, as such abbreviations are much cheaper to process than those that require consulting a time zone definition.

The `@INCLUDE` syntax allows inclusion of another file in the `.../share/timezonesets/` directory. Inclusion can be nested, to a limited depth.

The `@OVERRIDE` syntax indicates that subsequent entries in the file can override previous entries (typically, entries obtained from included files). Without this, conflicting definitions of the same timezone abbreviation are considered an error.

In an unmodified installation, the file `Default` contains all the non-conflicting time zone abbreviations for most of the world. Additional files `Australia` and `India` are provided for those regions: these files first include the `Default` file and then add or modify abbreviations as needed.

For reference purposes, a standard installation also contains files `Africa.txt`, `America.txt`, etc, containing information about every time zone abbreviation known to be in use according to the

IANA timezone database. The zone name definitions found in these files can be copied and pasted into a custom configuration file as needed. Note that these files cannot be directly referenced as `timezone_abbreviations` settings, because of the dot embedded in their names.

### Note

If an error occurs while reading the time zone abbreviation set, no new value is applied and the old set is kept. If the error occurs while starting the database, startup fails.

### Caution

Time zone abbreviations defined in the configuration file override non-timezone meanings built into LightDB. For example, the `Australia` configuration file defines `SAT` (for South Australian Standard Time). When this file is active, `SAT` will not be recognized as an abbreviation for Saturday.

### Caution

If you modify files in `.../share/timezonesets/`, it is up to you to make backups — a normal database dump will not include this directory.

## B.5. POSIX Time Zone Specifications

LightDB can accept time zone specifications that are written according to the POSIX standard's rules for the `TZ` environment variable. POSIX time zone specifications are inadequate to deal with the complexity of real-world time zone history, but there are sometimes reasons to use them.

A POSIX time zone specification has the form

```
STD offset [ DST [ dstoffset ] [ , rule ] ]
```

(For readability, we show spaces between the fields, but spaces should not be used in practice.) The fields are:

- *STD* is the zone abbreviation to be used for standard time.
- *offset* is the zone's standard-time offset from UTC.
- *DST* is the zone abbreviation to be used for daylight-savings time. If this field and the following ones are omitted, the zone uses a fixed UTC offset with no daylight-savings rule.
- *dstoffset* is the daylight-savings offset from UTC. This field is typically omitted, since it defaults to one hour less than the standard-time *offset*, which is usually the right thing.
- *rule* defines the rule for when daylight savings is in effect, as described below.

In this syntax, a zone abbreviation can be a string of letters, such as `EST`, or an arbitrary string surrounded by angle brackets, such as `<UTC-05>`. Note that the zone abbreviations given here are only used for output, and even then only in some timestamp output formats. The zone abbreviations recognized in timestamp input are determined as explained in Section B.4.

The offset fields specify the hours, and optionally minutes and seconds, difference from UTC. They have the format `hh[:mm[:ss]]` optionally with a leading sign (+ or -). The positive sign is used

for zones *west* of Greenwich. (Note that this is the opposite of the ISO-8601 sign convention used elsewhere in LightDB.) *hh* can have one or two digits; *mm* and *ss* (if used) must have two.

The daylight-savings transition *rule* has the format

```
dstdate [ / dsttime ] , stddate [ / stdtime ]
```

(As before, spaces should not be included in practice.) The *dstdate* and *dsttime* fields define when daylight-savings time starts, while *stddate* and *stdtime* define when standard time starts. (In some cases, notably in zones south of the equator, the former might be later in the year than the latter.) The date fields have one of these formats:

*n*

A plain integer denotes a day of the year, counting from zero to 364, or to 365 in leap years.

*Jn*

In this form, *n* counts from 1 to 365, and February 29 is not counted even if it is present. (Thus, a transition occurring on February 29 could not be specified this way. However, days after February have the same numbers whether it's a leap year or not, so that this form is usually more useful than the plain-integer form for transitions on fixed dates.)

*Mm.n.d*

This form specifies a transition that always happens during the same month and on the same day of the week. *m* identifies the month, from 1 to 12. *n* specifies the *n*'th occurrence of the weekday identified by *d*. *n* is a number between 1 and 4, or 5 meaning the last occurrence of that weekday in the month (which could be the fourth or the fifth). *d* is a number between 0 and 6, with 0 indicating Sunday. For example, *M3.2.0* means "the second Sunday in March".

### Note

The M format is sufficient to describe many common daylight-savings transition laws. But note that none of these variants can deal with daylight-savings law changes, so in practice the historical data stored for named time zones (in the IANA time zone database) is necessary to interpret past time stamps correctly.

The time fields in a transition rule have the same format as the offset fields described previously, except that they cannot contain signs. They define the current local time at which the change to the other time occurs. If omitted, they default to 02:00:00.

If a daylight-savings abbreviation is given but the transition *rule* field is omitted, the fallback behavior is to use the rule *M3.2.0,M11.1.0*, which corresponds to USA practice as of 2020 (that is, spring forward on the second Sunday of March, fall back on the first Sunday of November, both transitions occurring at 2AM prevailing time). Note that this rule does not give correct USA transition dates for years before 2007.

As an example, *CET-1CEST,M3.5.0,M10.5.0/3* describes current (as of 2020) timekeeping practice in Paris. This specification says that standard time has the abbreviation *CET* and is one hour ahead (east) of UTC; daylight savings time has the abbreviation *CEST* and is implicitly two hours ahead of UTC; daylight savings time begins on the last Sunday in March at 2AM CET and ends on the last Sunday in October at 3AM CEST.

The four timezone names *EST5EDT*, *CST6CDT*, *MST7MDT*, and *PST8PDT* look like they are POSIX zone specifications. However, they actually are treated as named time zones because (for historical reasons) there are files by those names in the IANA time zone database. The practical implication

of this is that these zone names will produce valid historical USA daylight-savings transitions, even when a plain POSIX specification would not.

One should be wary that it is easy to misspell a POSIX-style time zone specification, since there is no check on the reasonableness of the zone abbreviation(s). For example, `SET TIMEZONE TO FOOBAR0` will work, leaving the system effectively using a rather peculiar abbreviation for UTC.

## B.6. History of Units

The SQL standard states that “Within the definition of a ‘datetime literal’, the ‘datetime values’ are constrained by the natural rules for dates and times according to the Gregorian calendar”. LightDB follows the SQL standard's lead by counting dates exclusively in the Gregorian calendar, even for years before that calendar was in use. This rule is known as the *proleptic Gregorian calendar*.

The Julian calendar was introduced by Julius Caesar in 45 BC. It was in common use in the Western world until the year 1582, when countries started changing to the Gregorian calendar. In the Julian calendar, the tropical year is approximated as  $365 \frac{1}{4}$  days = 365.25 days. This gives an error of about 1 day in 128 years.

The accumulating calendar error prompted Pope Gregory XIII to reform the calendar in accordance with instructions from the Council of Trent. In the Gregorian calendar, the tropical year is approximated as  $365 + 97 / 400$  days = 365.2425 days. Thus it takes approximately 3300 years for the tropical year to shift one day with respect to the Gregorian calendar.

The approximation  $365+97/400$  is achieved by having 97 leap years every 400 years, using the following rules:

Every year divisible by 4 is a leap year.

However, every year divisible by 100 is not a leap year.

However, every year divisible by 400 is a leap year after all.

So, 1700, 1800, 1900, 2100, and 2200 are not leap years. But 1600, 2000, and 2400 are leap years. By contrast, in the older Julian calendar all years divisible by 4 are leap years.

The papal bull of February 1582 decreed that 10 days should be dropped from October 1582 so that 15 October should follow immediately after 4 October. This was observed in Italy, Poland, Portugal, and Spain. Other Catholic countries followed shortly after, but Protestant countries were reluctant to change, and the Greek Orthodox countries didn't change until the start of the 20th century. The reform was observed by Great Britain and its dominions (including what is now the USA) in 1752. Thus 2 September 1752 was followed by 14 September 1752. This is why Unix systems that have the `cal` program produce the following:

```
$ cal 9 1752
   September 1752
 S  M Tu  W Th  F  S
      1  2 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30
```

But, of course, this calendar is only valid for Great Britain and dominions, not other places. Since it would be difficult and confusing to try to track the actual calendars that were in use in various places at various times, LightDB does not try, but rather follows the Gregorian calendar rules for all dates, even though this method is not historically accurate.

Different calendars have been developed in various parts of the world, many predating the Gregorian system. For example, the beginnings of the Chinese calendar can be traced back to the 14th century BC. Legend has it that the Emperor Huangdi invented that calendar in 2637 BC. The People's Republic of China uses the Gregorian calendar for civil purposes. The Chinese calendar is used for determining festivals.

## B.7. Julian Dates

The *Julian Date* system is a method for numbering days. It is unrelated to the Julian calendar, though it is confusingly named similarly to that calendar. The Julian Date system was invented by the French scholar Joseph Justus Scaliger (1540–1609) and probably takes its name from Scaliger's father, the Italian scholar Julius Caesar Scaliger (1484–1558).

In the Julian Date system, each day has a sequential number, starting from JD 0 (which is sometimes called *the* Julian Date). JD 0 corresponds to 1 January 4713 BC in the Julian calendar, or 24 November 4714 BC in the Gregorian calendar. Julian Date counting is most often used by astronomers for labeling their nightly observations, and therefore a date runs from noon UTC to the next noon UTC, rather than from midnight to midnight: JD 0 designates the 24 hours from noon UTC on 24 November 4714 BC to noon UTC on 25 November 4714 BC.

Although LightDB supports Julian Date notation for input and output of dates (and also uses Julian dates for some internal datetime calculations), it does not observe the nicety of having dates run from noon to noon. LightDB treats a Julian Date as running from local midnight to local midnight, the same as a normal date.

This definition does, however, provide a way to obtain the astronomical definition when you need it: do the arithmetic in time zone UTC+12. For example,

```
=> SELECT extract(julian from '2021-06-23 7:00:00-04'::timestampz
  at time zone 'UTC+12');
  date_part
-----
 2459388.9583333335
(1 row)
=> SELECT extract(julian from '2021-06-23 8:00:00-04'::timestampz
  at time zone 'UTC+12');
  date_part
-----
 2459389
(1 row)
=> SELECT extract(julian from date '2021-06-23');
  date_part
-----
 2459389
(1 row)
```

---

# Appendix C. SQL Key Words

Table C.1 lists all tokens that are key words in the SQL standard and in LightDB 13.8-23.4. Background information can be found in Section 4.1.1. (For space reasons, only the latest two versions of the SQL standard, and SQL-92 for historical comparison, are included. The differences between those and the other intermediate standard versions are small.)

SQL distinguishes between *reserved* and *non-reserved* key words. According to the standard, reserved key words are the only real key words; they are never allowed as identifiers. Non-reserved key words only have a special meaning in particular contexts and can be used as identifiers in other contexts. Most non-reserved key words are actually the names of built-in tables and functions specified by SQL. The concept of non-reserved key words essentially only exists to declare that some predefined meaning is attached to a word in some contexts.

In the LightDB parser life is a bit more complicated. There are several different classes of tokens ranging from those that can never be used as an identifier to those that have absolutely no special status in the parser as compared to an ordinary identifier. (The latter is usually the case for functions specified by SQL.) Even reserved key words are not completely reserved in LightDB, but can be used as column labels (for example, `SELECT 55 AS CHECK`, even though `CHECK` is a reserved key word).

In Table C.1 in the column for LightDB we classify as “non-reserved” those key words that are explicitly known to the parser but are allowed as column or table names. Some key words that are otherwise non-reserved cannot be used as function or data type names and are marked accordingly. (Most of these words represent built-in functions or data types with special syntax. The function or type is still available but it cannot be redefined by the user.) Labeled “reserved” are those tokens that are not allowed as column or table names. Some reserved key words are allowable as names for functions or data types; this is also shown in the table. If not so marked, a reserved key word is only allowed as a column label. A blank entry in this column means that the word is treated as an ordinary identifier by LightDB.

Furthermore, while most key words can be used as “bare” column labels without writing `AS` before them (as described in Section 7.3.2), there are a few that require a leading `AS` to avoid ambiguity. These are marked in the table as “requires AS”.

As a general rule, if you get spurious parser errors for commands that contain any of the listed key words as an identifier you should try to quote the identifier to see if the problem goes away.

It is important to understand before studying Table C.1 that the fact that a key word is not reserved in LightDB does not mean that the feature related to the word is not implemented. Conversely, the presence of a key word does not indicate the existence of a feature.

**Table C.1. SQL Key Words**

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
A			non-reserved	non-reserved	
ABORT	non-reserved				
ABS			reserved	reserved	
ABSENT			non-reserved	non-reserved	
ABSOLUTE	non-reserved		non-reserved	non-reserved	reserved
ACCESS	non-reserved				
ACCORDING			non-reserved	non-reserved	
ACOS			reserved		



SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
ACTION	non-reserved		non-reserved	non-reserved	reserved
ACTIVE		non-reserved			
ADA			non-reserved	non-reserved	non-reserved
ADD	non-reserved		non-reserved	non-reserved	reserved
ADMIN	non-reserved		non-reserved	non-reserved	
AFTER	non-reserved		non-reserved	non-reserved	
AGGREGATE	non-reserved				
ALL	reserved, requires AS		reserved	reserved	reserved
ALLOCATE			reserved	reserved	reserved
ALSO	non-reserved				
ALTER	non-reserved		reserved	reserved	reserved
ALWAYS	non-reserved		non-reserved	non-reserved	
ANALYSE	reserved				
ANALYZE	reserved				
AND	reserved		reserved	reserved	reserved
ANY	reserved, requires AS		reserved	reserved	reserved
APPEND		non-reserved			
ARE			reserved	reserved	reserved
ARRAY	reserved, requires AS		reserved	reserved	
ARRAY_AGG			reserved	reserved	
ARRAY_MAX_CARDINALITY			reserved	reserved	
AS	reserved, requires AS		reserved	reserved	reserved
ASC	reserved		non-reserved	non-reserved	reserved
ASENSIIVE					
ASENSITIVE		non-reserved	reserved	reserved	
ASIN			reserved		
ASSERTION	non-reserved		non-reserved	non-reserved	reserved
ASSIGNMENT	non-reserved		non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
ASYMMETRIC	reserved		reserved	reserved	
AT	non-reserved		reserved	reserved	reserved
ATAN			reserved		
ATOMIC			reserved	reserved	
ATTACH	non-reserved				
ATTRIBUTE	non-reserved		non-reserved	non-reserved	
ATTRIBUTES			non-reserved	non-reserved	
AUTHID		non-reserved			
AUTHORIZATION	reserved (can be function or type)		reserved	reserved	reserved
AUTO_INCREMENT		non-reserved			
AVG			reserved	reserved	reserved
BACKWARD	non-reserved				
BASE64			non-reserved	non-reserved	
BEFORE	non-reserved		non-reserved	non-reserved	
BEGIN	non-reserved		reserved	reserved	reserved
BEGIN_FRAME			reserved	reserved	
BEGIN_PARTITION			reserved	reserved	
BERNOULLI			non-reserved	non-reserved	
BETWEEN	non-reserved (cannot be function or type)		reserved	reserved	reserved
BIGINT	non-reserved (cannot be function or type)		reserved	reserved	
BIGSERIAL		non-reserved			
BINARY	reserved (can be function or type)		reserved	reserved	
BIT	non-reserved (cannot be function or type)				reserved
BIT_LENGTH					reserved
BLOB			reserved	reserved	
BLOCKED			non-reserved	non-reserved	
BODY		non-reserved			

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
BOM			non-reserved	non-reserved	
BOOLEAN	non-reserved (cannot be function or type)		reserved	reserved	
BOTH	reserved		reserved	reserved	reserved
BREADTH			non-reserved	non-reserved	
BY	non-reserved		reserved	reserved	reserved
BYTE		non-reserved			
C			non-reserved	non-reserved	non-reserved
CACHE	non-reserved				
CALL	non-reserved		reserved	reserved	
CALLED	non-reserved		reserved	reserved	
CARDINALITY			reserved	reserved	
CASCADE	non-reserved		non-reserved	non-reserved	reserved
CASCADED	non-reserved		reserved	reserved	reserved
CASE	reserved		reserved	reserved	reserved
CAST	reserved		reserved	reserved	reserved
CATALOG	non-reserved		non-reserved	non-reserved	reserved
CATALOG_NAME			non-reserved	non-reserved	non-reserved
CEIL			reserved	reserved	
CEILING			reserved	reserved	
CHAIN	non-reserved		non-reserved	non-reserved	
CHAINING			non-reserved		
CHAR	non-reserved (cannot be function or type), requires AS		reserved	reserved	reserved
CHARACTER	non-reserved (cannot be function or type), requires AS		reserved	reserved	reserved
CHARACTERISTICS	non-reserved		non-reserved	non-reserved	
CHARACTERS			non-reserved	non-reserved	
CHARACTER_LENGTH			reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
CHARACTER_SET_CATALOG			non-reserved	non-reserved	non-reserved
CHARACTER_SET_NAME			non-reserved	non-reserved	non-reserved
CHARACTER_SET_SCHEMA			non-reserved	non-reserved	non-reserved
CHARSET		non-reserved			
CHAR_LENGTH			reserved	reserved	reserved
CHECK	reserved		reserved	reserved	reserved
CHECKPOINT	non-reserved				
CLASS	non-reserved				
CLASSIFIER			reserved		
CLASS_ORIGIN			non-reserved	non-reserved	non-reserved
CLOB			reserved	reserved	
CLOSE	non-reserved		reserved	reserved	reserved
CLUSTER	non-reserved				
COALESCE	non-reserved (cannot be function or type)		reserved	reserved	reserved
COBOL			non-reserved	non-reserved	non-reserved
COLLATE	reserved		reserved	reserved	reserved
COLLATION	reserved (can be function or type)		non-reserved	non-reserved	reserved
COLLATION_CATALOG			non-reserved	non-reserved	non-reserved
COLLATION_NAME			non-reserved	non-reserved	non-reserved
COLLATION_SCHEMA			non-reserved	non-reserved	non-reserved
COLLECT			reserved	reserved	
COLOCATE_WITH		non-reserved			
COLUMN	reserved		reserved	reserved	reserved
COLUMNS	non-reserved		non-reserved	non-reserved	
COLUMN_NAME			non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION			non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION_CODE			non-reserved	non-reserved	
COMMENT	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
COMMENTS	non-reserved				
COMMIT	non-reserved		reserved	reserved	reserved
COMMITTED	non-reserved		non-reserved	non-reserved	non-reserved
COMPRESS		non-reserved			
CONCURRENCY		non-reserved			
CONCURRENTLY	reserved (can be function or type)				
CONDITION			reserved	reserved	
CONDITIONAL			non-reserved		
CONDITION_NUMBER			non-reserved	non-reserved	non-reserved
CONFIGURATION	non-reserved				
CONFLICT	non-reserved				
CONNECT		non-reserved	reserved	reserved	reserved
CONNECTION	non-reserved		non-reserved	non-reserved	reserved
CONNECTION_NAME			non-reserved	non-reserved	non-reserved
CONNECT_BY_ISLEAF		non-reserved			
CONNECT_BY_ROOT		non-reserved			
CONSTRAINT	reserved		reserved	reserved	reserved
CONSTRAINTS	non-reserved		non-reserved	non-reserved	reserved
CONSTRAINT_CATALOG			non-reserved	non-reserved	non-reserved
CONSTRAINT_NAME			non-reserved	non-reserved	non-reserved
CONSTRAINT_SCHEMA			non-reserved	non-reserved	non-reserved
CONSTRUCTOR			non-reserved	non-reserved	
CONTAINS		non-reserved	reserved	reserved	
CONTENT	non-reserved		non-reserved	non-reserved	
CONTINUE	non-reserved		non-reserved	non-reserved	reserved
CONTROL			non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
CONVERSION	non-reserved				
CONVERT			reserved	reserved	reserved
COPY	non-reserved		reserved		
CORR			reserved	reserved	
CORRESPONDING			reserved	reserved	reserved
COS			reserved		
COSH			reserved		
COST	non-reserved				
COUNT			reserved	reserved	reserved
COVAR_POP			reserved	reserved	
COVAR_SAMP			reserved	reserved	
CREATE	reserved, requires AS		reserved	reserved	reserved
CROSS	reserved (can be function or type)		reserved	reserved	reserved
CSV	non-reserved				
CUBE	non-reserved		reserved	reserved	
CUME_DIST			reserved	reserved	
CURRENT	non-reserved		reserved	reserved	reserved
CURRENT_CATALOG	reserved		reserved	reserved	
CURRENT_DATE	reserved		reserved	reserved	reserved
CURRENT_DEFAULT_TRANSFORM_GROUP			reserved	reserved	
CURRENT_PATH			reserved	reserved	
CURRENT_ROLE	reserved		reserved	reserved	
CURRENT_ROW			reserved	reserved	
CURRENT_SCHEMA	reserved (can be function or type)		reserved	reserved	
CURRENT_TIME	reserved		reserved	reserved	reserved
CURRENT_TIMESTAMP	reserved		reserved	reserved	reserved
CURRENT_TRANSFORM_GROUP_FOR_TYPE			reserved	reserved	
CURRENT_USER	reserved		reserved	reserved	reserved
CURSOR	non-reserved		reserved	reserved	reserved
CURSOR_NAME			non-reserved	non-reserved	non-reserved
CYCLE	non-reserved		reserved	reserved	
DATA	non-reserved		non-reserved	non-reserved	non-reserved
DATABASE	non-reserved				
DATALINK			reserved	reserved	
DATE			reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
DATETIME		non-reserved (cannot be function or type)			
DATETIME_INTERVAL_CODE			non-reserved	non-reserved	non-reserved
DATETIME_INTERVAL_PRECISION			non-reserved	non-reserved	non-reserved
DAY	non-reserved, requires AS		reserved	reserved	reserved
DB			non-reserved	non-reserved	
DEALLOCATE	non-reserved		reserved	reserved	reserved
DEC	non-reserved (cannot be function or type)		reserved	reserved	reserved
DECFLOAT			reserved		
DECIMAL	non-reserved (cannot be function or type)		reserved	reserved	reserved
DECLARE	non-reserved, requires " "		reserved	reserved	reserved
DECODE	non-reserved				
DEFAULT	reserved		reserved	reserved	reserved
DEFAULTS	non-reserved		non-reserved	non-reserved	
DEFERRABLE	reserved		non-reserved	non-reserved	reserved
DEFERRED	non-reserved		non-reserved	non-reserved	reserved
DEFINE			reserved		
DEFINED			non-reserved	non-reserved	
DEFINER	non-reserved		non-reserved	non-reserved	
DEGREE			non-reserved	non-reserved	
DELETE	non-reserved		reserved	reserved	reserved
DELIMITER	non-reserved				
DELIMITERS	non-reserved				
DENSE_RANK			reserved	reserved	
DEPENDS	non-reserved				
DEPTH			non-reserved	non-reserved	
DEREF			reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
DERIVED			non-reserved	non-reserved	
DESC	reserved		non-reserved	non-reserved	reserved
DESCRIBE			reserved	reserved	reserved
DESCRIPTOR			non-reserved	non-reserved	reserved
DETACH	non-reserved				
DETERMINISTIC			reserved	reserved	
DIAGNOSTICS			non-reserved	non-reserved	reserved
DICTIONARY	non-reserved				
DISABLE	non-reserved				
DISCARD	non-reserved				
DISCONNECT			reserved	reserved	reserved
DISPATCH			non-reserved	non-reserved	
DISTINCT	reserved		reserved	reserved	reserved
DISTRIBUTED		non-reserved			
DLNEWCOPY			reserved	reserved	
DLPREVIOUSCOPY			reserved	reserved	
DLURLCOMPLETE			reserved	reserved	
DLURLCOMPLETEONLY			reserved	reserved	
DLURLCOMPLETEWRITE			reserved	reserved	
DLURLPATH			reserved	reserved	
DLURLPATHONLY			reserved	reserved	
DLURLPATHWRITE			reserved	reserved	
DLURLSCHEME			reserved	reserved	
DLURLSERVER			reserved	reserved	
DLVALUE			reserved	reserved	
DO	reserved				
DOCUMENT	non-reserved		non-reserved	non-reserved	
DOMAIN	non-reserved		non-reserved	non-reserved	reserved
DOUBLE	non-reserved		reserved	reserved	reserved
DROP	non-reserved		reserved	reserved	reserved
DUPLICATE		non-reserved			
DYNAMIC			reserved	reserved	
DYNAMIC_FUNCTION			non-reserved	non-reserved	non-reserved



SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
DYNAMIC_FUNCTION_CODE			non-reserved	non-reserved	
EACH	non-reserved		reserved	reserved	
EDITIONABLE		non-reserved			
EDITIONING		non-reserved			
ELEMENT			reserved	reserved	
ELSE	reserved		reserved	reserved	reserved
ELSIF		non-reserved			
EMPTY			reserved	non-reserved	
ENABLE	non-reserved				
ENCODING	non-reserved		non-reserved	non-reserved	
ENCRYPTED	non-reserved				
END	reserved		reserved	reserved	reserved
END-EXEC			reserved	reserved	reserved
END_FRAME			reserved	reserved	
END_PARTITION			reserved	reserved	
ENFORCED			non-reserved	non-reserved	
ENGINE		non-reserved			
ENUM	non-reserved				
EQUALS			reserved	reserved	
ERROR		non-reserved	non-reserved		
ESCAPE	non-reserved		reserved	reserved	reserved
EVENT	non-reserved				
EVERY		non-reserved	reserved	reserved	
EXCEPT		reserved, requires AS	reserved	reserved	reserved
EXCEPTION		non-reserved			reserved
EXCHANGE		non-reserved			
EXCLUDE	non-reserved		non-reserved	non-reserved	
EXCLUDING	non-reserved		non-reserved	non-reserved	
EXCLUSIVE	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
EXEC			reserved	reserved	reserved
EXECUTE	non-reserved		reserved	reserved	reserved
EXISTS	non-reserved (cannot be function or type)		reserved	reserved	reserved
EXP			reserved	reserved	
EXPAND		non- reserved			
EXPLAIN	non-reserved				
EXPRESSION	non-reserved		non- reserved	non- reserved	
EXTENSION	non-reserved				
EXTERNAL	non-reserved		reserved	reserved	reserved
EXTRACT	non-reserved (cannot be function or type)		reserved	reserved	reserved
FALSE	reserved		reserved	reserved	reserved
FAMILY	non-reserved				
FETCH	reserved, requires AS		reserved	reserved	reserved
FILE			non- reserved	non- reserved	
FILTER	non-reserved, requires AS		reserved	reserved	
FINAL			non- reserved	non- reserved	
FINISH			non- reserved		
FIRST	non-reserved		non- reserved	non- reserved	reserved
FIRST_VALUE			reserved	reserved	
FLAG			non- reserved	non- reserved	
FLOAT	non-reserved (cannot be function or type)		reserved	reserved	reserved
FLOOR			reserved	reserved	
FOLLOWING	non-reserved		non- reserved	non- reserved	
FOR	reserved, requires AS		reserved	reserved	reserved
FORCE	non-reserved				
FOREIGN	reserved		reserved	reserved	reserved
FORMAT		non- reserved	non- reserved		

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
FORTRAN			non-reserved	non-reserved	non-reserved
FORWARD	non-reserved				
FOUND			non-reserved	non-reserved	reserved
FRAME_ROW			reserved	reserved	
FREE			reserved	reserved	
FREEZE	reserved (can be function or type)				
FROM	reserved, requires AS		reserved	reserved	reserved
FS			non-reserved	non-reserved	
FULFILL			non-reserved		
FULL	reserved (can be function or type)		reserved	reserved	reserved
FULLSCAN		non-reserved			
FUNCTION	non-reserved		reserved	reserved	
FUNCTIONS	non-reserved				
FUSION			reserved	reserved	
G			non-reserved	non-reserved	
GENERAL			non-reserved	non-reserved	
GENERATED	non-reserved		non-reserved	non-reserved	
GET			reserved	reserved	reserved
GLOBAL	non-reserved		reserved	reserved	reserved
GO			non-reserved	non-reserved	reserved
GOTO			non-reserved	non-reserved	reserved
GRANT	reserved, requires AS		reserved	reserved	reserved
GRANTED	non-reserved		non-reserved	non-reserved	
GREATEST	non-reserved (cannot be function or type)				
GROUP	reserved, requires AS		reserved	reserved	reserved
GROUPING	non-reserved (cannot be function or type)		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
GROUPS	non-reserved		reserved	reserved	
GROUP_CONCAT		non-reserved			
HANDLER	non-reserved				
HASH		non-reserved			
HAVING	reserved, requires AS		reserved	reserved	reserved
HEADER	non-reserved				
HEX			non-reserved	non-reserved	
HIERARCHY			non-reserved	non-reserved	
HOLD	non-reserved		reserved	reserved	
HOURL	non-reserved, requires AS		reserved	reserved	reserved
ID			non-reserved	non-reserved	
IDENTIFIED		non-reserved			
IDENTITY	non-reserved		reserved	reserved	reserved
IF	non-reserved				
IGNORE		non-reserved	non-reserved	non-reserved	
ILIKE	reserved (can be function or type)				
IMMEDIATE	non-reserved		non-reserved	non-reserved	reserved
IMMEDIATELY			non-reserved	non-reserved	
IMMUTABLE	non-reserved				
IMPLEMENTATION			non-reserved	non-reserved	
IMPLICIT	non-reserved				
IMPORT	non-reserved		reserved	reserved	
IN	reserved		reserved	reserved	reserved
INCLUDE	non-reserved				
INCLUDING	non-reserved		non-reserved	non-reserved	
INCLUSIVE		non-reserved			
INCREMENT	non-reserved		non-reserved	non-reserved	
INDENT			non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
INDEX	non-reserved				
INDEXES	non-reserved				
INDICATOR			reserved	reserved	reserved
INHERIT	non-reserved				
INHERITS	non-reserved				
INITIAL			reserved		
INITIALLY	reserved		non-reserved	non-reserved	reserved
INITTRANS		non-reserved			
INLINE	non-reserved				
INNER	reserved (can be function or type)		reserved	reserved	reserved
INNODB		non-reserved			
INOUT	non-reserved (cannot be function or type)		reserved	reserved	
INPUT	non-reserved		non-reserved	non-reserved	reserved
INSENSITIVE	non-reserved		reserved	reserved	reserved
INSERT	non-reserved		reserved	reserved	reserved
INSTANCE			non-reserved	non-reserved	
INSTANTIABLE			non-reserved	non-reserved	
INSTEAD	non-reserved		non-reserved	non-reserved	
INT	non-reserved (cannot be function or type)		reserved	reserved	reserved
INTEGER	non-reserved (cannot be function or type)		reserved	reserved	reserved
INTEGRITY			non-reserved	non-reserved	
INTERSECT	reserved, requires AS		reserved	reserved	reserved
INTERSECTION			reserved	reserved	
INTERVAL	non-reserved (cannot be function or type)		reserved	reserved	reserved
INTO	reserved, requires AS		reserved	reserved	reserved
INVOKER	non-reserved		non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
IS	reserved (can be function or type)		reserved	reserved	reserved
ISNULL	reserved (can be function or type), requires AS				
ISOLATION	non-reserved		non-reserved	non-reserved	reserved
JOIN	reserved (can be function or type)		reserved	reserved	reserved
JSON			non-reserved		
JSON_ARRAY			reserved		
JSON_ARRAYAGG			reserved		
JSON_EXISTS			reserved		
JSON_OBJECT			reserved		
JSON_OBJECTAGG			reserved		
JSON_QUERY			reserved		
JSON_TABLE			reserved		
JSON_TABLE_PRIMITIVE			reserved		
JSON_VALUE			reserved		
K			non-reserved	non-reserved	
KEEP			non-reserved		
KEY	non-reserved		non-reserved	non-reserved	reserved
KEYS			non-reserved		
KEY_MEMBER			non-reserved	non-reserved	
KEY_TYPE			non-reserved	non-reserved	
LABEL	non-reserved				
LAG			reserved	reserved	
LANGUAGE	non-reserved		reserved	reserved	reserved
LARGE	non-reserved		reserved	reserved	
LAST	non-reserved		non-reserved	non-reserved	reserved
LAST_VALUE			reserved	reserved	
LATERAL	reserved		reserved	reserved	
LEAD			reserved	reserved	
LEADING	reserved		reserved	reserved	reserved
LEAKPROOF	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
LEAST	non-reserved (cannot be function or type)				
LEFT	reserved (can be function or type)		reserved	reserved	reserved
LENGTH			non- reserved	non- reserved	non- reserved
LESS		non- reserved			
LEVEL	non-reserved		non- reserved	non- reserved	reserved
LIBRARY			non- reserved	non- reserved	
LIKE	reserved (can be function or type)		reserved	reserved	reserved
LIKE_REGEX			reserved	reserved	
LIMIT	reserved, requires AS		non- reserved	non- reserved	
LINK			non- reserved	non- reserved	
LIST		non- reserved			
LISTAGG			reserved		
LISTEN	non-reserved				
LN			reserved	reserved	
LOAD	non-reserved				
LOCAL	non-reserved		reserved	reserved	reserved
LOCALTIME	reserved		reserved	reserved	
LOCALTIMESTAMP	reserved		reserved	reserved	
LOCATION	non-reserved		non- reserved	non- reserved	
LOCATOR			non- reserved	non- reserved	
LOCK	non-reserved				
LOCKED	non-reserved				
LOG			reserved		
LOG10			reserved		
LOGGED	non-reserved				
LOGGING		non- reserved			
LOOP		non- reserved			
LOWER			reserved	reserved	reserved
LT_SYNTAX_ COMPATIBLE_TYPE		reserved (can be			

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
		function or type)			
M			non-reserved	non-reserved	
MAP			non-reserved	non-reserved	
MAPPING	non-reserved		non-reserved	non-reserved	
MASTER		non-reserved			
MATCH	non-reserved		reserved	reserved	reserved
MATCHED		non-reserved	non-reserved	non-reserved	
MATCHES			reserved		
MATCH_NUMBER			reserved		
MATCH_RECOGNIZE			reserved		
MATERIALIZED	non-reserved				
MAX			reserved	reserved	reserved
MAXVALUE	non-reserved		non-reserved	non-reserved	
MEASURES			reserved		
MEMBER		non-reserved	reserved	reserved	
MERGE		non-reserved	reserved	reserved	
MESSAGE_LENGTH			non-reserved	non-reserved	non-reserved
MESSAGE_OCTET_LENGTH			non-reserved	non-reserved	non-reserved
MESSAGE_TEXT			non-reserved	non-reserved	non-reserved
METHOD	non-reserved		reserved	reserved	
MIN			reserved	reserved	reserved
MINUS		reserved, requires AS			
MINUTE	non-reserved, requires AS		reserved	reserved	reserved
MINVALUE	non-reserved		non-reserved	non-reserved	
MISSING		non-reserved			
MOD			reserved	reserved	
MODE	non-reserved				
MODIFIES			reserved	reserved	



SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
MODIFY		non-reserved			
MODULE			reserved	reserved	reserved
MONITORING		non-reserved			
MONTH	non-reserved		reserved	reserved	reserved
MORE			non-reserved	non-reserved	non-reserved
MOVE	non-reserved				
MULTISET			reserved	reserved	
MUMPS			non-reserved	non-reserved	non-reserved
MYISAM		non-reserved			
NAME	non-reserved		non-reserved	non-reserved	non-reserved
NAMES	non-reserved		non-reserved	non-reserved	reserved
NAMESPACE			non-reserved	non-reserved	
NATIONAL	non-reserved (cannot be function or type)		reserved	reserved	reserved
NATURAL	reserved (can be function or type)		reserved	reserved	reserved
NCHAR	non-reserved (cannot be function or type)		reserved	reserved	reserved
NCLOB			reserved	reserved	
NESTED		non-reserved	non-reserved		
NESTING			non-reserved	non-reserved	
NEW	non-reserved		reserved	reserved	
NEXT	non-reserved		non-reserved	non-reserved	reserved
NFC	non-reserved		non-reserved	non-reserved	
NFD	non-reserved		non-reserved	non-reserved	
NFKC	non-reserved		non-reserved	non-reserved	
NFKD	non-reserved		non-reserved	non-reserved	
NIL			non-reserved	non-reserved	
NO	non-reserved		reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
NOCACHE		non-reserved			
NOCOMPRESS		non-reserved			
NOCYCLE		non-reserved			
NOLOGGING		non-reserved			
NOMAXVALUE		non-reserved			
NOMINVALUE		non-reserved			
NONE	non-reserved (cannot be function or type)		reserved	reserved	
NONEDITIONABLE		non-reserved			
NOORDER		non-reserved			
NOPARALLEL		non-reserved			
NORMALIZE	non-reserved (cannot be function or type)		reserved	reserved	
NORMALIZED	non-reserved		non-reserved	non-reserved	
NOT	reserved		reserved	reserved	reserved
NOTHING	non-reserved				
NOTIFY	non-reserved				
NOTNULL	reserved (can be function or type), requires AS				
NOWAIT	non-reserved				
NTH_VALUE			reserved	reserved	
NTILE			reserved	reserved	
NULL	reserved		reserved	reserved	reserved
NULLABLE			non-reserved	non-reserved	non-reserved
NULLIF	non-reserved (cannot be function or type)		reserved	reserved	reserved
NULLS	non-reserved		non-reserved	non-reserved	
NUMBER		non-reserved (cannot be	non-reserved	non-reserved	non-reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
		function or type)			
NUMERIC	non-reserved (cannot be function or type)		reserved	reserved	reserved
OBJECT	non-reserved		non-reserved	non-reserved	
OCCURRENCES_REGEX			reserved	reserved	
OCTETS			non-reserved	non-reserved	
OCTET_LENGTH			reserved	reserved	reserved
OF	non-reserved		reserved	reserved	reserved
OFF	non-reserved		non-reserved	non-reserved	
OFFSET	reserved, requires AS		reserved	reserved	
OIDS	non-reserved				
OLD	non-reserved		reserved	reserved	
OMIT			reserved		
ON	reserved, requires AS		reserved	reserved	reserved
ONE			reserved		
ONLINE		non-reserved			
ONLY	reserved		reserved	reserved	reserved
OPEN			reserved	reserved	reserved
OPERATOR	non-reserved				
OPTION	non-reserved		non-reserved	non-reserved	reserved
OPTIONS	non-reserved		non-reserved	non-reserved	
OR	reserved		reserved	reserved	reserved
ORDER	reserved, requires AS		reserved	reserved	reserved
ORDERED		non-reserved			
ORDERING			non-reserved	non-reserved	
ORDINALITY	non-reserved		non-reserved	non-reserved	
OTHERS	non-reserved		non-reserved	non-reserved	
OUT	non-reserved (cannot be function or type)		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
OUTER	reserved (can be function or type)		reserved	reserved	reserved
OUTPUT			non-reserved	non-reserved	reserved
OVER	non-reserved, requires AS		reserved	reserved	
OVERFLOW		non-reserved	non-reserved		
OVERLAPS	reserved (can be function or type), requires AS		reserved	reserved	reserved
OVERLAY	non-reserved (cannot be function or type)		reserved	reserved	
OVERRIDING	non-reserved		non-reserved	non-reserved	
OWNED	non-reserved				
OWNER	non-reserved				
P			non-reserved	non-reserved	
PACKAGE		non-reserved			
PAD			non-reserved	non-reserved	reserved
PARALLEL	non-reserved				
PARALLEL_ENABLE		non-reserved			
PARAMETER			reserved	reserved	
PARAMETER_MODE			non-reserved	non-reserved	
PARAMETER_NAME			non-reserved	non-reserved	
PARAMETER_ORDINAL_POSITION			non-reserved	non-reserved	
PARAMETER_SPECIFIC_CATALOG			non-reserved	non-reserved	
PARAMETER_SPECIFIC_NAME			non-reserved	non-reserved	
PARAMETER_SPECIFIC_SCHEMA			non-reserved	non-reserved	
PARSER	non-reserved				
PARTIAL	non-reserved		non-reserved	non-reserved	reserved
PARTITION		reserved, requires AS	reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
PARTITIONS		non-reserved			
PASCAL			non-reserved	non-reserved	non-reserved
PASS			non-reserved		
PASSING	non-reserved		non-reserved	non-reserved	
PASSTHROUGH			non-reserved	non-reserved	
PASSWORD	non-reserved				
PAST			non-reserved		
PATH			non-reserved	non-reserved	
PATTERN			reserved		
PCTFREE		non-reserved			
PER			reserved		
PERCENT			reserved	reserved	
PERCENTILE_CONT			reserved	reserved	
PERCENTILE_DISC			reserved	reserved	
PERCENT_RANK			reserved	reserved	
PERIOD			reserved	reserved	
PERMISSION			non-reserved	non-reserved	
PERMUTE			reserved		
PIVOT	reserved				
PLACING	reserved		non-reserved	non-reserved	
PLAN			non-reserved		
PLANS	non-reserved				
PLI			non-reserved	non-reserved	non-reserved
POLICY	non-reserved				
PORTION			reserved	reserved	
POSITION	non-reserved (cannot be function or type)		reserved	reserved	reserved
POSITION_REGEX			reserved	reserved	
POWER			reserved	reserved	
PRECEDES			reserved	reserved	
PRECEDING	non-reserved		non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
PRECISION	non-reserved (cannot be function or type), requires AS		reserved	reserved	reserved
PREPARE	non-reserved		reserved	reserved	reserved
PREPARED	non-reserved				
PRESERVE	non-reserved		non- reserved	non- reserved	reserved
PRIMARY	reserved		reserved	reserved	reserved
PRIOR		reserved	non- reserved	non- reserved	reserved
PRIVATE			non- reserved		
PRIVILEGES	non-reserved		non- reserved	non- reserved	reserved
PROCEDURAL	non-reserved				
PROCEDURE	non-reserved		reserved	reserved	reserved
PROCEDURES	non-reserved				
PROGRAM	non-reserved				
PRUNE			non- reserved		
PTF			reserved		
PUBLIC	non-reserved		non- reserved	non- reserved	reserved
PUBLICATION	non-reserved				
QUOTE	non-reserved				
QUOTES			non- reserved		
RANDOMLY		non- reserved			
RANGE	non-reserved		reserved	reserved	
RANK			reserved	reserved	
READ	non-reserved		non- reserved	non- reserved	reserved
READABLE		non- reserved			
READS			reserved	reserved	
REAL	non-reserved (cannot be function or type)		reserved	reserved	reserved
REASSIGN	non-reserved				
REBUILD		non- reserved			
RECHECK	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
RECORD		non-reserved			
RECOVERY			non-reserved	non-reserved	
RECURSIVE	non-reserved		reserved	reserved	
REF	non-reserved		reserved	reserved	
REFERENCES	reserved		reserved	reserved	reserved
REFERENCING	non-reserved		reserved	reserved	
REFRESH	non-reserved				
REGR_AVGX			reserved	reserved	
REGR_AVGY			reserved	reserved	
REGR_COUNT			reserved	reserved	
REGR_INTERCEPT			reserved	reserved	
REGR_R2			reserved	reserved	
REGR_SLOPE			reserved	reserved	
REGR_SXX			reserved	reserved	
REGR_SXY			reserved	reserved	
REGR_SYY			reserved	reserved	
REINDEX	non-reserved				
RELATIVE	non-reserved		non-reserved	non-reserved	reserved
RELEASE	non-reserved		reserved	reserved	
RENAME	non-reserved				
REPEATABLE	non-reserved		non-reserved	non-reserved	non-reserved
REPLACE	non-reserved				
REPLICA	non-reserved				
REPLICATED		non-reserved			
REQUIRING			non-reserved	non-reserved	
RESET	non-reserved				
RESPECT			non-reserved	non-reserved	
RESTART	non-reserved		non-reserved	non-reserved	
RESTORE			non-reserved	non-reserved	
RESTRICT	non-reserved		non-reserved	non-reserved	reserved
RESULT			reserved	reserved	
RETURN		reserved, requires AS	reserved	reserved	

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
RETURNED_CARDINALITY			non-reserved	non-reserved	
RETURNED_LENGTH			non-reserved	non-reserved	non-reserved
RETURNED_OCTET_LENGTH			non-reserved	non-reserved	non-reserved
RETURNED_SQLSTATE			non-reserved	non-reserved	non-reserved
RETURNING	reserved, requires AS		non-reserved	non-reserved	
RETURNS	non-reserved		reserved	reserved	
REVOKE	non-reserved		reserved	reserved	reserved
RIGHT	reserved (can be function or type)		reserved	reserved	reserved
ROLE	non-reserved		non-reserved	non-reserved	
ROLLBACK	non-reserved		reserved	reserved	reserved
ROLLUP	non-reserved		reserved	reserved	
ROOTPARTITION		non-reserved			
ROUTINE	non-reserved		non-reserved	non-reserved	
ROUTINES	non-reserved				
ROUTINE_CATALOG			non-reserved	non-reserved	
ROUTINE_NAME			non-reserved	non-reserved	
ROUTINE_SCHEMA			non-reserved	non-reserved	
ROW	non-reserved (cannot be function or type)		reserved	reserved	
ROWNUM		reserved			
ROWS	non-reserved		reserved	reserved	reserved
ROWTYPE		non-reserved			
ROW_COUNT			non-reserved	non-reserved	non-reserved
ROW_NUMBER			reserved	reserved	
RULE	non-reserved				
RUNNING			reserved		
SAVEPOINT	non-reserved		reserved	reserved	
SCALAR			non-reserved		
SCALE			non-reserved	non-reserved	non-reserved



SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
SCHEMA	non-reserved		non-reserved	non-reserved	reserved
SCHEMAS	non-reserved				
SCHEMA_NAME			non-reserved	non-reserved	non-reserved
SCOPE			reserved	reserved	
SCOPE_CATALOG			non-reserved	non-reserved	
SCOPE_NAME			non-reserved	non-reserved	
SCOPE_SCHEMA			non-reserved	non-reserved	
SCROLL	non-reserved		reserved	reserved	reserved
SEARCH	non-reserved		reserved	reserved	
SECOND	non-reserved, requires AS		reserved	reserved	reserved
SECTION			non-reserved	non-reserved	reserved
SECURITY	non-reserved		non-reserved	non-reserved	
SEEK			reserved		
SELECT	reserved		reserved	reserved	reserved
SELECTIVE			non-reserved	non-reserved	
SELF			non-reserved	non-reserved	
SENSITIVE			reserved	reserved	
SEPARATOR		non-reserved			
SEQUENCE	non-reserved		non-reserved	non-reserved	
SEQUENCES	non-reserved				
SERIAL		non-reserved			
SERIALIZABLE	non-reserved		non-reserved	non-reserved	non-reserved
SERVER	non-reserved		non-reserved	non-reserved	
SERVER_NAME			non-reserved	non-reserved	non-reserved
SESSION	non-reserved		non-reserved	non-reserved	reserved
SESSION_USER	reserved		reserved	reserved	reserved
SET	non-reserved		reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
SETOF	non-reserved (cannot be function or type)				
SETS	non-reserved		non- reserved	non- reserved	
SHARD_COUNT		non- reserved			
SHARE	non-reserved				
SHOW	non-reserved		reserved		
SIMILAR	reserved (can be function or type)		reserved	reserved	
SIMPLE	non-reserved		non- reserved	non- reserved	
SIN			reserved		
SINH			reserved		
SIZE			non- reserved	non- reserved	reserved
SKIP	non-reserved		reserved		
SMALLINT	non-reserved (cannot be function or type)		reserved	reserved	reserved
SMALLSERIAL		non- reserved			
SNAPSHOT	non-reserved				
SOME	reserved, requires AS		reserved	reserved	reserved
SOURCE			non- reserved	non- reserved	
SPACE			non- reserved	non- reserved	reserved
SPECIFIC			reserved	reserved	
SPECIFICTYPE			reserved	reserved	
SPECIFIC_NAME			non- reserved	non- reserved	
SPLIT		non- reserved			
SQL	non-reserved		reserved	reserved	reserved
SQLCODE					reserved
SQLERROR					reserved
SQLEXCEPTION			reserved	reserved	
SQLSTATE			reserved	reserved	reserved
SQLWARNING			reserved	reserved	
SQRT			reserved	reserved	
STABLE	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
STANDALONE	non-reserved		non-reserved	non-reserved	
START	non-reserved		reserved	reserved	
STATE			non-reserved	non-reserved	
STATEMENT	non-reserved		non-reserved	non-reserved	
STATIC	non-reserved		reserved	reserved	
STATISTICS	non-reserved				
STDDEV_POP			reserved	reserved	
STDDEV_SAMP			reserved	reserved	
STDIN	non-reserved				
STDOUT	non-reserved				
STORAGE	non-reserved				
STORE		non-reserved			
STORED	non-reserved				
STRICT	non-reserved				
STRING			non-reserved		
STRIP	non-reserved		non-reserved	non-reserved	
STRUCTURE			non-reserved	non-reserved	
STYLE			non-reserved	non-reserved	
SUBCLASS_ORIGIN			non-reserved	non-reserved	non-reserved
SUBMULTISET			reserved	reserved	
SUBPARTITION		non-reserved			
SUBPARTITIONS		non-reserved			
SUBSCRIPTION	non-reserved				
SUBSET			reserved		
SUBSTRING	non-reserved (cannot be function or type)		reserved	reserved	reserved
SUBSTRING_REGEX			reserved	reserved	
SUBTYPE		non-reserved			
SUCCEEDS			reserved	reserved	
SUM			reserved	reserved	reserved
SUPPORT	non-reserved				
SYMMETRIC	reserved		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
SYNONYM	non-reserved				
SYSDATE		reserved (can be function or type)			
SYSID	non-reserved				
SYSTEM	non-reserved		reserved	reserved	
SYSTEM_TIME			reserved	reserved	
SYSTEM_USER			reserved	reserved	reserved
SYSTEMTIME		reserved (can be function or type)			
SYS_CONNECT_BY_PATH		non- reserved			
T			non- reserved	non- reserved	
TABLE	reserved		reserved	reserved	reserved
TABLES	non-reserved				
TABLESAMPLE	reserved (can be function or type)		reserved	reserved	
TABLESPACE	non-reserved				
TABLE_NAME			non- reserved	non- reserved	non- reserved
TAN			reserved		
TANH			reserved		
TEMP	non-reserved				
TEMPLATE	non-reserved				
TEMPORARY	non-reserved		non- reserved	non- reserved	reserved
TEXT	non-reserved				
THAN		non- reserved			
THEN	reserved		reserved	reserved	reserved
THROUGH			non- reserved		
TIES	non-reserved		non- reserved	non- reserved	
TIME	non-reserved (cannot be function or type)		reserved	reserved	reserved
TIMESTAMP	non-reserved (cannot be function or type)		reserved	reserved	reserved
TIMEZONE_HOUR			reserved	reserved	reserved
TIMEZONE_MINUTE			reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
TINYINT		non-reserved (cannot be function or type)			
TO	reserved, requires AS		reserved	reserved	reserved
TOKEN			non-reserved	non-reserved	
TOP_LEVEL_COUNT			non-reserved	non-reserved	
TRAILING	reserved		reserved	reserved	reserved
TRANSACTION	non-reserved		non-reserved	non-reserved	reserved
TRANSACTIONS_COMMITTED			non-reserved	non-reserved	
TRANSACTIONS_ROLLED_BACK			non-reserved	non-reserved	
TRANSACTION_ACTIVE			non-reserved	non-reserved	
TRANSFORM	non-reserved		non-reserved	non-reserved	
TRANSFORMS			non-reserved	non-reserved	
TRANSLATE			reserved	reserved	reserved
TRANSLATE_REGEX			reserved	reserved	
TRANSLATION			reserved	reserved	reserved
TREAT	non-reserved (cannot be function or type)		reserved	reserved	
TRIGGER	non-reserved		reserved	reserved	
TRIGGER_CATALOG			non-reserved	non-reserved	
TRIGGER_NAME			non-reserved	non-reserved	
TRIGGER_SCHEMA			non-reserved	non-reserved	
TRIM	non-reserved (cannot be function or type)		reserved	reserved	reserved
TRIM_ARRAY			reserved	reserved	
TRUE	reserved		reserved	reserved	reserved
TRUNCATE	non-reserved		reserved	reserved	
TRUSTED	non-reserved				
TYPE	non-reserved		non-reserved	non-reserved	non-reserved
TYPES	non-reserved				

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
UESCAPE	non-reserved		reserved	reserved	
UNBOUNDED	non-reserved		non-reserved	non-reserved	
UNCOMMITTED	non-reserved		non-reserved	non-reserved	non-reserved
UNCONDITIONAL			non-reserved		
UNDER			non-reserved	non-reserved	
UNENCRYPTED	non-reserved				
UNION	reserved, requires AS		reserved	reserved	reserved
UNIQUE	reserved		reserved	reserved	reserved
UNKNOWN	non-reserved		reserved	reserved	reserved
UNLIMITED		non-reserved			
UNLINK			non-reserved	non-reserved	
UNLISTEN	non-reserved				
UNLOGGED	non-reserved				
UNMATCHED			reserved		
UNNAMED			non-reserved	non-reserved	non-reserved
UNNEST			reserved	reserved	
UNSIGNED	non-reserved				
UNTIL	non-reserved				
UNTYPED			non-reserved	non-reserved	
UPDATE	non-reserved		reserved	reserved	reserved
UPPER			reserved	reserved	reserved
URI			non-reserved	non-reserved	
USAGE			non-reserved	non-reserved	reserved
USE		non-reserved			
USER	reserved		reserved	reserved	reserved
USER_DEFINED_TYPE_CATALOG			non-reserved	non-reserved	
USER_DEFINED_TYPE_CODE			non-reserved	non-reserved	
USER_DEFINED_TYPE_NAME			non-reserved	non-reserved	
USER_DEFINED_TYPE_SCHEMA			non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
USING	reserved		reserved	reserved	reserved
UTF16			non-reserved		
UTF32			non-reserved		
UTF8			non-reserved		
VACUUM	non-reserved				
VALID	non-reserved		non-reserved	non-reserved	
VALIDATE	non-reserved				
VALIDATOR	non-reserved				
VALUE	non-reserved		reserved	reserved	reserved
VALUES	non-reserved (cannot be function or type)		reserved	reserved	reserved
VALUE_OF			reserved	reserved	
VARBINARY			reserved	reserved	
VARCHAR	non-reserved (cannot be function or type)		reserved	reserved	reserved
VARIADIC	reserved				
VARYING	non-reserved, requires AS		reserved	reserved	reserved
VAR_POP			reserved	reserved	
VAR_SAMP			reserved	reserved	
VERBOSE	reserved (can be function or type)				
VERSION	non-reserved		non-reserved	non-reserved	
VERSIONING			reserved	reserved	
VIEW	non-reserved		non-reserved	non-reserved	reserved
VIEWS	non-reserved				
VOLATILE	non-reserved				
WELLFORMED		non-reserved			
WHEN	reserved		reserved	reserved	reserved
WHENEVER			reserved	reserved	reserved
WHERE	reserved, requires AS		reserved	reserved	reserved
WHILE		non-reserved			
WHITESPACE	non-reserved		non-reserved	non-reserved	

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
WIDTH_BUCKET			reserved	reserved	
WINDOW	reserved, requires AS		reserved	reserved	
WITH	reserved, requires AS		reserved	reserved	reserved
WITHIN	non-reserved, requires AS		reserved	reserved	
WITHOUT	non-reserved, requires AS		reserved	reserved	
WORK	non-reserved		non-reserved	non-reserved	reserved
WRAPPER	non-reserved		non-reserved	non-reserved	
WRITABLE		non-reserved			
WRITE	non-reserved		non-reserved	non-reserved	reserved
XML	non-reserved		reserved	reserved	
XMLAGG			reserved	reserved	
XMLATTRIBUTES	non-reserved (cannot be function or type)		reserved	reserved	
XMLBINARY			reserved	reserved	
XMLCAST			reserved	reserved	
XMLCOMMENT			reserved	reserved	
XMLCONCAT	non-reserved (cannot be function or type)		reserved	reserved	
XMLDECLARATION			non-reserved	non-reserved	
XMLDOCUMENT			reserved	reserved	
XMLELEMENT	non-reserved (cannot be function or type)		reserved	reserved	
XML EXISTS	non-reserved (cannot be function or type)		reserved	reserved	
XMLFOREST	non-reserved (cannot be function or type)		reserved	reserved	
XMLITERATE			reserved	reserved	
XMLNAMESPACES	non-reserved (cannot be function or type)		reserved	reserved	
XMLPARSE	non-reserved (cannot be function or type)		reserved	reserved	



SQL Key Words

Key Word	PostgreSQL	LightDB	SQL:2016	SQL:2011	SQL-92
XMLPI	non-reserved (cannot be function or type)		reserved	reserved	
XMLQUERY			reserved	reserved	
XMLROOT	non-reserved (cannot be function or type)				
XMLSCHEMA			non- reserved	non- reserved	
XMLSERIALIZE	non-reserved (cannot be function or type)		reserved	reserved	
XMLTABLE	non-reserved (cannot be function or type)		reserved	reserved	
XMLTEXT			reserved	reserved	
XMLVALIDATE			reserved	reserved	
YEAR	non-reserved, requires AS		reserved	reserved	reserved
YES	non-reserved		non- reserved	non- reserved	
ZONE	non-reserved		non- reserved	non- reserved	reserved

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# Appendix D. SQL Conformance

This section attempts to outline to what extent LightDB conforms to the current SQL standard. The following information is not a full statement of conformance, but it presents the main topics in as much detail as is both reasonable and useful for users.

The formal name of the SQL standard is ISO/IEC 9075 “Database Language SQL”. A revised version of the standard is released from time to time; the most recent update appearing in 2016. The 2016 version is referred to as ISO/IEC 9075:2016, or simply as SQL:2016. The versions prior to that were SQL:2011, SQL:2008, SQL:2006, SQL:2003, SQL:1999, and SQL-92. Each version replaces the previous one, so claims of conformance to earlier versions have no official merit. LightDB development aims for conformance with the latest official version of the standard where such conformance does not contradict traditional features or common sense. Many of the features required by the SQL standard are supported, though sometimes with slightly differing syntax or function. Further moves towards conformance can be expected over time.

SQL-92 defined three feature sets for conformance: Entry, Intermediate, and Full. Most database management systems claiming SQL standard conformance were conforming at only the Entry level, since the entire set of features in the Intermediate and Full levels was either too voluminous or in conflict with legacy behaviors.

Starting with SQL:1999, the SQL standard defines a large set of individual features rather than the ineffectively broad three levels found in SQL-92. A large subset of these features represents the “Core” features, which every conforming SQL implementation must supply. The rest of the features are purely optional.

The standard versions beginning with SQL:2003 are also split into a number of parts. Each is known by a shorthand name. Note that these parts are not consecutively numbered.

- ISO/IEC 9075-1 Framework (SQL/Framework)
- ISO/IEC 9075-2 Foundation (SQL/Foundation)
- ISO/IEC 9075-3 Call Level Interface (SQL/CLI)
- ISO/IEC 9075-4 Persistent Stored Modules (SQL/PSM)
- ISO/IEC 9075-9 Management of External Data (SQL/MED)
- ISO/IEC 9075-10 Object Language Bindings (SQL/OLB)
- ISO/IEC 9075-11 Information and Definition Schemas (SQL/Schemata)
- ISO/IEC 9075-13 Routines and Types using the Java Language (SQL/JRT)
- ISO/IEC 9075-14 XML-related specifications (SQL/XML)
- ISO/IEC 9075-15 Multi-dimensional arrays (SQL/MDA)

The LightDB core covers parts 1, 2, 9, 11, and 14. Part 3 is covered by the ODBC driver, and part 13 is covered by the PL/Java plug-in, but exact conformance is currently not being verified for these components. There are currently no implementations of parts 4, 10, and 15 for LightDB.

LightDB supports most of the major features of SQL:2016. Out of 177 mandatory features required for full Core conformance, LightDB conforms to at least 170. In addition, there is a long list of supported optional features. It might be worth noting that at the time of writing, no current version of any database management system claims full conformance to Core SQL:2016.

In the following two sections, we provide a list of those features that LightDB supports, followed by a list of the features defined in SQL:2016 which are not yet supported in LightDB. Both of these lists are approximate: There might be minor details that are nonconforming for a feature that is listed as supported, and large parts of an unsupported feature might in fact be implemented. The main body of the documentation always contains the most accurate information about what does and does not work.

### Note

Feature codes containing a hyphen are subfeatures. Therefore, if a particular subfeature is not supported, the main feature is listed as unsupported even if some other subfeatures are supported.

## D.1. Supported Features

Identifier	Core?	Description	Comment
B012		Embedded C	
B021		Direct SQL	
E011	Core	Numeric data types	
E011-01	Core	INTEGER and SMALLINT data types	
E011-02	Core	REAL, DOUBLE PRECISION, and FLOAT data types	
E011-03	Core	DECIMAL and NUMERIC data types	
E011-04	Core	Arithmetic operators	
E011-05	Core	Numeric comparison	
E011-06	Core	Implicit casting among the numeric data types	
E021	Core	Character data types	
E021-01	Core	CHARACTER data type	
E021-02	Core	CHARACTER VARYING data type	
E021-03	Core	Character literals	
E021-04	Core	CHARACTER_LENGTH function	trims trailing spaces from CHARACTER values before counting
E021-05	Core	OCTET_LENGTH function	
E021-06	Core	SUBSTRING function	
E021-07	Core	Character concatenation	
E021-08	Core	UPPER and LOWER functions	
E021-09	Core	TRIM function	
E021-10	Core	Implicit casting among the character string types	
E021-11	Core	POSITION function	
E021-12	Core	Character comparison	
E031	Core	Identifiers	
E031-01	Core	Delimited identifiers	

Identifier	Core?	Description	Comment
E031-02	Core	Lower case identifiers	
E031-03	Core	Trailing underscore	
E051	Core	Basic query specification	
E051-01	Core	SELECT DISTINCT	
E051-02	Core	GROUP BY clause	
E051-04	Core	GROUP BY can contain columns not in <select list>	
E051-05	Core	Select list items can be renamed	
E051-06	Core	HAVING clause	
E051-07	Core	Qualified * in select list	
E051-08	Core	Correlation names in the FROM clause	
E051-09	Core	Rename columns in the FROM clause	
E061	Core	Basic predicates and search conditions	
E061-01	Core	Comparison predicate	
E061-02	Core	BETWEEN predicate	
E061-03	Core	IN predicate with list of values	
E061-04	Core	LIKE predicate	
E061-05	Core	LIKE predicate ESCAPE clause	
E061-06	Core	NULL predicate	
E061-07	Core	Quantified comparison predicate	
E061-08	Core	EXISTS predicate	
E061-09	Core	Subqueries in comparison predicate	
E061-11	Core	Subqueries in IN predicate	
E061-12	Core	Subqueries in quantified comparison predicate	
E061-13	Core	Correlated subqueries	
E061-14	Core	Search condition	
E071	Core	Basic query expressions	
E071-01	Core	UNION DISTINCT table operator	
E071-02	Core	UNION ALL table operator	
E071-03	Core	EXCEPT DISTINCT table operator	
E071-05	Core	Columns combined via table operators need not have exactly the same data type	
E071-06	Core	Table operators in subqueries	
E081	Core	Basic Privileges	
E081-01	Core	SELECT privilege	
E081-02	Core	DELETE privilege	
E081-03	Core	INSERT privilege at the table level	
E081-04	Core	UPDATE privilege at the table level	
E081-05	Core	UPDATE privilege at the column level	
E081-06	Core	REFERENCES privilege at the table level	
E081-07	Core	REFERENCES privilege at the column level	
E081-08	Core	WITH GRANT OPTION	

<b>Identifier</b>	<b>Core?</b>	<b>Description</b>	<b>Comment</b>
E081-09	Core	USAGE privilege	
E081-10	Core	EXECUTE privilege	
E091	Core	Set functions	
E091-01	Core	AVG	
E091-02	Core	COUNT	
E091-03	Core	MAX	
E091-04	Core	MIN	
E091-05	Core	SUM	
E091-06	Core	ALL quantifier	
E091-07	Core	DISTINCT quantifier	
E101	Core	Basic data manipulation	
E101-01	Core	INSERT statement	
E101-03	Core	Searched UPDATE statement	
E101-04	Core	Searched DELETE statement	
E111	Core	Single row SELECT statement	
E121	Core	Basic cursor support	
E121-01	Core	DECLARE CURSOR	
E121-02	Core	ORDER BY columns need not be in select list	
E121-03	Core	Value expressions in ORDER BY clause	
E121-04	Core	OPEN statement	
E121-06	Core	Positioned UPDATE statement	
E121-07	Core	Positioned DELETE statement	
E121-08	Core	CLOSE statement	
E121-10	Core	FETCH statement implicit NEXT	
E121-17	Core	WITH HOLD cursors	
E131	Core	Null value support (nulls in lieu of values)	
E141	Core	Basic integrity constraints	
E141-01	Core	NOT NULL constraints	
E141-02	Core	UNIQUE constraints of NOT NULL columns	
E141-03	Core	PRIMARY KEY constraints	
E141-04	Core	Basic FOREIGN KEY constraint with the NO ACTION default for both referential delete action and referential update action	
E141-06	Core	CHECK constraints	
E141-07	Core	Column defaults	
E141-08	Core	NOT NULL inferred on PRIMARY KEY	
E141-10	Core	Names in a foreign key can be specified in any order	
E151	Core	Transaction support	
E151-01	Core	COMMIT statement	
E151-02	Core	ROLLBACK statement	
E152	Core	Basic SET TRANSACTION statement	

Identifier	Core?	Description	Comment
E152-01	Core	SET TRANSACTION statement: ISOLATION LEVEL SERIALIZABLE clause	
E152-02	Core	SET TRANSACTION statement: READ ONLY and READ WRITE clauses	
E153	Core	Updatable queries with subqueries	
E161	Core	SQL comments using leading double minus	
E171	Core	SQLSTATE support	
E182	Core	Host language binding	
F021	Core	Basic information schema	
F021-01	Core	COLUMNS view	
F021-02	Core	TABLES view	
F021-03	Core	VIEWS view	
F021-04	Core	TABLE_CONSTRAINTS view	
F021-05	Core	REFERENTIAL_CONSTRAINTS view	
F021-06	Core	CHECK_CONSTRAINTS view	
F031	Core	Basic schema manipulation	
F031-01	Core	CREATE TABLE statement to create persistent base tables	
F031-02	Core	CREATE VIEW statement	
F031-03	Core	GRANT statement	
F031-04	Core	ALTER TABLE statement: ADD COLUMN clause	
F031-13	Core	DROP TABLE statement: RESTRICT clause	
F031-16	Core	DROP VIEW statement: RESTRICT clause	
F031-19	Core	REVOKE statement: RESTRICT clause	
F032		CASCADE drop behavior	
F033		ALTER TABLE statement: DROP COLUMN clause	
F034		Extended REVOKE statement	
F034-01		REVOKE statement performed by other than the owner of a schema object	
F034-02		REVOKE statement: GRANT OPTION FOR clause	
F034-03		REVOKE statement to revoke a privilege that the grantee has WITH GRANT OPTION	
F041	Core	Basic joined table	
F041-01	Core	Inner join (but not necessarily the INNER keyword)	
F041-02	Core	INNER keyword	
F041-03	Core	LEFT OUTER JOIN	
F041-04	Core	RIGHT OUTER JOIN	
F041-05	Core	Outer joins can be nested	
F041-07	Core	The inner table in a left or right outer join can also be used in an inner join	
F041-08	Core	All comparison operators are supported (rather than just =)	
F051	Core	Basic date and time	

Identifier	Core?	Description	Comment
F051-01	Core	DATE data type (including support of DATE literal)	
F051-02	Core	TIME data type (including support of TIME literal) with fractional seconds precision of at least 0	
F051-03	Core	TIMESTAMP data type (including support of TIMESTAMP literal) with fractional seconds precision of at least 0 and 6	
F051-04	Core	Comparison predicate on DATE, TIME, and TIMESTAMP data types	
F051-05	Core	Explicit CAST between datetime types and character string types	
F051-06	Core	CURRENT_DATE	
F051-07	Core	LOCALTIME	
F051-08	Core	LOCALTIMESTAMP	
F052		Intervals and datetime arithmetic	
F053		OVERLAPS predicate	
F081	Core	UNION and EXCEPT in views	
F111		Isolation levels other than SERIALIZABLE	
F111-01		READ UNCOMMITTED isolation level	
F111-02		READ COMMITTED isolation level	
F111-03		REPEATABLE READ isolation level	
F131	Core	Grouped operations	
F131-01	Core	WHERE, GROUP BY, and HAVING clauses supported in queries with grouped views	
F131-02	Core	Multiple tables supported in queries with grouped views	
F131-03	Core	Set functions supported in queries with grouped views	
F131-04	Core	Subqueries with GROUP BY and HAVING clauses and grouped views	
F131-05	Core	Single row SELECT with GROUP BY and HAVING clauses and grouped views	
F171		Multiple schemas per user	
F181	Core	Multiple module support	
F191		Referential delete actions	
F200		TRUNCATE TABLE statement	
F201	Core	CAST function	
F202		TRUNCATE TABLE: identity column restart option	
F221	Core	Explicit defaults	
F222		INSERT statement: DEFAULT VALUES clause	
F231		Privilege tables	
F231-01		TABLE_PRIVILEGES view	
F231-02		COLUMN_PRIVILEGES view	
F231-03		USAGE_PRIVILEGES view	
F251		Domain support	

Identifier	Core?	Description	Comment
F261	Core	CASE expression	
F261-01	Core	Simple CASE	
F261-02	Core	Searched CASE	
F261-03	Core	NULLIF	
F261-04	Core	COALESCE	
F262		Extended CASE expression	
F271		Compound character literals	
F281		LIKE enhancements	
F302		INTERSECT table operator	
F302-01		INTERSECT DISTINCT table operator	
F302-02		INTERSECT ALL table operator	
F304		EXCEPT ALL table operator	
F311	Core	Schema definition statement	
F311-01	Core	CREATE SCHEMA	
F311-02	Core	CREATE TABLE for persistent base tables	
F311-03	Core	CREATE VIEW	
F311-04	Core	CREATE VIEW: WITH CHECK OPTION	
F311-05	Core	GRANT statement	
F321		User authorization	
F361		Subprogram support	
F381		Extended schema manipulation	
F381-01		ALTER TABLE statement: ALTER COLUMN clause	
F381-02		ALTER TABLE statement: ADD CONSTRAINT clause	
F381-03		ALTER TABLE statement: DROP CONSTRAINT clause	
F382		Alter column data type	
F383		Set column not null clause	
F384		Drop identity property clause	
F385		Drop column generation expression clause	
F386		Set identity column generation clause	
F391		Long identifiers	
F392		Unicode escapes in identifiers	
F393		Unicode escapes in literals	
F394		Optional normal form specification	
F401		Extended joined table	
F401-01		NATURAL JOIN	
F401-02		FULL OUTER JOIN	
F401-04		CROSS JOIN	
F402		Named column joins for LOBs, arrays, and multisets	
F411		Time zone specification	differences regarding literal interpretation



Identifier	Core?	Description	Comment
F421		National character	
F431		Read-only scrollable cursors	
F431-01		FETCH with explicit NEXT	
F431-02		FETCH FIRST	
F431-03		FETCH LAST	
F431-04		FETCH PRIOR	
F431-05		FETCH ABSOLUTE	
F431-06		FETCH RELATIVE	
F441		Extended set function support	
F442		Mixed column references in set functions	
F471	Core	Scalar subquery values	
F481	Core	Expanded NULL predicate	
F491		Constraint management	
F501	Core	Features and conformance views	
F501-01	Core	SQL_FEATURES view	
F501-02	Core	SQL_SIZING view	
F502		Enhanced documentation tables	
F531		Temporary tables	
F555		Enhanced seconds precision	
F561		Full value expressions	
F571		Truth value tests	
F591		Derived tables	
F611		Indicator data types	
F641		Row and table constructors	
F651		Catalog name qualifiers	
F661		Simple tables	
F672		Retrospective check constraints	
F690		Collation support	but no character set support
F692		Extended collation support	
F701		Referential update actions	
F711		ALTER domain	
F731		INSERT column privileges	
F751		View CHECK enhancements	
F761		Session management	
F762		CURRENT_CATALOG	
F763		CURRENT_SCHEMA	
F771		Connection management	
F781		Self-referencing operations	
F791		Insensitive cursors	
F801		Full set function	

Identifier	Core?	Description	Comment
F850		Top-level <order by clause> in <query expression>	
F851		<order by clause> in subqueries	
F852		Top-level <order by clause> in views	
F855		Nested <order by clause> in <query expression>	
F856		Nested <fetch first clause> in <query expression>	
F857		Top-level <fetch first clause> in <query expression>	
F858		<fetch first clause> in subqueries	
F859		Top-level <fetch first clause> in views	
F860		<fetch first row count> in <fetch first clause>	
F861		Top-level <result offset clause> in <query expression>	
F862		<result offset clause> in subqueries	
F863		Nested <result offset clause> in <query expression>	
F864		Top-level <result offset clause> in views	
F865		<offset row count> in <result offset clause>	
F867		FETCH FIRST clause: WITH TIES option	
S071		SQL paths in function and type name resolution	
S092		Arrays of user-defined types	
S095		Array constructors by query	
S096		Optional array bounds	
S098		ARRAY_AGG	
S111		ONLY in query expressions	
S201		SQL-invoked routines on arrays	
S201-01		Array parameters	
S201-02		Array as result type of functions	
S211		User-defined cast functions	
S301		Enhanced UNNEST	
T031		BOOLEAN data type	
T071		BIGINT data type	
T121		WITH (excluding RECURSIVE) in query expression	
T122		WITH (excluding RECURSIVE) in subquery	
T131		Recursive query	
T132		Recursive query in subquery	
T141		SIMILAR predicate	
T151		DISTINCT predicate	
T152		DISTINCT predicate with negation	
T171		LIKE clause in table definition	
T172		AS subquery clause in table definition	
T173		Extended LIKE clause in table definition	
T174		Identity columns	
T177		Sequence generator support: simple restart option	
T178		Identity columns: simple restart option	

Identifier	Core?	Description	Comment
T191		Referential action RESTRICT	
T201		Comparable data types for referential constraints	
T211-01		Triggers activated on UPDATE, INSERT, or DELETE of one base table	
T211-02		BEFORE triggers	
T211-03		AFTER triggers	
T211-04		FOR EACH ROW triggers	
T211-05		Ability to specify a search condition that must be true before the trigger is invoked	
T211-07		TRIGGER privilege	
T212		Enhanced trigger capability	
T213		INSTEAD OF triggers	
T231		Sensitive cursors	
T241		START TRANSACTION statement	
T261		Chained transactions	
T271		Savepoints	
T281		SELECT privilege with column granularity	
T285		Enhanced derived column names	
T312		OVERLAY function	
T321-01	Core	User-defined functions with no overloading	
T321-02	Core	User-defined stored procedures with no overloading	
T321-03	Core	Function invocation	
T321-04	Core	CALL statement	
T321-06	Core	ROUTINES view	
T321-07	Core	PARAMETERS view	
T323		Explicit security for external routines	
T325		Qualified SQL parameter references	
T331		Basic roles	
T341		Overloading of SQL-invoked functions and procedures	
T351		Bracketed SQL comments (/*...*/ comments)	
T431		Extended grouping capabilities	
T432		Nested and concatenated GROUPING SETS	
T433		Multiargument GROUPING function	
T441		ABS and MOD functions	
T461		Symmetric BETWEEN predicate	
T491		LATERAL derived table	
T501		Enhanced EXISTS predicate	
T521		Named arguments in CALL statement	
T523		Default values for INOUT parameters of SQL-invoked procedures	
T524		Named arguments in routine invocations other than a CALL statement	

Identifier	Core?	Description	Comment
T525		Default values for parameters of SQL-invoked functions	
T551		Optional key words for default syntax	
T581		Regular expression substring function	
T591		UNIQUE constraints of possibly null columns	
T611		Elementary OLAP operations	
T612		Advanced OLAP operations	
T613		Sampling	
T614		NTILE function	
T615		LEAD and LAG functions	
T617		FIRST_VALUE and LAST_VALUE function	
T620		WINDOW clause: GROUPS option	
T621		Enhanced numeric functions	
T622		Trigonometric functions	
T623		General logarithm functions	
T624		Common logarithm functions	
T631	Core	IN predicate with one list element	
T651		SQL-schema statements in SQL routines	
T653		SQL-schema statements in external routines	
T655		Cyclically dependent routines	
T831		SQL/JSON path language: strict mode	
T832		SQL/JSON path language: item method	
T833		SQL/JSON path language: multiple subscripts	
T834		SQL/JSON path language: wildcard member accessor	
T835		SQL/JSON path language: filter expressions	
T836		SQL/JSON path language: starts with predicate	
T837		SQL/JSON path language: regex_like predicate	
X010		XML type	
X011		Arrays of XML type	
X014		Attributes of XML type	
X016		Persistent XML values	
X020		XMLConcat	
X031		XMLElement	
X032		XMLForest	
X034		XMLAgg	
X035		XMLAgg: ORDER BY option	
X036		XMLComment	
X037		XMLPI	
X040		Basic table mapping	
X041		Basic table mapping: nulls absent	
X042		Basic table mapping: null as nil	

Identifier	Core?	Description	Comment
X043		Basic table mapping: table as forest	
X044		Basic table mapping: table as element	
X045		Basic table mapping: with target namespace	
X046		Basic table mapping: data mapping	
X047		Basic table mapping: metadata mapping	
X048		Basic table mapping: base64 encoding of binary strings	
X049		Basic table mapping: hex encoding of binary strings	
X050		Advanced table mapping	
X051		Advanced table mapping: nulls absent	
X052		Advanced table mapping: null as nil	
X053		Advanced table mapping: table as forest	
X054		Advanced table mapping: table as element	
X055		Advanced table mapping: with target namespace	
X056		Advanced table mapping: data mapping	
X057		Advanced table mapping: metadata mapping	
X058		Advanced table mapping: base64 encoding of binary strings	
X059		Advanced table mapping: hex encoding of binary strings	
X060		XMLParse: character string input and CONTENT option	
X061		XMLParse: character string input and DOCUMENT option	
X070		XMLSerialize: character string serialization and CONTENT option	
X071		XMLSerialize: character string serialization and DOCUMENT option	
X072		XMLSerialize: character string serialization	
X090		XML document predicate	
X120		XML parameters in SQL routines	
X121		XML parameters in external routines	
X221		XML passing mechanism BY VALUE	
X301		XMLTable: derived column list option	
X302		XMLTable: ordinality column option	
X303		XMLTable: column default option	
X304		XMLTable: passing a context item	must be XML DOCUMENT
X400		Name and identifier mapping	
X410		Alter column data type: XML type	

## D.2. Unsupported Features

The following features defined in SQL:2016 are not implemented in this release of LightDB. In a few cases, equivalent functionality is available.

Identifier	Core?	Description	Comment
B011		Embedded Ada	
B013		Embedded COBOL	
B014		Embedded Fortran	
B015		Embedded MUMPS	
B016		Embedded Pascal	
B017		Embedded PL/I	
B031		Basic dynamic SQL	
B032		Extended dynamic SQL	
B032-01		<describe input statement>	
B033		Untyped SQL-invoked function arguments	
B034		Dynamic specification of cursor attributes	
B035		Non-extended descriptor names	
B041		Extensions to embedded SQL exception declarations	
B051		Enhanced execution rights	
B111		Module language Ada	
B112		Module language C	
B113		Module language COBOL	
B114		Module language Fortran	
B115		Module language MUMPS	
B116		Module language Pascal	
B117		Module language PL/I	
B121		Routine language Ada	
B122		Routine language C	
B123		Routine language COBOL	
B124		Routine language Fortran	
B125		Routine language MUMPS	
B126		Routine language Pascal	
B127		Routine language PL/I	
B128		Routine language SQL	
B200		Polymorphic table functions	
B201		More than one PTF generic table parameter	
B202		PTF Copartitioning	
B203		More than one copartition specification	
B204		PRUNE WHEN EMPTY	
B205		Pass-through columns	
B206		PTF descriptor parameters	
B207		Cross products of partitionings	

Identifier	Core?	Description	Comment
B208		PTF component procedure interface	
B209		PTF extended names	
B211		Module language Ada: VARCHAR and NUMERIC support	
B221		Routine language Ada: VARCHAR and NUMERIC support	
F054		TIMESTAMP in DATE type precedence list	
F121		Basic diagnostics management	
F121-01		GET DIAGNOSTICS statement	
F121-02		SET TRANSACTION statement: DIAGNOSTICS SIZE clause	
F122		Enhanced diagnostics management	
F123		All diagnostics	
F263		Comma-separated predicates in simple CASE expression	
F291		UNIQUE predicate	
F301		CORRESPONDING in query expressions	
F312		MERGE statement	consider INSERT ... ON CONFLICT DO UPDATE
F313		Enhanced MERGE statement	
F314		MERGE statement with DELETE branch	
F341		Usage tables	no ROUTINE_*_USAGE tables
F403		Partitioned joined tables	
F404		Range variable for common column names	
F451		Character set definition	
F461		Named character sets	
F492		Optional table constraint enforcement	
F521		Assertions	
F671		Subqueries in CHECK	intentionally omitted
F673		Reads SQL-data routine invocations in CHECK constraints	
F693		SQL-session and client module collations	
F695		Translation support	
F696		Additional translation documentation	
F721		Deferrable constraints	foreign and unique keys only
F741		Referential MATCH types	no partial match yet
F812	Core	Basic flagging	
F813		Extended flagging	
F821		Local table references	
F831		Full cursor update	

Identifier	Core?	Description	Comment
F831-01		Updatable scrollable cursors	
F831-02		Updatable ordered cursors	
F841		LIKE_REGEX predicate	
F842		OCCURRENCES_REGEX function	
F843		POSITION_REGEX function	
F844		SUBSTRING_REGEX function	
F845		TRANSLATE_REGEX function	
F846		Octet support in regular expression operators	
F847		Nonconstant regular expressions	
F866		FETCH FIRST clause: PERCENT option	
R010		Row pattern recognition: FROM clause	
R020		Row pattern recognition: WINDOW clause	
R030		Row pattern recognition: full aggregate support	
S011	Core	Distinct data types	
S011-01	Core	USER_DEFINED_TYPES view	
S023		Basic structured types	
S024		Enhanced structured types	
S025		Final structured types	
S026		Self-referencing structured types	
S027		Create method by specific method name	
S028		Permutable UDT options list	
S041		Basic reference types	
S043		Enhanced reference types	
S051		Create table of type	partially supported
S081		Subtables	
S091		Basic array support	partially supported
S091-01		Arrays of built-in data types	
S091-02		Arrays of distinct types	
S091-03		Array expressions	
S094		Arrays of reference types	
S097		Array element assignment	
S151		Type predicate	
S161		Subtype treatment	
S162		Subtype treatment for references	
S202		SQL-invoked routines on multisets	
S231		Structured type locators	
S232		Array locators	
S233		Multiset locators	
S241		Transform functions	
S242		Alter transform statement	
S251		User-defined orderings	



Identifier	Core?	Description	Comment
S261		Specific type method	
S271		Basic multiset support	
S272		Multisets of user-defined types	
S274		Multisets of reference types	
S275		Advanced multiset support	
S281		Nested collection types	
S291		Unique constraint on entire row	
S401		Distinct types based on array types	
S402		Distinct types based on distinct types	
S403		ARRAY_MAX_CARDINALITY	
S404		TRIM_ARRAY	
T011		Timestamp in Information Schema	
T021		BINARY and VARBINARY data types	
T022		Advanced support for BINARY and VARBINARY data types	
T023		Compound binary literal	
T024		Spaces in binary literals	
T041		Basic LOB data type support	
T041-01		BLOB data type	
T041-02		CLOB data type	
T041-03		POSITION, LENGTH, LOWER, TRIM, UPPER, and SUBSTRING functions for LOB data types	
T041-04		Concatenation of LOB data types	
T041-05		LOB locator: non-holdable	
T042		Extended LOB data type support	
T043		Multiplier T	
T044		Multiplier P	
T051		Row types	
T053		Explicit aliases for all-fields reference	
T061		UCS support	
T076		DECFLOAT data type	
T101		Enhanced nullability determination	
T111		Updatable joins, unions, and columns	
T175		Generated columns	mostly supported
T176		Sequence generator support	supported except for NEXT VALUE FOR
T180		System-versioned tables	
T181		Application-time period tables	
T211		Basic trigger capability	
T211-06		Support for run-time rules for the interaction of triggers and constraints	

Identifier	Core?	Description	Comment
T211-08		Multiple triggers for the same event are executed in the order in which they were created in the catalog	intentionally omitted
T251		SET TRANSACTION statement: LOCAL option	
T272		Enhanced savepoint management	
T301		Functional dependencies	partially supported
T321	Core	Basic SQL-invoked routines	
T321-05	Core	RETURN statement	
T322		Declared data type attributes	
T324		Explicit security for SQL routines	
T326		Table functions	
T332		Extended roles	mostly supported
T434		GROUP BY DISTINCT	
T471		Result sets return value	
T472		DESCRIBE CURSOR	
T495		Combined data change and retrieval	different syntax
T502		Period predicates	
T511		Transaction counts	
T522		Default values for IN parameters of SQL-invoked procedures	supported except DEFAULT key word in invocation
T561		Holdable locators	
T571		Array-returning external SQL-invoked functions	
T572		Multiset-returning external SQL-invoked functions	
T601		Local cursor references	
T616		Null treatment option for LEAD and LAG functions	
T618		NTH_VALUE function	function exists, but some options missing
T619		Nested window functions	
T625		LISTAGG	
T641		Multiple column assignment	only some syntax variants supported
T652		SQL-dynamic statements in SQL routines	
T654		SQL-dynamic statements in external routines	
T811		Basic SQL/JSON constructor functions	
T812		SQL/JSON: JSON_OBJECTAGG	
T813		SQL/JSON: JSON_ARRAYAGG with ORDER BY	
T814		Colon in JSON_OBJECT or JSON_OBJECTAGG	
T821		Basic SQL/JSON query operators	
T822		SQL/JSON: IS JSON WITH UNIQUE KEYS predicate	
T823		SQL/JSON: PASSING clause	
T824		JSON_TABLE: specific PLAN clause	

Identifier	Core?	Description	Comment
T825		SQL/JSON: ON EMPTY and ON ERROR clauses	
T826		General value expression in ON ERROR or ON EMPTY clauses	
T827		JSON_TABLE: sibling NESTED COLUMNS clauses	
T828		JSON_QUERY	
T829		JSON_QUERY: array wrapper options	
T830		Enforcing unique keys in SQL/JSON constructor functions	
T838		JSON_TABLE: PLAN DEFAULT clause	
T839		Formatted cast of datetimes to/from character strings	
M001		Datalinks	
M002		Datalinks via SQL/CLI	
M003		Datalinks via Embedded SQL	
M004		Foreign data support	partially supported
M005		Foreign schema support	
M006		GetSQLString routine	
M007		TransmitRequest	
M009		GetOpts and GetStatistics routines	
M010		Foreign data wrapper support	different API
M011		Datalinks via Ada	
M012		Datalinks via C	
M013		Datalinks via COBOL	
M014		Datalinks via Fortran	
M015		Datalinks via M	
M016		Datalinks via Pascal	
M017		Datalinks via PL/I	
M018		Foreign data wrapper interface routines in Ada	
M019		Foreign data wrapper interface routines in C	different API
M020		Foreign data wrapper interface routines in COBOL	
M021		Foreign data wrapper interface routines in Fortran	
M022		Foreign data wrapper interface routines in MUMPS	
M023		Foreign data wrapper interface routines in Pascal	
M024		Foreign data wrapper interface routines in PL/I	
M030		SQL-server foreign data support	
M031		Foreign data wrapper general routines	
X012		Multisets of XML type	
X013		Distinct types of XML type	
X015		Fields of XML type	
X025		XMLCast	
X030		XMLDocument	
X038		XMLText	

Identifier	Core?	Description	Comment
X065		XMLParse: BLOB input and CONTENT option	
X066		XMLParse: BLOB input and DOCUMENT option	
X068		XMLSerialize: BOM	
X069		XMLSerialize: INDENT	
X073		XMLSerialize: BLOB serialization and CONTENT option	
X074		XMLSerialize: BLOB serialization and DOCUMENT option	
X075		XMLSerialize: BLOB serialization	
X076		XMLSerialize: VERSION	
X077		XMLSerialize: explicit ENCODING option	
X078		XMLSerialize: explicit XML declaration	
X080		Namespaces in XML publishing	
X081		Query-level XML namespace declarations	
X082		XML namespace declarations in DML	
X083		XML namespace declarations in DDL	
X084		XML namespace declarations in compound statements	
X085		Predefined namespace prefixes	
X086		XML namespace declarations in XMLTable	
X091		XML content predicate	
X096		XMLExists	XPath 1.0 only
X100		Host language support for XML: CONTENT option	
X101		Host language support for XML: DOCUMENT option	
X110		Host language support for XML: VARCHAR mapping	
X111		Host language support for XML: CLOB mapping	
X112		Host language support for XML: BLOB mapping	
X113		Host language support for XML: STRIP WHITESPACE option	
X114		Host language support for XML: PRESERVE WHITESPACE option	
X131		Query-level XMLBINARY clause	
X132		XMLBINARY clause in DML	
X133		XMLBINARY clause in DDL	
X134		XMLBINARY clause in compound statements	
X135		XMLBINARY clause in subqueries	
X141		IS VALID predicate: data-driven case	
X142		IS VALID predicate: ACCORDING TO clause	
X143		IS VALID predicate: ELEMENT clause	
X144		IS VALID predicate: schema location	
X145		IS VALID predicate outside check constraints	
X151		IS VALID predicate with DOCUMENT option	
X152		IS VALID predicate with CONTENT option	

Identifier	Core?	Description	Comment
X153		IS VALID predicate with SEQUENCE option	
X155		IS VALID predicate: NAMESPACE without ELEMENT clause	
X157		IS VALID predicate: NO NAMESPACE with ELEMENT clause	
X160		Basic Information Schema for registered XML Schemas	
X161		Advanced Information Schema for registered XML Schemas	
X170		XML null handling options	
X171		NIL ON NO CONTENT option	
X181		XML(DOCUMENT(UNTYPED)) type	
X182		XML(DOCUMENT(ANY)) type	
X190		XML(SEQUENCE) type	
X191		XML(DOCUMENT(XMLSCHEMA)) type	
X192		XML(CONTENT(XMLSCHEMA)) type	
X200		XMLQuery	
X201		XMLQuery: RETURNING CONTENT	
X202		XMLQuery: RETURNING SEQUENCE	
X203		XMLQuery: passing a context item	
X204		XMLQuery: initializing an XQuery variable	
X205		XMLQuery: EMPTY ON EMPTY option	
X206		XMLQuery: NULL ON EMPTY option	
X211		XML 1.1 support	
X222		XML passing mechanism BY REF	parser accepts BY REF but ignores it; passing is always BY VALUE
X231		XML(CONTENT(UNTYPED)) type	
X232		XML(CONTENT(ANY)) type	
X241		RETURNING CONTENT in XML publishing	
X242		RETURNING SEQUENCE in XML publishing	
X251		Persistent XML values of XML(DOCUMENT(UNTYPED)) type	
X252		Persistent XML values of XML(DOCUMENT(ANY)) type	
X253		Persistent XML values of XML(CONTENT(UNTYPED)) type	
X254		Persistent XML values of XML(CONTENT(ANY)) type	
X255		Persistent XML values of XML(SEQUENCE) type	
X256		Persistent XML values of XML(DOCUMENT(XMLSCHEMA)) type	

Identifier	Core?	Description	Comment
X257		Persistent XML values of XML(CONTENT(XMLSCHEMA)) type	
X260		XML type: ELEMENT clause	
X261		XML type: NAMESPACE without ELEMENT clause	
X263		XML type: NO NAMESPACE with ELEMENT clause	
X264		XML type: schema location	
X271		XMLValidate: data-driven case	
X272		XMLValidate: ACCORDING TO clause	
X273		XMLValidate: ELEMENT clause	
X274		XMLValidate: schema location	
X281		XMLValidate with DOCUMENT option	
X282		XMLValidate with CONTENT option	
X283		XMLValidate with SEQUENCE option	
X284		XMLValidate: NAMESPACE without ELEMENT clause	
X286		XMLValidate: NO NAMESPACE with ELEMENT clause	
X300		XMLTable	XPath 1.0 only
X305		XMLTable: initializing an XQuery variable	

## D.3. XML Limits and Conformance to SQL/XML

Significant revisions to the XML-related specifications in ISO/IEC 9075-14 (SQL/XML) were introduced with SQL:2006. LightDB's implementation of the XML data type and related functions largely follows the earlier 2003 edition, with some borrowing from later editions. In particular:

- Where the current standard provides a family of XML data types to hold “document” or “content” in untyped or XML Schema-typed variants, and a type XML ( SEQUENCE ) to hold arbitrary pieces of XML content, LightDB provides the single xml type, which can hold “document” or “content”. There is no equivalent of the standard's “sequence” type.
- LightDB provides two functions introduced in SQL:2006, but in variants that use the XPath 1.0 language, rather than XML Query as specified for them in the standard.

This section presents some of the resulting differences you may encounter.

### D.3.1. Queries Are Restricted to XPath 1.0

The LightDB-specific functions `xpath()` and `xpath_exists()` query XML documents using the XPath language. LightDB also provides XPath-only variants of the standard functions `XMLEXISTS` and `XMLTABLE`, which officially use the XQuery language. For all of these functions, LightDB relies on the libxml2 library, which provides only XPath 1.0.

There is a strong connection between the XQuery language and XPath versions 2.0 and later: any expression that is syntactically valid and executes successfully in both produces the same result (with a minor exception for expressions containing numeric character references or predefined entity references, which XQuery replaces with the corresponding character while XPath leaves them alone).

But there is no such connection between these languages and XPath 1.0; it was an earlier language and differs in many respects.

There are two categories of limitation to keep in mind: the restriction from XQuery to XPath for the functions specified in the SQL standard, and the restriction of XPath to version 1.0 for both the standard and the LightDB-specific functions.

### D.3.1.1. Restriction of XQuery to XPath

Features of XQuery beyond those of XPath include:

- XQuery expressions can construct and return new XML nodes, in addition to all possible XPath values. XPath can create and return values of the atomic types (numbers, strings, and so on) but can only return XML nodes that were already present in documents supplied as input to the expression.
- XQuery has control constructs for iteration, sorting, and grouping.
- XQuery allows declaration and use of local functions.

Recent XPath versions begin to offer capabilities overlapping with these (such as functional-style `for-each` and `sort`, anonymous functions, and `parse-xml` to create a node from a string), but such features were not available before XPath 3.0.

### D.3.1.2. Restriction of XPath to 1.0

For developers familiar with XQuery and XPath 2.0 or later, XPath 1.0 presents a number of differences to contend with:

- The fundamental type of an XQuery/XPath expression, the `sequence`, which can contain XML nodes, atomic values, or both, does not exist in XPath 1.0. A 1.0 expression can only produce a node-set (containing zero or more XML nodes), or a single atomic value.
- Unlike an XQuery/XPath sequence, which can contain any desired items in any desired order, an XPath 1.0 node-set has no guaranteed order and, like any set, does not allow multiple appearances of the same item.

#### Note

The libxml2 library does seem to always return node-sets to LightDB with their members in the same relative order they had in the input document. Its documentation does not commit to this behavior, and an XPath 1.0 expression cannot control it.

- While XQuery/XPath provides all of the types defined in XML Schema and many operators and functions over those types, XPath 1.0 has only node-sets and the three atomic types `boolean`, `double`, and `string`.
- XPath 1.0 has no conditional operator. An XQuery/XPath expression such as `if ( hat ) then hat/@size else "no hat"` has no XPath 1.0 equivalent.
- XPath 1.0 has no ordering comparison operator for strings. Both `"cat" < "dog"` and `"cat" > "dog"` are false, because each is a numeric comparison of two NaNs. In contrast, `=` and `!=` do compare the strings as strings.
- XPath 1.0 blurs the distinction between *value comparisons* and *general comparisons* as XQuery/XPath define them. Both `sale/@hatsize = 7` and `sale/@customer = "alice"` are existentially quantified comparisons, true if there is any `sale` with the given value for the attribute,

but `sale/@taxable = false()` is a value comparison to the *effective boolean value* of a whole node-set. It is true only if no `sale` has a `taxable` attribute at all.

- In the XQuery/XPath data model, a *document node* can have either document form (i.e., exactly one top-level element, with only comments and processing instructions outside of it) or content form (with those constraints relaxed). Its equivalent in XPath 1.0, the *root node*, can only be in document form. This is part of the reason an `xml` value passed as the context item to any LightDB XPath-based function must be in document form.

The differences highlighted here are not all of them. In XQuery and the 2.0 and later versions of XPath, there is an XPath 1.0 compatibility mode, and the W3C lists of function library changes<sup>1</sup> and language changes<sup>2</sup> applied in that mode offer a more complete (but still not exhaustive) account of the differences. The compatibility mode cannot make the later languages exactly equivalent to XPath 1.0.

### D.3.1.3. Mappings between SQL and XML Data Types and Values

In SQL:2006 and later, both directions of conversion between standard SQL data types and the XML Schema types are specified precisely. However, the rules are expressed using the types and semantics of XQuery/XPath, and have no direct application to the different data model of XPath 1.0.

When LightDB maps SQL data values to XML (as in `xmlelement`), or XML to SQL (as in the output columns of `xmltable`), except for a few cases treated specially, LightDB simply assumes that the XML data type's XPath 1.0 string form will be valid as the text-input form of the SQL datatype, and conversely. This rule has the virtue of simplicity while producing, for many data types, results similar to the mappings specified in the standard.

Where interoperability with other systems is a concern, for some data types, it may be necessary to use data type formatting functions (such as those in Section 9.8) explicitly to produce the standard mappings.

## D.3.2. Incidental Limits of the Implementation

This section concerns limits that are not inherent in the libxml2 library, but apply to the current implementation in LightDB.

### D.3.2.1. Only BY VALUE Passing Mechanism Is Supported

The SQL standard defines two *passing mechanisms* that apply when passing an XML argument from SQL to an XML function or receiving a result: `BY REF`, in which a particular XML value retains its node identity, and `BY VALUE`, in which the content of the XML is passed but node identity is not preserved. A mechanism can be specified before a list of parameters, as the default mechanism for all of them, or after any parameter, to override the default.

To illustrate the difference, if `x` is an XML value, these two queries in an SQL:2006 environment would produce true and false, respectively:

```
SELECT XMLQUERY('$a is $b' PASSING BY REF x AS a, x AS b NULL ON
EMPTY);
SELECT XMLQUERY('$a is $b' PASSING BY VALUE x AS a, x AS b NULL ON
EMPTY);
```

LightDB will accept `BY VALUE` or `BY REF` in an `XMLEXISTS` or `XMLTABLE` construct, but it ignores them. The `xml` data type holds a character-string serialized representation, so there is no node identity to preserve, and passing is always effectively `BY VALUE`.

<sup>1</sup> <https://www.w3.org/TR/2010/REC-xpath-functions-20101214/#xpath1-compatibility>

<sup>2</sup> <https://www.w3.org/TR/xpath20/#id-backwards-compatibility>



### **D.3.2.2. Cannot Pass Named Parameters to Queries**

The XPath-based functions support passing one parameter to serve as the XPath expression's context item, but do not support passing additional values to be available to the expression as named parameters.

### **D.3.2.3. No XML ( SEQUENCE ) Type**

The LightDB `xml` data type can only hold a value in `DOCUMENT` or `CONTENT` form. An XQuery/XPath expression context item must be a single XML node or atomic value, but XPath 1.0 further restricts it to be only an XML node, and has no node type allowing `CONTENT`. The upshot is that a well-formed `DOCUMENT` is the only form of XML value that LightDB can supply as an XPath context item.

---

# Appendix E. Release Notes

The release notes contain significant changes in each LightDB release, with major features and migration issues listed at the top. The release notes do not contain changes that affect only a few users or internal changes which mean not user-visible. For example, the optimizer may be improved in almost every release, but the improvements are usually observed by users as simply faster queries.

## E.1. Release 13.8-23.4

**Release date:** 2023-12-31

### E.1.1. Oracle Compatibility

- Supports the `set definecommand`, which can be used to enable or disable variable replacement functionality. see `set define on/off` command.
- Client command line support `'/`. see `Slashes`.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle
```

```
Select 1+2;
?column?
-----
3
(1 row)
```

```
/
```

- Uppercase field names can be added with double quotation marks during queries. see `Lexical Structure`.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle
```

```
create table t1(id int, "Id" int);

insert into t1 values(1,2),(3,4),(5,6);

select "ID" from t1;
  ID
----
  1
  3
  5
(3 rows)
```

- Addition and subtraction of `timestamp,oracle.date` and numeric values are supported. see `orafce`.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

Create table t_data(dt date, d1 integer, d2 bigint, d3 smallint,
d4 numeric(10, 2), dd date);

insert into t_data values(to_date('2023-11-28 20:10:30', 'YYYY-
MM-DD HH24:mi:ss'), 1, 2, 3, 4.4, to_date('2023-11-27 20:10:30',
'YYYY-MM-DD HH24:mi:ss'));

insert into t_data values(to_date('2023-11-28 00:00:01', 'YYYY-
MM-DD HH24:mi:ss'), 1, 2, 3, 4.5, to_date('2023-11-27 00:00:02',
'YYYY-MM-DD HH24:mi:ss'));

select dt, dt - d1, dt - d1 + d2 , dt - d1 + d2 - d3, dt - d1 +
d2 - d3 + d4, dt - dd from t_data;
      dt          |          ?column?          |          ?column?
|          ?column?          |          ?column?          |          ?column?
-----+-----+-----
+-----+-----+-----
+-----+-----+-----
2023-11-28 20:10:30 | 2023-11-27 20:10:30 | 2023-11-29
20:10:30 | 2023-11-26 20:10:30 | 2023-12-01 05:46:30 |
1.00000000000000000000
2023-11-28 00:00:01 | 2023-11-27 00:00:01 | 2023-11-29
00:00:01 | 2023-11-26 00:00:01 | 2023-11-30 12:00:01 |
0.99998842592592592500
(2 rows)
```

- Rownum can be used as an rvalue expression. See ROWNUM.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

SELECT TO_CHAR(TO_DATE(TRIM('20230110'), 'YYYYMMDD') + ROWNUM,
'YYYYMMDD') from dual;
to_char
-----
20230111
(1 row)
```

- The value type in the decode function parameter is equivalent to the invalid 0 in the decimal place of the value. see DECODE.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
```

```

\c test_oracle

SELECT decode(0.0, 0, 1, 2), decode(0, 0, 1, 2), decode(0, 0.0,
  1, 2), decode(0, 1, 2, 0.0, 4, 5) FROM dual;
  decode | decode | decode | decode
-----+-----+-----+-----
         1 |         1 |         1 | 4
(1 row)

```

```

SELECT decode(1.10, 1.1, 1, 2) FROM dual;
  decode
-----
         1
(1 row)

```

```

SELECT decode(1.0, 1, 1, 2) FROM dual;
  decode
-----
         1
(1 row)

```

- The `substr` function supports a combination of `text,numeric,numeric` or `text,numeric`. see `orafce`.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle

create table tt_substr(a number(10), b number(10));

INSERT INTO tt_substr (a, b) VALUES(2, 1);

select substr('aaaaa'::varchar2, 2, a + b) FROM tt_substr;
  substr
-----
     aaa
(1 row)

select substr('aaaaa'::varchar2, a) FROM tt_substr;
  substr
-----
     aaaa
(1 row)

```

- The `to_char` function changes the date and number format to text format. see `orafce`.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle

Select to_char(sysdate+1 + interval '-1'
  year,'d','NLS_DATE_LANGUAGE=''SIMPLIFIED CHINESE''');

```

```

to_char
-----
6
(1 row)

```

- The rawtohex function supports the uuid type as a parameter. see orafce.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

select rawtohex(sys_guid()) from dual;
           rawtohex
-----
6653ab0b8ad34634bdc1645f3f264455
(1 row)

```

- The rowidtochar function converts the rowid type to a character type. see orafce.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table tt1(idd int);

insert into tt1 values(3);

create table tt7 as select rowidtochar(rowid) as rowid1,* from
tt1;

\d tt7
           Table "public.tt7"
  Column |   Type   | Collation | Nullable | Default
-----+-----+-----+-----+-----
 rowid1 | varchar2 |           |          |
  idd   | integer  |           |          |

```

- The to\_timestamp converts the character time value to a timestamp format. see orafce.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

SELECT TO_TIMESTAMP('2023-10-11 10:10:10', 'YYYY-MM-DD HH:MI:SS
PM') FROM dual;
           to_timestamp
-----
2023-10-11 10:10:10+08
(1 row)

```

- Support `empty_clob/empty_blob` initialization of LOB objects, The return is not null, `empty_blob()` is null is not established. see orafce.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
Select empty_clob();
empty_clob
```

```
-----
```

```
(1 row)
```

```
Select empty_blob();
empty_blob
```

```
-----
```

```
\x
```

```
(1 row)
```

- The `sysimestamp(n)` supports precision parameters. see Date/Time Functions.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
select current_timestamp,sysimestamp(0);
```

```
current_timestamp | sysimestamp
```

```
-----+-----
```

```
2024-01-02 01:48:16.899369-05 | 2024-01-02 01:48:17-05
```

```
(1 row)
```

```
select current_timestamp,sysimestamp(1);
```

```
current_timestamp | sysimestamp
```

```
-----+-----
```

```
2024-01-02 01:48:16.900603-05 | 2024-01-02 01:48:16.9-05
```

- The parameters of the `NVL` function can be set to null. see orafce.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
select nvl(null::numeric, '0');
```

```
nvl
```

```
-----
```

```
0
```

```
(1 row)
```

- The time string of the supported `to_date` function does not match the output data format. see orafce.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

select to_date('2022/02/02','yyyy-mm-dd') from dual;
      to_date
-----
2022-02-02 00:00:00
(1 row)
```

- The `xmlparse` and `xmlagg` functions are supported. see XML Functions.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

SELECT XMLPARSE(CONTENT '124 <purchaseOrder poNo="12435">
<customerName> Acme Enterprises</customerName>
<itemNo>32987457</itemNo>
</purchaseOrder>'
WELLFORMED) AS PO FROM DUAL;

po
-----
124 <purchaseOrder poNo="12435">
<customerName> Acme Enterprises</customerName>
<itemNo>32987457</itemNo>
</purchaseOrder>
(1 row)
```

- Create a partition table name that does not exceed 31 characters in length. see CREATE TABLE.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

CREATE TABLE test_partition_table_len_31__lh(a int,b int)
PARTITION BY list(a)
SUBPARTITION BY hash(b)
(
  PARTITION p11 VALUES(1,2,3,4),
  PARTITION p12 VALUES(5,6,7,8)
);
```

- The object type can be rebuilt by `replace`. see CREATE TYPE.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE OR REPLACE TYPE employee_type AS OBJECT(
x int,
y int,
MEMBER FUNCTION psum(a int, b int) RETURN int,
MEMBER PROCEDURE p(prompt varchar)
);
CREATE TYPE.
```

- Support commands of alter session enable/disable parallel dml. see ALTER SESSION.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

alter session enable parallel dml;
```

- Supports tabs view, a built-in view of all tablespaces and their associated objects in the database. see orafce.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE TABLE measurement (
```

```
    city_id          int not null,
    logdate           date not null,
    peaktemp         int,
    unitsales        int
```

```
) PARTITION BY RANGE (logdate);
```

```
SELECT table_name, tablespace_name FROM oracle.TABS WHERE
TABLE_NAME IN ('TEST_VIEW', 'MEASUREMENT', 'MEASUREMENT_Y2018')
ORDER BY TABLE_NAME;
```

```
table_name | tablespace_name
-----+-----
MEASUREMENT | DEFAULT
(1 row)
```

- Support online conversion of regular tables to list type partitioned tables, and synchronously update indexes. see CREATE TABLE.

For example:



```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE TABLE my_list_tab ( a NUMBER(38,0), cu VARCHAR2(20));
insert into my_list_tab values(1,'china');
insert into my_list_tab values(2,'THAILAND');
insert into my_list_tab values(3,'GERMANY');
insert into my_list_tab values(4,'ITALY');
insert into my_list_tab values(5,'SWITZERLAND');
insert into my_list_tab values(6,'AMERICA');
insert into my_list_tab values(7,'INDIA');
```

```
CREATE INDEX i_a ON my_list_tab (a);
CREATE INDEX i_cu ON my_list_tab (cu);
```

```
ALTER TABLE my_list_tab MODIFY PARTITION BY LIST (cu) (
PARTITION asia VALUES ('CHINA', 'THAILAND'),
PARTITION europe VALUES ('GERMANY', 'ITALY', 'SWITZERLAND'),
PARTITION west VALUES ('AMERICA'),
PARTITION east VALUES ('INDIA'),
PARTITION rest VALUES (DEFAULT))
online
update indexes
( i_a GLOBAL,
i_cu local
);
```

```
\d+ my_list_tab
```

Partitioned table

```
"public.my_list_tab"
Column |      Type      | Collation | Nullable | Default |
Storage | Stats target | Description
-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
a      | numeric(38,0) |          |          |          | main
|          |          |          |          |          |
cu     | varchar2(20)  |          |          |          |
extended |          |          |          |          |
Partition key: LIST (cu)
Indexes:
  "i_a" btree (a)
  "i_cu" btree (cu)
Partitions: "my_list_tab$asia" FOR VALUES IN ('CHINA',
'THAILAND'),
            "my_list_tab$east" FOR VALUES IN ('INDIA'),
            "my_list_tab$europe" FOR VALUES IN ('GERMANY',
'ITALY', 'SWITZERLAND'),
            "my_list_tab$west" FOR VALUES IN ('AMERICA'),
            "my_list_tab$rest" DEFAULT
```

- If (+) is used to join multiple tables in a SELECT query, you can specify the table name for the distinct column in the where condition. see SELECT.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
Create table t1(key1 int, key2 int);
```

```
Create table t2(key1 int);
```

```
Select * from t1, t2 where t1.key1(+)=t2.key1 and key2=2;
  key1 | key2 | key1
-----+-----+-----
(0 rows)
```

- Supports the combination of aggregate count (\*) and order by. see SELECT.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE TABLE EMP
(  EMPNO      NUMBER(4, 0),
  ENAME      VARCHAR2(10),
  JOB        VARCHAR2(9),
  MGR        NUMBER(4, 0),
  HIREDATE   DATE,
  SAL        NUMBER(7, 2),
  COMM       NUMBER(7, 2),
  DEPTNO     NUMBER(2, 0),
  DNAME      VARCHAR2(100),
  CONSTRAINT PK_EMP PRIMARY KEY (EMPNO)
);
```

```
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7369, 'SMITH', 'CLERK', 7902,
  to_date('1980-12-17', 'yyyy-mm-dd'), 800.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7499, 'ALLEN', 'SALESMAN', 7698,
  to_date('1981-02-20', 'yyyy-mm-dd'), 1600.00, 300.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7521, 'WARD', 'SALESMAN', 7698,
  to_date('1981-02-22', 'yyyy-mm-dd'), 1250.00, 500.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7566, 'JONES', 'MANAGER', 7839,
  to_date('1981-04-02', 'yyyy-mm-dd'), 2975.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7654, 'MARTIN', 'SALESMAN', 7698,
  to_date('1981-09-28', 'yyyy-mm-dd'), 1250.00, 1400.00, 30, null);
```

```
select count(*) from emp order by empno;
  count
-----
      6
(1 row)
```

- connect by supports binding variables. see SELECT.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
PREPARE my_query (VARCHAR) AS
SELECT LEVEL, empno
FROM emp
CONNECT BY PRIOR empno = mgr
START WITH ename = $1;
```

```
EXECUTE my_query('ALLEN');
  level | empno
-----+-----
       1 |  7499
(1 row)
```

- The `merge into` statement supports the branch of the `insert` statement and the use of table aliases. see `MERGE INTO`.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE TABLE EMP
(  EMPNO      NUMBER(4, 0),
  ENAME       VARCHAR2(10),
  JOB         VARCHAR2(9),
  MGR         NUMBER(4, 0),
  HIREDATE    DATE,
  SAL         NUMBER(7, 2),
  COMM        NUMBER(7, 2),
  DEPTNO      NUMBER(2, 0),
  DNAME       VARCHAR2(100),
  CONSTRAINT PK_EMP PRIMARY KEY (EMPNO)
);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7369, 'SMITH', 'CLERK', 7902,
  to_date('1980-12-17','yyyy-mm-dd'), 800.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7499, 'ALLEN', 'SALESMAN', 7698,
  to_date('1981-02-20','yyyy-mm-dd'), 1600.00, 300.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7521, 'WARD', 'SALESMAN', 7698,
  to_date('1981-02-22','yyyy-mm-dd'), 1250.00, 500.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7566, 'JONES', 'MANAGER', 7839,
  to_date('1981-04-02','yyyy-mm-dd'), 2975.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7654, 'MARTIN', 'SALESMAN', 7698,
  to_date('1981-09-28','yyyy-mm-dd'), 1250.00, 1400.00, 30, null);
```

```

declare
i number;
begin
execute immediate q'[MERGE INTO emp e
USING (
    SELECT
        1 as empno,
        'ename' as ename
    FROM dual
) new_data
ON (e.empno = new_data.empno)
WHEN MATCHED THEN
    UPDATE SET e.ename = new_data.ename
WHEN NOT MATCHED THEN
    INSERT (e.empno, e.ename) VALUES (
        new_data.empno,
        new_data.ename
    )]';
commit;
end;
/

```

- Added 6 optimizer hints. see `lt_hint_plan`.
- Supported `ignore_row_on_dupkey_index` hint, Prompt: Ignore unique key violations for specific column sets or specified indexes.
- Supported `push_subq` hint. Prompt: Force the optimizer to push down the filter condition of the band link, and only use this condition to filter data at the end.
- Supported `no_push_subq` hint. Prompt: Force the optimizer to push down the filter condition of the band link, and use this condition to filter the data as early as possible.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table test_no_push_subq1 as select * from pg_class order
by oid limit 100;
create table test_no_push_subq2 as select * from pg_class order
by oid limit 100;
create table test_no_push_subq3 as select * from pg_class order
by oid limit 100;
create table test_no_push_subq4 as select * from pg_class order
by oid limit 100;

EXPLAIN (COSTS false)
select a.oid from test_no_push_subq1 a join test_no_push_subq3
b on a.reltype =b.reltype and a.oid = b.oid
where a.oid = (select/*+no_push_subq*/ max(oid) from
test_no_push_subq2);

```

QUERY PLAN

```

-----
Hash Join
  Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))

```

```
Join Filter: (a.oid = $0)
InitPlan 1 (returns $0)
-> Aggregate
    -> Seq Scan on test_no_push_subq2 @"lt#0"
-> Seq Scan on test_no_push_subq1 a @"lt#1"
-> Hash
    -> Seq Scan on test_no_push_subq3 b @"lt#1"
(9 rows)
```

- Supported `opt_param` hint. Prompt: Modify the GUC parameters during the generation of an execution plan.
- Supported `no_star_transformation` hint. Prompt: The optimizer does not perform star query transformations.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle
```

```
CREATE TABLE times (
    time_id NUMBER PRIMARY KEY,
    calendar_quarter_desc VARCHAR2(20)
);
```

```
CREATE TABLE customers (
    cust_id NUMBER PRIMARY KEY,
    cust_city VARCHAR2(20),
    cust_state_province VARCHAR2(20)
);
```

```
CREATE TABLE channels (
    channel_id NUMBER PRIMARY KEY,
    channel_class VARCHAR2(20),
    channel_desc VARCHAR2(20)
);
```

```
CREATE TABLE sales (
    time_id NUMBER REFERENCES times(time_id),
    cust_id NUMBER REFERENCES customers(cust_id),
```

```

channel_id NUMBER REFERENCES channels(channel_id),

amount_sold NUMBER

);

EXPLAIN (COSTS false) SELECT/*+no_star_transformation*/
ch.channel_class, c.cust_city, t.calendar_quarter_desc,
SUM(s.amount_sold) sales_amount
FROM sales s, times t, customers c, channels ch
WHERE s.time_id = t.time_id
AND s.cust_id = c.cust_id
AND s.channel_id = ch.channel_id
AND c.cust_state_province = 'CA'
AND ch.channel_desc in ('Internet','Catalog')
AND t.calendar_quarter_desc IN ('1999-Q1','1999-Q2')
GROUP BY ch.channel_class, c.cust_city,
t.calendar_quarter_desc;
LOG:  lt_hint_plan:
used hint:
no_star_transformation
not used hint:
duplication hint:
error hint:

```

## QUERY PLAN

```

-----
GroupAggregate
  Group Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Sort
      Sort Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Nested Loop
      -> Nested Loop
          -> Hash Join
              Hash Cond: (s.cust_id = c.cust_id)
              -> Seq Scan on sales s @"lt#0"
              -> Hash
                  -> Seq Scan on customers c
@"lt#0"
              Filter:
((cust_state_province)::text
= 'CA'::text)
          -> Index Scan using times_pkey on times t
@"lt#0"
              Index Cond: (time_id = s.time_id)
              Filter:
((calendar_quarter_desc)::text = ANY ('{1
999-Q1,1999-Q2}'::text[]))
          -> Index Scan using channels_pkey on channels
ch @"lt#0"
              Index Cond: (channel_id = s.channel_id)

```

```

                Filter: ((channel_desc)::text = ANY
({Internet,Catalog
}>::text[]))
(18 rows)

```

- Supported `no_push_pred` hint. Prompt#The optimizer does not push the join predicate into a subquery.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table test_no_push_pred1 (key1 int primary key, key2
int);
create table test_no_push_pred2 (key1 int primary key, key2
int);
create table test_no_push_pred3 (key1 int primary key, key2
int);

set enable_hashjoin to off;
set enable_mergejoin to off;

EXPLAIN (COSTS false)
select /*+leading(a) no_push_pred(b)*/ from test_no_push_pred1
a join (select * from test_no_push_pred2 order by key1 limit
1) b on a.key1 =b.key2;

```

QUERY PLAN

```

-----
-----
Nested Loop
  Join Filter: (a.key1 = test_no_push_pred2.key2)
  -> Seq Scan on test_no_push_pred1 a @"lt#1"
  -> Materialize
      -> Limit
          -> Index Scan using test_no_push_pred2_pkey on
test_no_push_pred2
(6 rows)

```

- Supported `append` hint. Prompt: The optimizer to use direct-path insertion for statements in insert select mode.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table test_append(key1 int, key2 int, key3 int, key4
int);
create table test_append1(key1 int, key2 int, key3 int, key4
int);

```

```

insert into test_append1 values(1,2,3,4);
insert into test_append1 values(11,21,31,41);
insert into test_append1 values(111,211,311,411);

EXPLAIN (COSTS FALSE) insert/*+append */ into test_append
  select 1, 1, 1, 2 from dual;
LOG:  lt_hint_plan:
used hint:
not used hint:
append
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Insert on test_append @"lt#1"
  -> Result
(2 rows)

```

- The `to_char` supports HH24MiSS time format. see oraface.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle

select to_char(timestamp 'now', 'HH24MiSS');
  to_char
-----
  042121
(1 row)

```

- Table functions `column_value` pseudo-columns. see Table function.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle

create type phone as table of int;
CREATE TYPE

select column_value from table(phone(3,6,9));
  column_value
-----
              3
              6
              9
(3 rows)

```

- Support `pivot` function. Only single clustering functions, single columns and multiple groups are supported. see oraface.



For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table test123(name varchar(40),chinese int,math int,
course varchar(40), score int);
insert into test123 values('lisi',88,99,'math',99);
insert into test123 values('lisi',88,99,'chinese',88);
insert into test123 values('zhangsan',90,100,'chinese',90);
insert into test123 values('zhangsan',90,100,'math',100);

select * from test123 pivot (sum(score) for course
in('chinese','math'));
  name | chinese | math | 'chinese' | 'math'
-----+-----+-----+-----+-----
lisi |      88 |   99 |          88 |      99
lisi |      89 |  100 |           |      99
lisi |     100 |   70 |         100 |
zhangsan |     76 |   89 |          99 |
zhangsan |     90 |  100 |          90 |     100
zhangsan |     95 |   85 |           |     100
(6 rows)

drop table test123;
```

- Merge INTO supports CTE general table expressions. see MERGE INTO.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

CREATE TABLE target (tid integer, balance integer);
CREATE TABLE source (sid integer, delta integer);
INSERT INTO target VALUES (2, 20);
INSERT INTO target VALUES (3, 30);

INSERT INTO source VALUES (1, 11);
INSERT INTO source VALUES (5, 55);

WITH s AS (
    SELECT sid, delta
    FROM source ),
U AS (
UPDATE target AS t
    SET tid = 5
    FROM s
    WHERE t.tid = s.sid
    RETURNING t.tid )
INSERT INTO target (
    SELECT * FROM s where sid NOT IN (
        SELECT tid FROM U) );
```

```

table target;
  tid | balance
-----+-----
    2 |         20
    3 |         30
    5 |         10
    1 |         11
(4 rows)

```

- Immutable tables are supported. see CREATE TABLE.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

CREATE IMMUTABLE TABLE trade_ledger1
    (id NUMBER,
     luser VARCHAR2(40),
     value NUMBER)
NO DROP
NO DELETE;

CREATE TABLE

```

- The group by follows the string constant. see SELECT.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

select * from dual group by 1;
  dummy
-----
    X
(1 row)

```

- Supported alter to add constraints to tables. see ALTER TABLE.

For example:

```

create database test_oracle with lightdb_syntax_compatible_type
oracle;
\c test_oracle

create table add_constraints(id int);

alter table add_constraints add constraint u_add_constraints
unique(id);
ALTER TABLE

```

- Listagg on overflow truncate and error syntax are supported. see see orafce.

- Creating views supports `force editionable` and with `read only` syntax. see `CREATE VIEW`.
- Global temporary tables can be created in different `schema` modes. see `System Catalogs`.
- `varchar2` supports `toast` attributes. see `orafce`.
- The `number` type is formatted without keeping the decimal suffix `invalid 0`. see `orafce`.

For example:

```
create database test_oracle with lightdb_syntax_compatible_type
  oracle;
\c test_oracle

select nvl(cast(NULL as int), '1.100');
nvl
-----
1.1
(1 row)
```

- `dblink` is supported. see `oracle_fdw`.

## E.1.2. plorasql Enhancements

- The number of input and output parameters supported by the function exceeds 100. see `Anonymous Block`.
- The input and exit parameters of the stored procedure that can be created are `sys_refcursor`. see `Creating Cursor Variables`.
- Support for `varray` arrays. see `Varrays`.
- Anonymous blocks, functions, stored procedures, and packages support `integer` types with length information, up to 19 bits. see `Integer Types`.
- Support `execute immediate` using `in out` syntax. see `Executing Dynamic Commands`.

## E.1.3. MySQL Compatibility

- Added `CAST cast` to `SIGNED` or `UNSIGNED` destination type. See `myfce`.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
  mysql;
\c test_mysql
select cast(2.5 as unsigned);
numeric2unsigned
-----
3
(1 row)

select cast('2.5' as unsigned);
numeric2unsigned
-----
3
(1 row)
```

```
select cast(2.5 as signed);
      signed
-----
          3
(1 row)
```

```
select cast('2.5' as signed);
      signed
-----
          2
(1 row)
```

- Added cast to char target type, The default length of the char is 1, and the number of forcibly converted, the string will not be truncated if the length exceeds 1, and the upper limit is 1GB. See data type.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
select cast(2.5 as char);
      varchar
-----
          2.5
(1 row)
```

- Support for comparison of numeric types and null characters. The value of the string is 0. See myfce.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
select 0 = '';
      ?column?
-----
          t
(1 row)
```

When characters (including text, varchar, char only) are converted Numeric values (including int, bigint, numeric, small int only), Ignore invalid characters at the trail.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
select '1a' > '';
      ?column?
-----
          t
(1 row)
```

- Optimize transform\_null\_equals parameters. Compatible with null and '' relational operations. See myfce.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
SELECT '' IS null;
?column?
-----
f
(1 row)

SELECT null = '';
?column?
-----

(1 row)
```

- Time types and strings are supported. See myfce.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
select current_date > '2023-01-01';
?column?
-----
t
(1 row)
```

- Add a time type function.
- DATEDIFF function. Support the difference between date and value type, and the difference between value type and value type; When the numeric type is floating-point type, the truncate floating-point type is an integer first, and then the difference is calculated. See myfce.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
SELECT DATEDIFF(curdate(),curdate()+1.5);
datediff
-----
-1
(1 row)

SELECT DATEDIFF(curdate(),curdate()-1.5);
datediff
-----
2
(1 row)
```

- `TIMESTAMPDIFF` function. See `myfce`.
- `CURRENT_DATE` function. See `Current Date/Time`.
- `CURDATE` function. The function return format only supports 'YYYY-MM-DD', and does not support multiplication and division. See `myfce`.
- `QUARTER` function. The return date represents the quarter, and the number range is 1 ~ 4. If the date is `NULL`, `NULL` is returned; Input parameters only support `date` and `timestamp (datetime)` types. See `myfce`.
- `LAST_DAY` function. Returns the date value of the last day of the month in which the parameter is located. See `myfce`.
- `SUBSTRING_INDEX` function. Returns the substring from the specified string before the specified delimiter appears `n` times. See `myfce`.
- `UUID` function. Generate a 36-byte `UUID` string. See `myfce`.
- `AES` Encrypt and decrypt. Perform the following AES encryption and decryption and hexadecimal conversion operations. See `myfce`.
  - `HEX` function. The `HEX` function converts `bytea` data to `text`.
  - `UNHEX` function. The `UNHEX` function converts `varchar` data to `bytea`.
  - `AES_ENCRYPT` function. AES encryption functions.
  - `AES_DECRYPT` function. AES decryption function.
- The `time` type supports string assignment. In the `insert` and `update` statements, Values of `type char(n)`, `varchar`, and `text` can be used Assign a value to a property of `type timestamp with time zone, datetime`. See `myfce`.
- Dynamic preprocessing statements are supported.
  - Support `SET` to assign values to `@variables`. See `User Variable`.
  - `PREPARE FROM` preprocessing syntax. See `PREPARE`.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
create table my_table(a varchar(200));

SET @sql = 'INSERT INTO my_table values('a')';
        @sql
-----
INSERT INTO my_table values('a')
(1 row)

PREPARE stmt FROM @sql;

EXECUTE stmt;
INSERT 0 1

DEALLOCATE PREPARE stmt;
```

- `WITH ROLLUP` syntax to generate extra rows in the aggregate query for data aggregation. See `GROUP BY`.

For example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
CREATE TABLE score (
  id int,
  name varchar(100),
  course varchar(100),
  score int
);
```

```
INSERT INTO score VALUES(1,'zhangsan','yuwen',58);
INSERT INTO score VALUES(2,'lisi','shuxue',38);
```

```
SELECT name, COUNT(id), SUM(score) FROM score GROUP BY name WITH
ROLLUP;
```

name	count	sum
	2	96
lisi	1	38
zhangsan	1	58

(3 rows)

- `CASE WHEN` type compatible. The result set of a `CASE WHEN` expression can be a character, a numeric value, a date. If it contains any two or more characters, values, and dates, the return value is a string. See [Conditional Expressions](#) .
- Numeric types are compatible with Boolean types. The value of the integer type is used as a boolean. See [myfce](#).
- Autoincrement sequences support `NULL`. See [myfce](#).

## E.1.4. Lightdb-x New Features

- Added a record of modifying the `guc` parameter in `lightdb.conf`. See [Parameter Interaction via SQL](#) .
- All types, system tables, and functions are built into the OID unchanged.
- Adjust keyword level. See [SQL Key Words](#) .
- The template library distinguishes between Oracle, MySQL and Postgres patterns. See [CREATE DATABASE](#).

## E.1.5. Itjdbc Enhancements

- Support for converting `numeric` to `varchar`.
- Support for converting `int` to `double`.
- Support `varchar` conversion to `long`.
- Support for converting `timestampz` to `java.time.LocalDateTime`.
- Anonymous block parameter binding is supported, and the maximum number of bindings is 32767.
- The `clob.setCharacterstream` function is supported.
- The `getColumnType` method of `metaData` returns the `varchar2` type.
- Primary key conflict throws an anomaly of `java.sql.SQLIntegrityConstraintViolationException`
- The binding parameters are passed with `setNull`, and the types can be matched correctly.

## E.1.6. Add Reserved Keywords

- pivot.

## E.2. Release 13.8-23.3

Release date: 2023-09-30

### E.2.1. Oracle Compatibility

- The `CREATE SEQUENCE` command supports declaring `NOMAXVALUE` when creating a sequence, which is compatible with the `NOMAXVALUE` definition when creating a sequence in Oracle. See `CREATE SEQUENCE`.

Example:

```
create sequence s1 nomaxvalue;
\d+ s1
Sequence "public.s1"
Type | Start | Minimum | Maximum | Increment |
Cycles? | Cache
-----+-----+-----+-----+-----+-----
+-----+-----
bigint | 1 | 1 | 9223372036854775807 | 1 | no
| 1
```

- The `CREATE SEQUENCE` command supports declaring `MAXVALUE` when creating a sequence, which is compatible with the `MAXVALUE` definition when creating a sequence in Oracle. See `CREATE SEQUENCE`.

Example:

```
create sequence s2 maxvalue 100000;
\d+ s2
Sequence "public.s2"
Type | Start | Minimum | Maximum | Increment | Cycles? | Cache
-----+-----+-----+-----+-----+-----+-----
+-----+-----
bigint | 1 | 1 | 100000 | 1 | no | 1
```

- The `CREATE TABLE` command supports the `nocompress/compress` keywords when creating partitions. See `CREATE TABLE`.

Example:

```
CREATE TABLE lt_oracle_partition_list1
(
  a int,
  b float,
  c date,
  d timestamp,
  e varchar2(20)
) PARTITION BY LIST(e)
```



```
(
  PARTITION p1 VALUES ('0001', '0002', '0003', '0004', '0005')
  compress,
  PARTITION p2 VALUES ('0006', '0007', '0008', '0009')
  nocompress,
  PARTITION p3 VALUES ('0010', '0011')
);
\d+ lt_oracle_partition_list1
```

Partitioned table "public.lt\_oracle\_partition\_list1"

Column	Type	Collation	Nullable
Default	Storage	Stats target	Description
a	integer		
	plain		
b	double precision		
	plain		
c	oracle.date		
	plain		
d	timestamp without time zone		
	plain		
e	varchar2(20)		
	extended		

Partition key: LIST (e)

Partitions: "lt\_oracle\_partition\_list1\$p\$p1" FOR VALUES IN ('0001', '0002', '0003', '0004', '0005'),  
 "lt\_oracle\_partition\_list1\$p\$p2" FOR VALUES IN ('0006', '0007', '0008', '0009'),  
 "lt\_oracle\_partition\_list1\$p\$p3" FOR VALUES IN ('0010', '0011')

- The CREATE TABLE command supports creating partitions using a list+hash composite partition. See CREATE TABLE.

Example:

```
create table lt_lh_partition(a int, b int)
partition by list(a)
subpartition by hash(b)
(
  partition l_1 values(1),
  partition l_2 values(2)
);
```

```
\d+ lt_lh_partition
```

Partitioned table "public.lt\_lh\_partition"

Column	Type	Collation	Nullable	Default	Storage
Stats target	Description				
a	integer				plain
b	integer				plain

Partition key: LIST (a)

```

Partitions: "lt_lh_partition${p$1}_1" FOR VALUES IN (1),
PARTITIONED,
"lt_lh_partition${p$1}_2" FOR VALUES IN (2), PARTITIONED

\d+ lt_lh_partition${p$1}_1

Partitioned table "public.lt_lh_partition${p$1}_1"
Column | Type | Collation | Nullable | Default | Storage |
Stats target | Description
-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+-----+
a | integer | | | | plain |
| | | | | | |
b | integer | | | | plain |
| | | | | | |
Partition of: lt_lh_partition FOR VALUES IN (1)
Partition constraint: ((a IS NOT NULL) AND (a = 1))
Partition key: HASH (b)
Partitions: "lt_lh_partition${p$1}_1_p0" FOR VALUES WITH (modulus
1, remainder 0)

```

- The `CREATE TABLE` command supports options such as `compress/nocompress` and `logging/nologging`. Previous versions had order restrictions for these options, but this version allows them to appear in arbitrary order. See `CREATE TABLE`.
- It is not allowed to have the same table name as a package name when creating a table using `CREATE TABLE` and when creating a package using `CREATE PACKAGE`.
- The `ALTER TABLE` command supports adding multiple columns at once by placing the column definitions in parentheses. See `ALTER TABLE`.

Example:

```

CREATE TABLE foo(a int);
ALTER TABLE foo ADD COLUMN a1 int;
ALTER TABLE foo ADD COLUMN a2 int default 3;
ALTER TABLE foo ADD COLUMN b1 int, ADD COLUMN b2 int;
ALTER TABLE foo ADD (c1 int);
ALTER TABLE foo ADD (c2 int default 3);
ALTER TABLE foo ADD (e1 int), ADD e2 int, ADD COLUMN e3 int, ADD
(e4 int, e5 int);
begin
execute immediate 'alter table foo add(d int)';
end;
/

```

- The `ALTER TABLE` command supports the `TRUNCATE PARTITION partition_name` statement with the `update indexes` specified. See `ALTER TABLE`.

Example:

```

create table part_update_indexes_range(id int primary key)
PARTITION by range(id)(
partition p1 VALUES LESS THAN (202000) nocompress,
partition p2 VALUES LESS THAN (202001) compress,
partition p3 VALUES LESS THAN (202002)

```

```
);
```

```
ALTER TABLE part_update_indexes_range TRUNCATE PARTITION p1
update indexes;
```

- The `DROP TABLE` command supports cascading the deletion of all constraints in the table using the `cascade constraints` option. See `DROP TABLE`.

Example:

```
CREATE TABLE student(id int, name varchar2(100));
```

```
ALTER TABLE student ADD CONSTRAINT uk_student unique(id);
```

```
\d student
```

```
Table "public.student"
```

Column	Type	Collation	Nullable	Default
id	integer			
name	varchar2(100)			

```
Indexes:
```

```
"uk_student" UNIQUE CONSTRAINT, btree (id)
```

```
DROP TABLE student cascade constraints;
```

- A new syntax has been added for creating object types using `CREATE TYPE name { AS | IS } OBJECT`. See `CREATE TYPE`.

Example:

```
select dbms_output.serveroutput(true);
CREATE TYPE stock AS OBJECT (
    stock_no int,
    price    numeric(16,2),
    member procedure dis(prompt varchar)
);
```

```
CREATE TYPE BODY stock AS
    member procedure dis(prompt varchar) is
    begin
        dbms_output.put_line(prompt || ':' || self.stock_no ||
        '-' || self.price);
    end;
END;
/
```

```
DECLARE
    s stock := stock(600570, 180.00);
BEGIN
    s.dis('current');
END;
/
```

```
current:600570-180.00
DO
```

- A new TO\_CLOB function has been added, which allows converting data from a text string type to a CLOB type. See orafce.

Example:

```
CREATE TABLE testorafce_to_clob (  
    col_char CHAR(10),  
    col_varchar2 VARCHAR2(20),  
    col_varchar VARCHAR(20),  
    col_nchar NCHAR(10),  
    col_nvarchar2 NVARCHAR2(20),  
    col_smallint smallint,  
    col_integer integer,  
    col_bigint bigint,  
    col_decimal decimal,  
    col_numeric numeric,  
    col_real real,  
    col_double double precision,  
    col_clob CLOB,  
    col_raw raw(10)  
);  
  
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint,  
    col_integer, col_bigint, col_decimal, col_numeric, col_real,  
    col_double, col_clob, col_raw)  
VALUES ('ABC1', 'Hello', 'world', 'hello', 'world', 1, 2, 3, 4,  
    5, 6, 7, 'This is a CLOB', 'AB');
```

```
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint,  
    col_integer, col_bigint, col_decimal, col_numeric, col_real,  
    col_double, col_clob, col_raw)  
VALUES ('ABC2', 'Hello', 'world', 'hello', 'world', 1, 2, 3, 4,  
    5, 6, 7, 'This is a CLOB', '1');
```

```
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint,  
    col_integer, col_bigint, col_decimal, col_numeric, col_real,  
    col_double, col_clob, col_raw)  
VALUES ('ABC3', 'Hello', 'world', 'hello', 'world', 1, 2, 3, 4,  
    5, 6, 7, to_clob('This is a CLOB'), '1AB456789');
```

```
SELECT to_clob(col_char) AS clob_char,  
to_clob(col_varchar2) AS clob_varchar2,  
to_clob(col_varchar) AS col_varchar,  
to_clob(col_nchar) AS clob_nchar,  
to_clob(col_nvarchar2) AS clob_nvarchar2,  
to_clob(col_clob) AS clob_clob,  
to_clob(col_smallint) AS col_smallint,  
to_clob(col_integer) AS col_integer,  
to_clob(col_bigint) AS col_bigint,  
to_clob(col_decimal) AS col_decimal,  
to_clob(col_numeric) AS col_numeric,  
to_clob(col_real) AS col_real,
```

```

to_clob(col_double) AS col_double,
to_clob(col_raw) AS clob_nclob
FROM testorafce_to_clob order by col_char asc;

```

```

clob_char | clob_varchar2 | col_varchar | clob_nchar |
clob_nvarchar2 | clob_clob | col_smallint | col_integer |
col_bigint | col_decimal | col_numeric | col_real | col_double |
clob_nclob
-----+-----+-----+-----+
+-----+-----+-----+-----+
+-----+-----+-----+-----+
+-----+
ABC1      | Hello          | world        | hello        | world
          | This is a CLOB | 1            | 2            | 3
          | 4              | 5            | 6            | 7            | AB
ABC2      | Hello          | world        | hello        | world
          | This is a CLOB | 1            | 2            | 3
          | 4              | 5            | 6            | 7            | 01
ABC3      | Hello          | world        | hello        | world
          | This is a CLOB | 1            | 2            | 3
          | 4              | 5            | 6            | 7            | 01AB456789
(3 rows)

```

- A new XMLType object type has been added, which supports the XMLType.getClobVal method. See orafce.

Example:

```

CREATE TABLE xml_table (id NUMBER, xml_column XMLType );

INSERT INTO xml_table (id, xml_column) VALUES (1,
XMLType('<root><name>John</name></root>'));

DECLARE
    v_clob CLOB;
BEGIN
    SELECT XMLType.getClobVal(xml_column) INTO v_clob FROM
xml_table WHERE id = 1;
    DBMS_OUTPUT.PUT_LINE('CLOB value: ' || v_clob);
END;
/
CLOB value: <root><name>John</name></root>
DO

DECLARE
    xml_data XMLType;
    clob_data CLOB;
BEGIN
    xml_data := XMLType('<root><name>John Doe</name></root>');
    clob_data := xml_data.getClobVal();
    DBMS_OUTPUT.PUT_LINE(clob_data);
END;
/
<root><name>John Doe</name></root>
DO

```

```
SELECT XMLType.getClobVal(xml_column) from xml_table;
getclobval
-----
<root><name>John</name></root>
(1 row)
```

- A new GUC parameter `lightdb_oracle_sql_mode` has been added to support the default conversion of Oracle mode table names to uppercase. See `lightdb_oracle_sql_mode`.

Example:

```
create table std(no int, name varchar2(32));

insert into std values(1, 'zhangsan');

select * from std;
no | name
----+-----
1 | zhangsan
(1 row)

set lightdb_oracle_sql_mode to 'true';

select * from std;
NO | NAME
----+-----
1 | zhangsan
(1 row)
```

- The `ltsql` command has added support for the Oracle SQL\*Plus `RENAME old_name TO new_name` command, which allows renaming tables. See `RENAME` command.
- The `ltsql` command has added support for the Oracle SQL\*Plus `SPOOL` command. See `SPOOL` command.
- In Oracle mode, support is added for `binary_float` and `binary_double`, both of which follow the IEEE754 standard. See `orafce`.
- In Oracle mode, `'\0'` can be inserted normally into `char(n)` type strings.

Example:

```
create database oradb with lightdb_ascii_zero_store_value 20
  lightdb_syntax_compatible_type 'oracle';
\c oradb

create table t00(a char(1), b char(2));

insert into t00(a,b) values(E'\0',E'\0');

insert into t00(a,b) values(chr(0),chr(0));

select * from t00;
```

```

a   |   b
-----+-----
\x14 | \x14
\x14 | \x14
(2 rows)

```

'\0' is converted to the `lightdb_ascii_zero_store_value` value for storage.

- In Oracle mode, the result of subtracting dates is compatible with Oracle and returns a numeric type.
- The `col` view is compatible with Oracle, and the width field remains compatible with Oracle.
- `greatest/least` are compatible with Oracle. See `GREATEST` and `LEAST`.

The following compatibility features have been mainly implemented:

Returns `NULL` if there is a `NULL` parameter.

The types of the remaining parameters are forced to convert to the type of the first parameter.

If a `NULL` parameter is encountered, parsing of the remaining parameters is stopped.

- All Oracle functions in `orafce` are now default safe, and parallel processing is enabled by default.

## E.2.2. plorasql Enhancements

- PL/oraSQL functions support transaction commit and rollback. See Enhancements for Oracle.
- PL/oraSQL functions support `inout` parameters. See Declaring Function Parameters.
- PL/oraSQL functions support DML statements. See Executing DML in PL/oraSQL.
- PL/oraSQL stored procedures support the use of `CREATE DOMAIN` to create cursor type variables.

Example:

```

SELECT dbms_output.serveroutput(true);
CREATE TABLE employees(employee_id int, first_name varchar2(100),
  last_name varchar2(100));
INSERT INTO employees values(1500, 'first15', 'last15');
CREATE DOMAIN mycursor AS refcursor;
CREATE OR REPLACE PROCEDURE get_employee_name AS
  employee_cursor mycursor;
  v_employee_name VARCHAR2(50);
BEGIN
  OPEN employee_cursor FOR SELECT first_name FROM employees
  WHERE employee_id = 1500;
  LOOP
    FETCH employee_cursor INTO v_employee_name;
    EXIT WHEN employee_cursor%NOTFOUND;
    DBMS_OUTPUT.PUT_LINE('Employee Name: ' ||
  v_employee_name);
  END LOOP;
  CLOSE employee_cursor;
END;
/
call get_employee_name ();
Employee Name: first15

```

CALL

## E.2.3. MySQL Compatibility

- New `INSERT IGNORE` functionality. See `INSERT` for more information.

Example:

```
create database test_mysql with lightdb_syntax_compatible_type
mysql;
\c test_mysql
```

```
create table t(a int primary key, b int);
insert ignore into t(a,b) values(1,1),(1,1),(2,2);
select * from t;
```

```
a | b
---+---
1 | 1
2 | 2
(2 rows)
```

- A new collection of `JSON` functions has been added. See `myfce JSON` functions for more information. The list of functions is as follows:

`JSON_ARRAY`

`JSON_OBJECT`

`JSON_EXTRACT`

`JSON_CONTAINS`

`JSON_CONTAINS_PATH`

`JSON_PRETTY`

`JSON_REMOVE`

`JSON_INSERT`

`JSON_REPLACE`

`JSON_SET`

- A new parameter `lightdb_mysql_lower_case_table_names` has been added. When creating a database using the `create database` statement, you can specify this parameter to set whether case-sensitive functionality is enabled. See `CREATE DATABASE` for more information.
- The `varchar` type is compatible with `boolean` type data. See `myfce` for more information.

## E.2.4. Lightdb-x New Features

- A new upgrade check tool called `lt_upgrade_check` has been added to perform compatibility and exception checks before upgrading, in order to minimize the possibility of upgrade failures. See `lt_upgrade_check` for more information.
- Support for using `'-'` and `'//'` comments has been added to `ECPG` code. See `ECPG` for more information.
- New support for GBK, GB18030-2022 on both server and client sides has passed the national standard certification of the People's Bank of China. See `localization` for details.



- The new behavior of `lt_createdb` is to propagate to DN nodes by default in a CN distributed environment. See `lt_createdb` for more information.
- A new GUC parameter called `lightdb_cursor_after_commit` has been added to control fetch behavior. When `lightdb_cursor_after_commit` is set to `off`, fetch operations cannot be performed on a result set after a transaction commit. When set to `on`, the cursor can continue to be used after a transaction commit. See `lightdb_cursor_after_commit` for more information.
- Added support for the `distinct connect by level` syntax.
- Added support for the `connect_by_isleaf` syntax. See `SELECT` for more information.
- Enhanced support for displaying the compatibility mode of the current service database in `ltsql`.
- Enhanced support for cross-version upgrades in `lt_upgrade`.
- `ltloader` enhances performance to over 80% of Oracle's `sqlldr`. See `ltldr` for more information.
- Enhancements have been made to `lt_dump`. See `lt_dump` for more information. The enhancements include:

The `--lt-exclude-lightdb-objects` option supports filtering out built-in users `lightdb` and `lt_probackup`.

The `--lt-exclude-lightdb-objects` option supports exporting `ACCESS METHOD`.

Both `lt_dump` and `lt_dumpall` have added the `--lt-target-version` option, which allows you to specify the target version for the exported content.

The default template for exporting is now `templatel`.

The `create database` statement now supports the `lightdb_syntax_compatible_type` option logic.

- Enhanced support for querying fields larger than 64K has been added to `mysql_fdw`.

## E.2.5. Itjdbc Enhancements

- `ltjdbc` supports numeric with `Short` type.
- `ltjdbc` supports passing `Types.CLOB` and `Types.BLOB` to `setNull` function.
- `ltjdbc` supports using `string` type for integer values.
- `ltjdbc` supports the function `xmlparse`.

## E.3. Release 13.8-23.2

Release date: 2023-06-30

### E.3.1. Oracle Compatibility

- The `CHAR` data type now supports specifying byte or character lengths. When defining a column in a table using the `CHAR` data type, you can now specify the length of the column value, which can be either byte length or character length. See `Character Types`.

For example:

```
create table t (id char (1 char));
create table t (id char (1 byte));
```

- The hierarchical query has been enhanced to include new features such as `CONNECT_BY_ROOT`, which displays the root node of the current row, and `CONNECT BY LEVEL < n`, which displays all recursive results up to a specified level `n`. Additionally, hierarchical queries now support subqueries, join queries, and expression calculations. See `CONNECT BY Clause`.

For example:

```

SELECT employee, CONNECT_BY_ROOT employee_id as "Manager",
SYS_CONNECT_BY_PATH(employee, '/') "Path"
FROM example
START WITH manager_id is not null
CONNECT BY PRIOR employee_id = manager_id
ORDER BY employee_id, manager_id;
  employee | Manager | Path
-----+-----+-----
  Josh     |        | /Josh
  Ali      |        | /Ali
  Ali      |        | /Josh/Ali
  Kyle     |        | /Kyle
(4 rows)

```

- The ALTER TABLE command has been enhanced to support deleting indexes and constraints on the same column. See ALTER TABLE.

For example:

```

ALTER TABLE my_table
DROP CONSTRAINT my_constraint,
DROP INDEX my_index;

```

- Support the use of the + symbol to represent LEFT JOIN and RIGHT JOIN. See oracle plus.

For example:

```

SELECT *
FROM table1, table2
WHERE table1.id = table2.id (+);

```

- USING INDEX clause is now supported in CREATE TABLE and ALTER TABLE statements to specify an index to support a constraint. See ALTER TABLE.

For example:

```

ALTER TABLE employees
ADD CONSTRAINT emp_id_pk
PRIMARY KEY (id)
USING INDEX;

```

- FROM is now optional in DELETE statements. See DELETE.

For example:

```

DELETE table_name WHERE col = 1;

```

- SYS.COL system view is now available to display columns information for all tables, including column name, data type, length, precision, nullability, default value, and character set name. See orafce.

For example:

```
create table test_col_view(key0 varchar(100), key1 number not
null, key2 number(38,0));

select * from col where tname= 'TEST_COL_VIEW' order by colno;
  tname      | colno | cname | coltype | width | scale |
precision | nulls  | defaultval | character_set_name
-----+-----+-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----+-----+-----
TEST_COL_VIEW |      1 | KEY0  | VARCHAR | 100   |       |
| NULL      |       |       |         |       |       |
TEST_COL_VIEW |      2 | KEY1  | NUMBER  |       |       |
| NOT NULL  |       |       |         |       |       |
TEST_COL_VIEW |      3 | KEY2  | NUMBER  | 38,0  | 0     |
38 | NULL      |       |         |       |       |
(3 rows)
```

- INSERT ALL syntax is now supported for inserting multiple rows into one or more tables in a single statement. See INSERT.

For example:

```
INSERT ALL
  INTO table_name (column1, column2, column3) VALUES (value1,
value2, value3)
  INTO table_name (column1, column2, column3) VALUES (value1,
value2, value3)
SELECT 1 FROM DUAL;
```

- INSERT INTO statement now supports using aliases to specify the table to insert data into. See INSERT.

For example:

```
INSERT INTO employees e (employee_id, first_name, last_name)
VALUES (1001, 'John', 'Doe');
```

- MERGE INTO statement now supports distributed scenarios. See MERGE INTO.

For example:

```
MERGE INTO target t
USING source s
ON t.tid = s.sid
WHEN MATCHED THEN
  update set balance = t.balance + s.delta
WHEN NOT MATCHED THEN
  INSERT VALUES(s.sid, s.delta);
```

- Support implicit type conversion for NUMBER and BOOLEAN data types. See orafce.

For example:

```
select 0::NUMBER = TRUE;
?column?
-----
f
(1 row)
```

```
select 1::NUMBER = TRUE;
?column?
-----
t
(1 row)
```

- Partitioned tables are now more compatible with Oracle, as they support both Oracle-compatible partition naming and operations on subpartitions. See ALTER TABLE.

For example:

```
alter table lt_truncate_t_r truncate partition p1;
alter table lt_truncate_t_r add partition p2 values less
than(30);
alter table lt_truncate_t_r truncate partition p2;
alter table lt_truncate_t_r drop partition p2;
```

- CREATE TABLE now supports the STORAGE, compress / nocompress, and logging / nologging keywords, although these are only syntactic sugar and do not provide actual functionality. See CREATE TABLE.

For example:

```
create table comp_log1(id int) compress;
create table comp_log3(id int) logging;
create table comp_log5(id int) compress logging;
create table comp_log13(id int) storage(abcd);
```

- PROMPT command is now supported to display text messages to users. See prompt command.

For example:

```
PROMPT Creating table...

CREATE TABLE test_table (
  id NUMBER PRIMARY KEY,
  name VARCHAR2(50)
);

PROMPT Inserting data...

BEGIN;
INSERT INTO test_table (id, name) VALUES (1, 'John Doe');
INSERT INTO test_table (id, name) VALUES (2, 'Jane Smith');
COMMIT;

PROMPT Querying data...
```

```
SELECT * FROM test_table;
DROP table test_table;
PROMPT Done.
```

- ALTER INDEX now supports the REBUILD keyword to rebuild a specific index. See ALTER INDEX.

For example:

```
CREATE TABLE tt(a int);
CREATE INDEX idx_tt_a on tt(a);
ALTER INDEX idx_tt_a REBUILD;
```

- SEQUENCE statement now supports order / noorder / nocycle / nocache keywords, although these are only syntactic sugar and do not provide actual functionality. See CREATE SEQUENCE.

For example:

```
create sequence lt_seq_test1 order start 100;
create sequence lt_seq_test3 start 100 nocycle;
create sequence lt_seq_test5 start 100 ORDER nocache NOCYCLE;
alter sequence lt_seq_test1 nocache nocycle noorder;
```

- CREATE FORCE VIEW statement is now supported, although this is only syntactic sugar and does not provide actual functionality. See CREATE VIEW.

For example:

```
CREATE FORCE VIEW force_view as SELECT 1 as ltapk, 2 as ltaut;
```

- ECPG now supports anonymous execution blocks with binding parameters. See Executing a Do Statement with Input and Output Parameters.

For example:

```
EXEC SQL EXECUTE
begin
begin
update/*3631412*/ t1 set c = 'C' where id = :v_error_no;
exception
when others then
:iReturnCode = 456;
rollback;
when DUP_VAL_ON_INDEX then
null;
if SQL%NOTFOUND then
null;
end if;

end;
end;
```

---

```
END-EXEC;
```

## E.3.2. plorasql Enhancements

- Added support for `sqlcode` in `plorasql`. Users can now create functions that return `sqlcode` values like in Oracle. See support `SQLCODE`.

For example, the following code will output the SQL error code when a zero divide error occurs:

```
create or replace function zero_divide_f return int as
  a int := 10;
  b int := 0;
  code int;
begin
  a := a / b;
  exception
    when zero_divide then
      code := sqlcode;
      dbms_output.put_line('this is a normal error ' || code
|| ' ' || sqlcode || 'sqlcode_to_sqlstate(code) || ' ' ||
sqlcode_to_sqlstate(sqlcode));
      return 1;
end;
/
```

- Added support for the `with` clause in `plorasql`. Users can now use the `with` clause to define temporary result sets within a single SQL statement. See `Execute a DML Query with with_clause`.

For example:

```
declare
  v_count varchar(100);
begin
  with tmp as (select * from company where id=2) select * into
v_count from tmp;
  DBMS_OUTPUT.PUT_LINE(v_count);
end;
/
```

- Added support for parsing the `PRAGMA AUTONOMOUS_TRANSACTION` syntax in `plorasql`. Note that this is a syntax sugar feature and does not implement the actual functionality in Oracle. See `AUTONOMOUS TRANSACTION Pragma`.

For example:

```
CREATE OR REPLACE PROCEDURE test_pragma_procedure()
IS
  PRAGMA AUTONOMOUS_TRANSACTION;
BEGIN
  NULL;
END;
/
```

- Enabled case-insensitive cursor variable names in plorasql. This means that users can now use cursor variable names with different capitalizations than when they were declared without causing syntax errors. See Cursors .

For example:

```
DECLARE
  CURSOR D_tmp(zxc NUMBER,bnm NUMBER,ff smallint default 1234) IS
    SELECT ff || a as feiwu FROM tt;
  ddd D_tmp%ROWTYPE;
BEGIN
  OPEN D_tmP(5,6);
  FETCH d_tmp INTO ddd;
  DBMS_OUTPUT.PUT_LINE(ddd.feiwu);
  CLOSE D_tmP;
end;
/
```

- Added support for referencing the type of a variable defined in a package using the %TYPE syntax in plorasql. See Declarations .

For example:

```
create table t_binjiang(a int, b int);
-- define package
create or replace package pkgtype is
  v_a int := 0;
  v_b int := 0;
end;
/

-- anonymous block references variables in the package
declare
  a pkgtype.v_a%type := 1;
  b pkgtype.v_b%type := 1;
begin
  insert into t_binjiang values(a, b);
end;
/
```

- Added support for the goto statement in plorasql. Users can now use the goto statement to jump to a specific label within a block. See GOTO Statement .

For example:

```
DO $$
BEGIN
  RAISE NOTICE 'out block 1';
  goto testlabel;
  RAISE NOTICE 'out block 2';
  <<testlabel>>
  BEGIN
    RAISE NOTICE 'in block 1';
    goto testlabel2;
  END;
END;
```

```

        RAISE NOTICE 'in block 2';
    END;

    RAISE NOTICE 'out block 3';

    <<testlabel2>>
    RAISE NOTICE 'out block 4';

END$$;
NOTICE:  out block 1
NOTICE:  in block 1
NOTICE:  out block 4

```

- Enabled the ability to call package functions in distributed scenarios in plorasql. See Packages .

For example:

```

create or replace package typkg
as
    type nt is table of tabl%rowtype;
    res nt;
    function myfunc(v int) return nt;
end;
/

create or replace package body typkg
as
    function myfunc(v int) return nt
    is
    begin
        res(1) := ROW(1,1);
        res(2) := ROW(2,2);
        res(3) := ROW(3,3);
        return res;
    end;
end;
/

select * from table(typkg.myfunc(1)) t0
where t0.a in (select a from tabl) order by t0.a;

```

### E.3.3. MySQL Compatibility

- Supports `DROP INDEX [IF EXISTS] index_name ON table_name`; See `DROP INDEX` .

For example:

```

create table t1(id int);
create unique index idx_t1_id on t1(id);
drop index idx_t1_id on t1;

```

- Case-insensitive column querying and case-sensitive column display. In `mysql` mode, `guc` parameter `lightdb_sql_mode` is set to `uppercase_identifier`. See `SELECT` .



For example:

```
create table test_case_1(identifier1 varchar(10));

select * from test_case_1;
identifier1
-----
(0 rows)

select Identifier1 from test_case_1;
Identifier1
-----
(0 rows)

select identifier1 as Identifier1 from test_case_1;
Identifier1
-----
(0 rows)
```

- Supports `INSERT IGNORE INTO` syntax. `INSERT IGNORE INTO` statement is used to insert data into a table. If the inserted data violates uniqueness constraints such as primary key or unique index, the data will be ignored without throwing any errors or warnings. See `INSERT` .

For example:

```
INSERT IGNORE INTO table_name (column1, column2, column3, ...)
VALUES (value1, value2, value3, ...);
```

- Supports adding comments to database objects (such as tables, columns, etc.) using the `COMMENT` keyword. See `CREATE TABLE` .

For example:

```
create table t1 (
    id int primary comment 'this is id of t1' not null,
    name varchar(10) not null comment 'this is name of t1'
) comment = 'this is t1';
```

- Supports JSON-related functions. See `myfnc` .

`JSON_ARRAY`: creates a JSON array.

`JSON_OBJECT`: creates a JSON object.

`JSON_EXTRACT`: extracts values from JSON data.

`JSON_CONTAINS`: checks whether JSON data contains the specified value.

`JSON_CONTAINS_PATH`: checks whether the specified path exists in JSON string.

`JSON_PRETTY`: a function used to format JSON string. It takes an unformatted JSON string as input and formats it into an easy-to-read form.

- Supports `sysdate()` function for retrieving the current execution time. See `Current Date/Time` .

For example:

```
select sysdate();
       sysdate
-----
2023-05-09 13:21:13
(1 row)
```

- Fixed the issue of dual virtual table in mysql mode, which caused unauthorized access for ordinary users. See `myfce` .

For example:

```
create user mytestuser with password 'mytestuser';
\c - mytestuser

select 2 from dual;
?column?
-----
          2
(1 row)
```

## E.3.4. Lightdb-x New Features

- PWR accurately measures real-time query IO events, IPC events, race conditions and other time overhead, and optimizes the performance report statistics of PWR. See `lt_profile` .
- `lt_hint_plan` optimizes scenarios that do not support hints and ignores unimplemented hints. See `lt_hint_plan` .
- Supports incremental checkpoint to reduce the performance impact on the database system when triggering checkpoints. See `CHECKPOINT` .
- Supports debugging PL/pgsql stored procedures in pgadmin/navicat. See `pldebugger` .
- PL/pgsql supports `execute immediate` syntax. Note that this is only a syntax sugar feature and does not implement the corresponding functionality. See `Executing Dynamic Commands` .

For example:

```
CREATE OR REPLACE FUNCTION get_employee_name_func(p_employee_id
INTEGER)
RETURNS VARCHAR AS $$
DECLARE
    sql_query TEXT;
    emp_name VARCHAR;
BEGIN
    sql_query := 'SELECT first_name FROM test_employees WHERE
employee_id = $1';
    EXECUTE IMMEDIATE sql_query INTO emp_name USING
p_employee_id;

    RAISE NOTICE 'Employee name is: %', emp_name;
    RETURN emp_name;
END;
$$ LANGUAGE plpgsql;
```

- Released a client package. After extracting and configuring the environment variables, users can directly use the relevant tools, including the following tools:

`lt_distributed_probackup.py`

`lt_distributed_dump.py`

`lt_distributed_restore.py`

`ltuldr`

`lt_basebackup`

`lt_dump`

`lt_dumpall`

`lt_isready`

`lt_probackup`

`lt_restore`

`lt_verifybackup`

`ltsql`

### E.3.5. Itjdbc Enhancements

- Added support for reading BLOB values in the form of byte arrays using the `java.sql.ResultSet #getBlob (java.lang.String)` method. See LightDB JDBC .
- Added support for executing SQL statements to create stored procedures and functions using syntax such as `CREATE PROCEDURE` and `CREATE FUNCTION` in the Itjdbc library. See LightDB JDBC .
- Added support for converting date column types to `LocalDateTime` objects using the `java.sql.ResultSet#getObject(int, java.lang.Class<T>)` method. See See LightDB JDBC .

## E.4. Release 13.8-23.1

Release date: 2023-03-30

### E.4.1. New feature

- Out of memory problems occur when memory is allocated, add detail and hint hints.
- LightDB supports kubernetes(K8S) HA deployment,. The core modules include `LightDB-patroni` image and `LightDB-operator` image. `LightDB-patroni` image contains `LightDB` and `Patroni` for support HA deployment in container. `LightDB-operator` image are used to manage `LightDB` cluster in kubernetes.
- Added `guc` parameter `lightdb_server_version_num` to identify the `LightDB` version number. This value cannot be modified at the session level, in the `lightdb.conf` configuration file. see `SHOW`.

Show lightdb server version number:

```
SHOW lightdb_server_version_num;
lightdb_server_version_num
-----
220400
(1 row)
```

- Added extension `lt_sql_inspect` to define transaction hours, as well as intercept and audit execution of dangerous SQL and commands during trading hours. see `lt_sql_inspect`.

## E.4.2. Optimize

`lt_probackup` supports distributed optimization. see `lt_distributed_probackup`.

- Added distributed backup ids in the script.
- You can view the overall status of backups by distributed backup id.

## E.4.3. Compatibility

### E.4.3.1. MySQL compatible

- Supports functions `substr` and `substring`. see function.

for example:

```
lightdb@postgres=# create database test_createdb_mysql with
lightdb_syntax_compatible_type mysql;
CREATE DATABASE
lightdb@postgres=# \c test_createdb_mysql
You are now connected to database "test_createdb_mysql" as user
"lightdb".
lightdb@test_createdb_mysql=# select substr('sadayertyui',-3,3)
FROM DUAL;
substr
-----
yui
(1 row)
```

- Support MySQL division, including integer division by integer, division by 0 operation, etc see `myfce`.

for example:

```
lightdb@test_createdb_mysql=# select 4/0;
WARNING: division by zero
?column?
-----

(1 row)
lightdb@test_createdb_mysql=# select 4/1;
?column?
-----
4.0000000000000000
(1 row)
```

- Support for `str_to_date` function. see `myfce`.

- Prepare statements are not supported for variable binding.
- Due to the use of Julian days to express time, it is impossible to express the illegal date of 1999-00-00.
- The `lightdb_sql_mode` value is `no_zero_date`, and the return value is an empty string, not NULL.
- Illegal date error is reported, using LightDB error reporting logic.

for example:

```
select str_to_date('2022/09/10 11,13,13', '%Y/%m/%d %h,%i,%s');
      str_to_date
-----
      2022-09-10 11:13:13
(1 row)
```

- Support for @ variables. see User Variable.
  - If the variable is not initialized, the type of the variable is `text`.
  - If the variable type is `float`, `float8`, the storage type is `float8`.
  - If the value of the variable is an integer type (`smallint`, `bigint`, `int`), the storage type is `bigint`.
  - If the type of the variable is `numeric`, the storage type is `numeric`.
  - If the variable type is another type, the variable type is `text`.

User variables are written as `@var_name`, where the variable name `var_name` must be an Identifiers or an Key Words. If you quote it identifier#var\_name will be treated as a column name (for example, `@"my-var"`). `@var_name` and `@ var_name` are different. `@var_name` is a user variable expression, `@ var_name` is the absolute value of the column `var_name`.

```
lightdb@test=# select @c1 := 5;
      @c1
-----
      5
(1 row)

lightdb@test=# SELECT c1, @c1, @ c1 FROM t;
 c1 | @c1 | ?column?
-----+-----+-----
  0 |  5 |          0
  1 |  5 |          1
(2 rows)
```

- Support specifying indexes when querying, only syntax support. `force index` enforces the use of the specified index; `ignore index` discards the specified index. see `SELECT`.

```
-- multiple index
select * from lt_test_mysql_ddl use
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);
select * from lt_test_mysql_ddl force
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);
```

```

select * from lt_test_mysql_ddl ignore
index(pk_lt_test_mysql_ddl,uk_lt_test_mysql_ddl);

-- multiple table join
select * from lt_test_mysql_ddl a use index for order
by(primary) join b using(id);
select * from lt_test_mysql_ddl a force index for order
by(pk_lt_test_mysql_ddl) join b using(id);
select * from lt_test_mysql_ddl a ignore index for order
by(primary,pk_lt_test_mysql_ddl) join b using(id);
select * from lt_test_mysql_ddl a ignore index for order
by(pk_lt_test_mysql_ddl) join b using(id);

```

- Support specifying engine, collate, character set, comment and other attributes when creating a table, among which engine and comment are only supported syntactically. Compatible with backquotes (") and tinyint type compatible. see Integer Types.
- Support duplicate key update syntax, when the PRIMARY KEY or UNIQU constraint is violated, update the operation, and vice versa. see ON DUPLICATE KEY UPDATE.

```

INSERT INTO t1 (a,b,c) VALUES (1,2,3) ON DUPLICATE KEY UPDATE
c=t1.c+1;

```

```

UPDATE t1 SET c=c+1 WHERE a=1;

```

- Support replace into syntax, when the PRIMARY KEY or UNIQU constraint is violated, delete the old tuple first, and then insert the new tuple. see REPLACE INTO.

```

lightdb@testdb=# REPLACE INTO test VALUES (1, 'Old name', '18');
INSERT 0 1

```

```

lightdb@testdb=# REPLACE INTO test VALUES (1, 'New name');
INSERT 0 1

```

```

lightdb@testdb=# SELECT * FROM test;
 id |          name          | age
-----+-----+-----
  1 | New name              |   0
(1 row)

```

### E.4.3.2. Oracle compatible

- Added no\_unnest and pq\_distribute optimization prompts. see lt\_hint\_plan.

no\_unnest optimization prompts.

```

lightdb@postgres=# EXPLAIN (COSTS false) select * from test1
where exists(select * from test2 where test1.key1=test2.key1);
QUERY PLAN

```

```

-----
Hash Join
Hash Cond: (test1.key1 = test2.key1)
-> Seq Scan on test1
-> Hash
    -> HashAggregate

```

```

Group Key: test2.key1
-> Seq Scan on test2
(7 rows)
lightdb@postgres=# EXPLAIN (COSTS false) select * from
test1 where exists(select/*+no_unnest*/ * from test2 where
test1.key1=test2.key1);
QUERY PLAN

```

```

-----
Seq Scan on test1 @"lt#1"
  Filter: (alternatives: SubPlan 1 or hashed SubPlan 2)
  SubPlan 1
    -> Seq Scan on test2 @"lt#0"
        Filter: (test1.key1 = key1)
  SubPlan 2
    -> Seq Scan on test2 test2_1 @"lt#0"
(7 rows)

```

pq\_distribute optimization prompts.

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
lightdb@lt_test=# EXPLAIN (COSTS false) SELECT /*+ leading(t1 t2)
hashjoin(t1 t2)*/ * FROM t1 join t2 on t1.id=t2.id;
QUERY PLAN

```

```

-----
Gather
  Workers Planned: 3
  -> Parallel Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Parallel Seq Scan on t1 @"lt#0"
      -> Parallel Hash
          -> Parallel Seq Scan on t2 @"lt#0"
(7 rows)

```

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
lightdb@lt_test=# EXPLAIN (COSTS false) select/*+leading(t1 t2)
hashjoin(t1 t2) pq_distribute(t2 none broadcast)*/ * from t1
join t2 on t1.id=t2.id;
QUERY PLAN

```

```

-----
Gather
  Workers Planned: 3
  -> Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Parallel Seq Scan on t1 @"lt#0"
      -> Hash
          -> Seq Scan on t2 @"lt#0"
(7 rows)

```

- Support Oracle to create user (CREATE USER)syntax; Supports cascading drop of users (DROP USER) and grant statements (see Examples).

for example:

```

CREATE USER user_name IDENTIFIED BY passwd DEFAULT TABLESPACE
dt_space TEMPORARY TABLESPACE tt_space;
DROP USER user_name CASCADE;
GRANT CONNECT TO HS_SES;
GRANT RESOURCE TO HS_SES;
GRANT UNLIMITED TABLESPACE TO HS_SES;

```

- Support global temporary tables. see Compatibility.
- Support Oracle global temporary session tables.
- Support Oracle global temporary transaction tables.

Create a session-level global temporary table.

```

CREATE GLOBAL TEMPORARY TABLE gtt_session(id number,ename
varchar(15)) ON COMMIT PRESERVE ROWS;

```

Create a transaction-level global temporary table.

```

CREATE GLOBAL TEMPORARY TABLE gtt_transaction(id number,ename
varchar(15)) ON COMMIT DELETE ROWS;

```

- Automatically create a user with the same name as the database, and the automatically created user with the same name has create, connect, temporary, login permissions in the created database, and this function cannot be used in distributed systems. see CREATE DATABASE.

```

lightdb@postgres=# create database testdb with
lightdb_syntax_compatible_type oracle;
NOTICE: auto create user "testdb" success
CREATE DATABASE

```

- When the length of the variable type declaration can be supported, it can be supported in characters or bytes, and when the unit is currently characters, only syntax is supported. see orafce.

```

create table hs_es(id int, name varchar2(10 byte));
create table hs_lt(id int, name varchar2(10 char));

```

- Added import tool ltldr, compatible with sqldr tool. By importing data from a specified table into the database through a control file, multiple tables can be imported at the same time. For businesses that use sqldr tools to import data, there are innate advantages.
- Compatible with DBMS\_UTILITY built-in package format\_error\_backtrace function, only record the latest record of the PlorasSQL execution error, use this function to view the location of the error. see support DBMS\_UTILITY built-in package format\_error\_backtrace.

Use function of DBMS\_UTILITY.format\_error\_backtrace, for example:

```

create or replace procedure pr_error_code_test1 is
v_backtrace varchar(1000);
v_error varchar(1000);

```



```

begin

    INSERT INTO test_error_stack values (2);
    INSERT INTO test_error_stack values (1);
    commit;
    exception when others then
        insert into t_errlog(operate_error_msg) select
to_char(DBMS_UTILITY.format_error_backtrace);
        commit;
        rollback;
    end pr_error_code_test1;
/

select select to_char(DBMS_UTILITY.format_error_backtrace)

```

- PloraSQL supports stored procedures to use both return parameters with out decoration and return returns as null. The return null function is to abort the stored procedure. see Returning from a Procedure.

```

create or replace procedure p_fmt_post_update_cash
(
    p_src_system varchar2 DEFAULT '0',
    p_init_date number DEFAULT 0,
    p_company_no varchar2 DEFAULT '0',
    o_return_msg out varchar2,
    o_return_code out integer
) as
    v_init_date int := 0;
begin
    if v_init_date = 0 then
        o_return_code := 1;
        o_return_msg := '#####';
    return;
    end if;
end;
/

```

## E.5. Release 13.8-22.4

**Release date:** 2022-12-27

- Add the guc parameter `lightdb_arch_mode`, and there are two values. `classic` means that the current data system is not a distributed architecture. `dist` means that the current data system is a distributed architecture, under this architecture, the table created with `create table` defaults to a distributed table. see Compatibility.
- `lt_check` is a LightDB check sha256sum tool. Ensure that the files in the LightDB installation directory are complete. see `lt_check`.
- Added detection for unconditional and pageless queries. see LightDB DML Specification Check.

In the following scenarios, a prompt message is printed indicating that the user should use pagination/where:

- `select` does not specify `limit`, `offset` or `where`.
- `update` does not specify `where`.

- delete does not specify where.

for example:

```
lightdb@lt_test=# set lightdb_best_practice_level to 'warn';
SET
lightdb@lt_test=# set lightdb_best_practice_mode to 'no_paging';
SET
lightdb@lt_test=# create table dc_np_t1(c_a int primary key,
    c_b varchar, gmt_create timestamp null, gmt_modified timestamp
    null);
CREATE TABLE
lightdb@lt_test=# SELECT * from dc_np_t1;
WARNING: LightDB DML check warning! select sql not where/limit/
offset clause!
  c_a | c_b | gmt_create | gmt_modified
-----+-----+-----+-----
(0 rows)
```

- Check the correctness of each item in the checklist. It can be used to detect whether there are risks in operating system parameters, LightDB installation file sha256sum, LightDB version number, etc. If there are risks, give a risk report. see `check_list`.
- Support `database()` functions can be used in both oracle and postgres modes. The `database()` function is placed in the extension `ltfce`. see `ltfce`.

for example:

```
lightdb@postgres=# select database();
database
-----
public
(1 row)
lightdb@postgres=# \c test_createdb_oracle
You are now connected to database "test_createdb_oracle" as user
"lightdb".
lightdb@test_createdb_oracle=# show
lightdb_dblevel_syntax_compatible_type;
lightdb_dblevel_syntax_compatible_type
-----
Oracle
(1 row)
lightdb@test_createdb_oracle=# select database();
database
-----
public
(1 row)
```

- Archive log cleaning optimization. see `lightdb_archive_dir`.
  - Remove the settings for the cleanup logic in `archive_command` from the installer script. Set `lightdb_archive_dir` at the same time.
  - When starting LightDB, check `archive_command`, `lightdb_archive_retion_size` and `lightdb_archive_dir` when `archive_mode` is on.
  - Adjustment parameters:

- `lightdb_archive_retion_size` can only be set at startup.
- `lightdb_archive_dir` can only be set at startup.
- Ensure that fewer wal logs are deleted in the archive than are retained in the `lt_wal` directory.
- Add `walminer` extension to mine all the useful information of wal logs to provide LightDB data recovery support. The database log level configuration needs to be greater than `minimal`. see `lt_walminer`.
- Supports single-instance multi-mode. see `CREATE DATABASE`.

for example:

```
lightdb@postgres=# create database test_createdb_oracle with
  lightdb_syntax_compatible_type oracle;
CREATE DATABASE
lightdb@postgres=# \c test_createdb_oracle
You are now connected to database "test_createdb_oracle" as user
  "lightdb".
lightdb@test_createdb_oracle=# show
  lightdb_dblevel_syntax_compatible_type;
  lightdb_dblevel_syntax_compatible_type
-----
Oracle
(1 row)
```

- Add the `lightdb_aborted_rollback` parameter to support the error reporting of the current statement in the transaction and rollback the entire transaction. see `lightdb_aborted_rollback`.

Before adding this feature,for example:

```
lightdb@lt_test=# begin;
BEGIN
lightdb@lt_test=# create table aborted_rollback(name
  varchar(100));
CREATE TABLE
lightdb@lt_test=# insert into aborted_rollback1 values(1);
ERROR:  relation "aborted_rollback1" does not exist
LINE 1: insert into aborted_rollback1 values(1);
          ^

lightdb@lt_test=!# insert into aborted_rollback1 values(1);
ERROR:  current transaction is aborted, commands ignored until
  end of transaction block
lightdb@lt_test=!# commit;
ROLLBACK
```

After adding this feature,for example:

```
lightdb@lt_test=# set lightdb_aborted_rollback to on;
SET
lightdb@lt_test=# begin;
BEGIN
lightdb@lt_test=# create table aborted_rollback(name
  varchar(100));
CREATE TABLE
```

```
lightdb@lt_test=*# insert into aborted_rollback1 values(1);
ERROR: relation "aborted_rollback1" does not exist
LINE 1: insert into aborted_rollback1 values(1);
          ^
ERROR: current transaction is aborted, "insert into
aborted_rollback1 values(1);" causes transaction rollback.
```

- Solve the problem of type mismatch when the unknown type participates in the operation. see optional.

for example:

```
lightdb@lt_test=# select '1'+1;
?column?
-----
          2
(1 row)
```

Note: Operator overloading may affect the return value of the expression. For example, for an expression such as `select '1' * 1`, it previously returned an int type, but now it returns a numeric type.

- The problem of high CPU usage in optimizing the `lt_cron` process. see `lt_cron`.
- Add an option `table_exists_action`, to tell `lt_restore` what to do if the table it is trying to create already exists. `table_exists_action` has four options: `skip`, `append`, `truncate` or `replace`. see `lt_restore`.
- `lt_upgrade` supports package upgrade. see `lt_upgrade`.
- `lt_upgradecheck` supports cross-version upgrade. see `lt_upgrade_check`.
- Statement level rollback optimization, This feature is supported in both Oracle and MySQL modes. Statement level rollback is enabled, and the performance loss is about 5%. see `lt_statement_rollback_enable`.
- `ltdts_ora` is a data synchronization tool for synchronizing Oracle data to LightDB. see `ltdts_ora`.
- `ltdts_mysql` is a data synchronization tool for synchronizing MySQL|MariaDB data to LightDB. see `ltdts_mysql`.
- `lt_patch` enhancements, and many of new parameters shown below have been added. see `lt_patch`.
  - Support automatic execution of SQL scripts.
  - Added `lt_patch` table to save patch information. The `apply_type` and `apply_version` attributes are added to the patch description information.
  - Add the patch dependency directory.
  - Solve the half state problem in the patch success process.
  - More stringent verification and other details optimization.
- Use `lt_dump` and `lt_restore` tools to implement backup and recovery of distributed clusters:
  - Use `lt_dump` tools to implement backup of distributed clusters. see `lt_distributed_dump`.
  - Use `lt_restore` tools to implement recovery of distributed clusters. see `lt_distributed_restore`.

- Use `lt_probackup` tools to implement backup and recovery of distributed clusters. see `lt_distributed_probackup`.
- Oracle compatibility enhancements, and many of new features shown below have been added.
- Online change from common table to partitioned table. see `ALTER TABLE`.

for example:

```
lightdb@test_createdb_oracle=# CREATE TABLE
  lt_oracle_partition_range5
lightdb@test_createdb_oracle=# (
lightdb@test_createdb_oracle(# a int,
lightdb@test_createdb_oracle(# b float,
lightdb@test_createdb_oracle(# c date,
lightdb@test_createdb_oracle(# d timestamp
lightdb@test_createdb_oracle(# )PARTITION BY RANGE (c)
lightdb@test_createdb_oracle=# (
lightdb@test_createdb_oracle(# PARTITION p1 VALUES LESS
  THAN(to_date('2022-01-01', 'yyyy-mm-dd')),
lightdb@test_createdb_oracle(#      PARTITION p2 VALUES LESS
  THAN(to_date('2022-02-01', 'yyyy-mm-dd')),
lightdb@test_createdb_oracle(#      PARTITION p3 VALUES LESS
  THAN(to_date('2022-03-01', 'yyyy-mm-dd'))
lightdb@test_createdb_oracle(# );
CREATE TABLE
lightdb@test_createdb_oracle=#
lightdb@test_createdb_oracle=# \d+ lt_oracle_partition_range5
          Partitioned table
"public.lt_oracle_partition_range5"
Column |          Type          | Collation | Nullable |
Default | Storage | Stats target | Description
-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
a      | integer          |           |          |
      | plain           |           |          |
b      | double precision |           |          |
      | plain           |           |          |
c      | date             |           |          |
      | plain           |           |          |
d      | timestamp without time zone |           |          |
      | plain           |           |          |
Partition key: RANGE (c)
Partitions: lt_oracle_partition_range5_1_prt_p1 FOR VALUES FROM
  (MINVALUE) TO ('2022-01-01'),
            lt_oracle_partition_range5_1_prt_p2 FOR VALUES FROM
  ('2022-01-01') TO ('2022-02-01'),
            lt_oracle_partition_range5_1_prt_p3 FOR VALUES FROM
  ('2022-02-01') TO ('2022-03-01')
```

- Support oracle cardinality and `ordered_predicates` hint. see `lt_hint_plan`.

for example:

```
lightdb@postgres=# explain select /*+ cardinality(b
  1000)use_nl(a b) leading(a b)*/* from t1 a , t2 b where
  a.key1=b.key1;
```

## QUERY PLAN

```
-----
Nested Loop (cost=0.15..433.43 rows=1000 width=16)
  -> Seq Scan on t1 a @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
  -> Index Scan using t2_pkey on t2 b @"lt#0"
(cost=0.15..0.18 rows=1 width=8)
      Index Cond: (key1 = a.key1)
(4 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select /*
+ordered_predicates*/ from test1 where mod(key1,10)=2 and
key2=2;
```

## QUERY PLAN

```
-----
Seq Scan on test1 @"lt#0"
  Filter: ((mod(key1, 10) = 2) AND (key2 = 2))
(2 rows)
```

- alter table modify, default values and not null attributes can swap locations. see ALTER TABLE.

for example:

```
lightdb@lt_test=# create table aborted_rollback(name
varchar(100));
CREATE TABLE
lightdb@lt_test=# alter table aborted_rollback modify name text
not null default 1;
ALTER TABLE
```

- New export tool ltuldr (compatible with oracle sqluldr2 tool). see ltuldr.
- Support connect by hierarchical query. see CONNECT BY Clause.

for example:

```
lightdb@test_createdb_oracle=# SELECT id, manager_id from t_tab
CONNECT BY prior id = manager_id order by id;
 id | manager_id
-----+-----
  1 |           0
  2 |           1
  2 |           1
  3 |           2
  3 |           2
  3 |           2
(6 rows)
```

- orafce Enhancements, see orafce.
- varchar2 calculates the length in characters.
- Support raw type.

for example:

```
lightdb@test_createdb_oracle=# create table test_type(name
varchar2(100), id raw);
```

```
CREATE TABLE
```

```
lightdb@test_createdb_oracle=# \d test_type
```

Column	Type	Collation	Nullable	Default
name	varchar2(100)			
id	raw			

## E.6. Release 13.8-22.3

LightDB 13.8-22.3 contains a variety of fixes and new feature from LightDB 13.3-22.2.

**Release date:** 2022-09-30

- Support q escape. for example:

```
select q'!name LIKE '%DBMS_%%'!';
       ?column?
```

```
-----
name LIKE '%DBMS_%%'
(1 row)
```

see Q-Quoted String Constants.

- Rownum performance optimization. Like oracle, support count stop key to improve rownum performance.

```
lightdb@lt_test=# explain select * from public.test where rownum
< 3;
```

```
QUERY PLAN
```

```
-----
Count StopKey (cost=0.00..0.03 rows=2 width=4)
-> Seq Scan on test (cost=0.00..159.75 rows=11475 width=4)
(2 rows)
```

- libpq supports getting LightDB version number.
- listagg supports for analytic functions. There is a description of listagg in the orafce chapter.
- NVL function parameters support more parameter combinations such as strings and numbers.
- Modify the default database to lt\_test, Replace the original default database postgres.
- lt\_upgrade supports upgrading LightDB from version 22.2 to version 22.3 (lt\_upgrade will check the consistency of lightdb\_syntax\_compatible\_type while upgrading, notice that if the value are both 'oracle', lt\_upgrade is not recommended). see lt\_upgrade.
- Add new GUC parameters nls\_date\_format and nls\_timestamp\_format for Oracle time function compatibility, see nls\_date\_format and nls\_timestamp\_format for more details.
- search\_path contains lt\_catalog by default. see Search Path.

schema oracle and mysql are processed specially, can only be set when they are consistent with the lightdb\_syntax\_compatible\_type.

- Support for non-reserved keywords as column aliases (When there is no keyword `as` and no quotation marks). see Key Words.

```
select 3 type;
      type
-----
      3
(1 row)
```

- when `lightdb_enable_default_tablespace` is enabled, add the default tablespace `lt_users`. The `lt_users` is the default tablespace of other databases created by ourselves. (unless overridden by a `TABLESPACE` clause in `CREATE DATABASE`). Its storage path is in the same level directory of the instance path. This can ensure that the amount of data under the instance path is not too large. see Tablespaces.
- `lightdb_service.py` supports any single node start stop.
- Fixed `lt_probackup` recovery failure for the amount of data exceeds 2G.
- Support for modifying column by `modify column clause` like oracle. see `ALTER TABLE` for details.
- Support the drop primary key clause when alter table. see `ALTER TABLE` for details.
- Add function and table for modifying tables that have view dependencies. see oracle for details.
- Remove read-only table related features.
- `lt_dump` enhancements, and many of new parameters shown below have been added. see `lt_dump`.
  - Add parameter `--lt-exclude-lightdb-objects` and parameter `--lt-dump-lightdb-tables`, To solve the problem of database object conflicts created by the LightDB built-in plug-in during export and import and to solve the problem of overwriting the table created by the LightDB built-in plug-in during import.
  - Add parameter `--lt-disable-auto-analyze`, To solve the problem of `lt_restore` multithreaded import deadlock.
- PL/oraSQL enhancements, and many of new features shown below have been added.
  - Package supports backup using `lt_dump`. see `lt_dump`.
  - Package supports associative arrays. see Section 42.8.
  - Support `table function`. see Table function.
  - Support `nested table`. see Nested Tables.
  - Support `error handling`. see Error Handling.
  - Support stored procedure(including stored procedure in `package`) and anonymous block after opening the cursor. in the transaction block, you can continue the fetch operation after `commit` or `rollback`. see `cursor-with-transactions`.
  - Fix open cursor parameter is inconsistent with the defined cursor parameter. see `cursor-default-values`.
- oracle Enhancements:



- Add new oracle's Built-in package: `dbms_metadata`, `dbms_job`, `dbms_lock`, `dbms_obfuscation_toolkit`, `utl_url`, `utl_encode`, `utl_raw` and `dbms_snapshot`.
- Improve the original built-in package: `dbms_application_info`, `dbms_utility` and `dbms_lob`.
- Add new oracle's system view like `[DBA/ALL/USER]_TABLES`, `[DBA/ALL/USER]_TAB_COLUMNS` and `[DBA/ALL/USER]_INDEXES`.
- Add new oracle's function: `BIN_TO_NUM`, `BITOR/BITXOR`, `REMAINDER`, `ROUND_TIES_TO_EVEN`, `INSTRB`, `REGEXP_INSTR/REGEXP_REPLACE`, `REPLACE`, `SOUNDEX`, `MONTHS_BETWEEN`, `TZ_OFFSET`, `CONVERT`, `NUMTOYMINTERVAL`, `TO_BLOB`, `NLS_CHARSET_ID /NLS_CHARSET_NAME`, `SYS_CONTEXT/USERENV`, `EMPTY_CLOB`, `ORA_HASH` and `VSIZE`.
- Add new oracle's agg function: `ANY_VALUE`, `BIT_AND_AGG/BIT_OR_AGG/ BIT_XOR_AGG`, `KURTOSIS_POP/KURTOSIS_SAMP` and `SKEWNESS_POP/ SKEWNESS_SAMP`.

see oracle for details.

- Oracle compatibility enhancements, and many of new features shown below have been added.
  - Support Oracle partition syntax. see `CREATE TABLE` and `ALTER TABLE`.
  - Support statement rollback. see `lt_statement_rollback_enable`.
  - Support `raise_application_error()` function. see Section 42.8.
  - `listagg` supports analysis functions. the oracle chapter.
  - Enhance compatibility between empty string and `NULL`. see Section 17.11.
- MySQL compatibility enhancements, and many of new features shown below have been added.
  - Support `year()` function.
  - Support `day()` function.
  - Support `date_format()` function.
  - Support `str_to_date()` function.
  - Support `from_unixtime()` function.
  - Support `unix_timestamp()` function.
  - Support `ifnull()` function.
  - Add interval constant compatibility.
  - Support `date_add()` function.
  - Support `date_sub()` function.
  - Support `dayofweek()` function.
  - Support `weekofyear()` function.

- Support `compress()` function.
- Support `uncompress()` function.
- Support `timestamp` and `string` comparison.
- Fix `smallint` error when using `'is true'` or `'= true'`.
- Fix `select` and `group by` field inconsistent report error.
- Fix `distinct` and `order by` field inconsistent report error.

see the `myfcs` chapter for details.

- JDBC driver library, We fixed some of the issues and enhanced data type compatibility:
  - Support `numeric` data type convert to Java Integer.
  - Add connection param `extendSchema`, The default value is `'lt_catalog,oracle'` when `currentSchema` is set, `extendSchema` will automatic append to `currentSchema`'s value.
  - Remove expiration time limit.
  - Support MySQL `SQL_CALC_FOUND_ROWS` and `SELECT FOUND_ROWS()` feature#only when they are executed sequentially.

## E.7. Release 13.3-22.2

**Release date:** 2022-06-30

- Support patch for quick upgrade, see `lt_patch`.
- Add `PL/oraSQL` loadable procedural language, see `plorasql`
- `lt_hint_plan` Enhancements
  - Add three new hints: `use_hash`, `use_nl`, `full`, semantics are consistent with Oracle.
  - The table name in hint is case-insensitive.
  - Hint `parallel` default is `hard` and supports no table specification.
  - Hints can be applied to the tables of the subquery when the subquery has only one table.

```
EXPLAIN (COSTS false) select /*+use_hash(t1 y)*/ from t1,
(select * from t2) y where t1.id=y.id;
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (t1.id = t2.id)
-> Seq Scan on t1 @"lt#0"
-> Hash
    -> Seq Scan on t2 @"lt#1"
(5 rows)
```

- Support User-defined type priority for better function and operator match, see type compatible.
- Support `CREATE TABLE DISTRIBUTED BY` to create distribute table(depends on extension canopy), see `CREATE TABLE`.

```
create table dist1(a int, b int) distributed by hash(a)
  shard_count(4);
```

- Auto-explain execution plan logs are printed in a separate log file (\*.slow) using JSON format.
- Add extension wal2sql to support Real-time synchronization to Oracle.
- `lt_dump` support `--recreate-schema` to generate drop schema(use CASCADE mode) command for better performance, see `lt_dump`.
- Client Applications and libpq Support LightDB environment variables.
- `sysdate` and `systimestamp` indicates the statement start time.

```
lightdb@postgres=# begin;
BEGIN
lightdb@postgres=# select sysdate from dual;
  sysdate
-----
2022-06-28 19:44:15
(1 row)

lightdb@postgres=# select sysdate from dual;
  sysdate
-----
2022-06-28 19:44:16
(1 row)

lightdb@postgres=# end;
COMMIT
```

For details, see `datetime`.

- When install with high availability, enable replication slot default.
- Support Order-Preserving Encryption ,see `lt_ope`
- The following platform support is added:

Architecture	OS
LoongArch <sup>1</sup>	Kylin V10(SP1) <sup>2</sup>
x86_64	rockylinux <sup>3</sup>
aarch64	rockylinux <sup>4</sup>

- Add cluster control tool `lightdb_service.py` to facilitate the overall start and stop of services in high availability and distributed environments.

start cluster:

```
lightdb_service.py -c start
```

<sup>1</sup> <https://www.loongson.cn/>

<sup>2</sup> <https://www.kylinos.cn/>

<sup>3</sup> <https://rockylinux.org/>

<sup>4</sup> <https://rockylinux.org/>

stop cluster:

```
lightdb_service.py -c stop
```

- The value 0 in PWR is display as empty, for details, see lt\_profile.
- In non-distributed installation, the canopy extension not installed.
- When keepalived and ltcluster are restarted, new log files are generated to avoid confusion with old logs.
- lt\_initdb does not restrict the order of options.
- Fix cannot assign XIDs during a parallel operation error occurs occasionally during parallel query in lt\_show\_plans.
- Release the JDBC driver library based on LightDB.
  - maven repository

```
<dependency>
  <groupId>io.github.hslightdb</groupId>
  <artifactId>lightdb-jdbc</artifactId>
  <version>42.2.30</version>
</dependency>
```

We fixed some of the issues and enhanced data type compatibility:

- fix#fetchSize does not take effect in automatic commit mode, causing the whole data to be loaded into the memory and causing out-of-memory problem.
- support oracle anonymous blocks syntax (see plorasql).
- support to\_number() function compatible with oracle.
- support numeric data type convert to Java Long.
- support char(1) data type convert to Java Character.
- fix loss of precision when Java setDouble operates on numeric field.
- lt\_cron supports linux command.

```
SELECT cron.schedule('daily-touch', '59 23 * * *', 'rm -rf
  $LTDATA/log/*', 'next', '8', 'linux');
```

- Built-in tool application lvs for load balancing in distributed environment wiith multi-CN.
- Built-in tool application postgresrest.
- Changed file naming rules in the installation directory and instance directory.
- The extension objects in public schema are all moved to the lt\_catalog schema.
- RPM dependencies are built into the installation package.
- Support merge into in distributed environment.

## E.8. Release 13.3-22.1

Release date: 2022-04-06

This release contains a variety of changes from LightDB 13.3-21.3.

- Oracle compatibility enhancements, and many of new features shown below have been added.
- If only one subquery is used in the `SELECT FROM` clause, you do not need to use the `as` clause to explicitly specify an alias for the subquery. See `SELECT` for more details.
- You can use `ROWNUM` as the filter condition in the `WHERE` clause of `UPDATE` and `DELETE` statements to specify the updated or deleted rows, for example:

```
UPDATE mytable SET column = value WHERE ROWNUM =  
rownum;  
DELETE FROM mytable WHERE ROWNUM = rownum;
```

You can also use `ROWNUM` to assign unique values to each row of a table, as in this example:

```
UPDATE mytable SET column = ROWNUM;
```

To use this feature, you need to set `lightdb_syntax_compatible_type` to `oracle`, for example:

```
SET lightdb_syntax_compatible_type = 'oracle';
```

See Section 7.9 for more details.

- Support `MERGE` syntax, `MERGE` performs actions that modify rows in the *target\_table\_name*, using the *data\_source*. `MERGE` provides a single SQL statement that can conditionally `INSERT` or `UPDATE` rows, a task that would otherwise require multiple procedural language statements. See `MERGE` for more details.
- support `SYSTIMESTAMP` function, `SYSTIMESTAMP` returns the system date, including fractional seconds and time zone, of the system on which the database resides. The return type is `TIMESTAMP WITH TIME ZONE`. For example:

```
SELECT SYSTIMESTAMP FROM DUAL;  
SELECT TO_CHAR(SYSTIMESTAMP, 'SSSS.FF') FROM DUAL;
```

See Section 9.9.4 for more details.

- If you have set `lightdb_syntax_compatible_type` to `oracle`, then the result of expression `"value || NULL"` will be the value, otherwise the result will be `NULL`.
- If you have set `lightdb_syntax_compatible_type` to `oracle`, then the result of expression `""::text is NULL"` will be true, otherwise the result will be false.
- The `LISTAGG` function in `orafce` extension now support `DISTINCT` and `WITHIN GROUP` syntax, you can use it as in this example:

```
SELECT LISTAGG(DISTINCT column, ',') WITHIN GROUP  
(ORDER BY column) FROM mytable;
```

- Add new keyword MINUS for SELECT statements and as the alias of EXCEPT, they are completely equivalent. See SELECT for more details.
- GUC parameters `lightdb_enable_rowid` and `lightdb_enable_rownum` are removed, and set `lightdb_syntax_compatible_type` to `oracle` to instead.
- `pg_hint_plan` enhancements and several new hints such as `USE_HASH_AGGREGATION`, `Semijoin`, `Antijoin` and `Swap_join_inputs` have been added. Besides, it also realizes the support of canopy for distributed database. See `lthint_plan` for more details.
- Support Transparent Data Encryption(TDE). TDE can (and can only) be enabled by specifying the `-K` option when generating a data directory using `initdb` or `lt_initdb`, and this option passes in a 32-bytes hexadecimal key string, which is used for encryption and decryption. See encryption key command for more details.
- Adding new extension `lt_sm` to support `sm2`, `sm3` and `sm4` encryption. `lt_sm` is a extension for LightDB that provides a series of functions for `sm2`, `sm3` and `sm4` encryption algorithms. Data can be encrypted and decrypted using the above functions. See `lt_sm` for more details.
- Adding New GUC parameters `lightdb_tsearch_non_stopwords` and `lightdb_tsearch_word_superpose` for full text search.

LightDB full text search has many built-in stop words. Words connected by stop words will be split into multiple independent words by `to_tsvector` function, for example, "2022-04-10" will be split into "2022", "04" and "10".

`lightdb_tsearch_non_stopwords` is used to customize non-stop words, which is just the opposite of stop words, that is, non-stop words are considered to be an integral part of a word and thus will not be split into multiple independent words by `to_tsvector` function any more. Still the above example, if you set '-' as non-stop words, you will only get a result of "2022-04-10".

`lightdb_tsearch_word_superpose` is used to overlay the effect of using stop words and non-stop words. For example, if you set `lightdb_tsearch_word_superpose` to `on` and set `lightdb_tsearch_non_stopwords` to '-', you will get the results including "2022", "04", "10" and "2022-04-10" at the same time when using `to_tsvector("2022-04-10")`.

See Section 12.1.3 for more details.

- Adding new GUC parameters `lt_ring_buffers` to set the maximum amount of memory used for ring buffers within each database session. When running a sequential scan query that needs to access a large number of pages(more than a quarter of the total pages of `shared_buffers`) just once, a special access strategy called bulk-read is used. A page that has been touched only by such a scan is unlikely to be needed again soon, so instead of blowing out the entire buffer cache, a small ring of buffers that specified by `lt_ring_buffers` is allocated and those buffers are reused for the whole scan. This also implies that much of the write traffic caused by such a statement will be done by the backend itself and not pushed off onto other processes.
- `pg_profile` enhancements, adding new `wait_event_type` named `DBCpu` in wait event statistics, which indicate how much cpu time the user activity spends on database. See `pgprofile` for more details.
- `pg_cron` enhancements, support three task scheduling modes: `asap`, `next interval` and `fixed interval`.
  - `asap`: Each task creates only one session and corresponds to a task queue, and multiple tasks can be stored in the queue. If the subsequent scheduling cycle comes during the execution of the current task, they will be put into the queue. At the same time, the current execution will complete all tasks in the queue one by one.
  - `next interval`: Each task creates only one session and corresponds to a task queue, and only one task is stored in the queue. If the subsequent scheduling cycle comes during the execution of

the current task, they will not be put into the queue, but the next scheduling cycle after current task execution.

- fixed interval: This mode is similar to next interval, but the difference is that if the subsequent scheduling cycle comes during the execution of the current task, a separate session will be created for the subsequent scheduling to execute, that is, multiple scheduling tasks will be executed in parallel, but the maximum number of parallel executions is `cron.max_connections_per_task`.

In addition, the task timeout function is also added. If the task execution time exceeds the specified maximum time, the task will be forcibly interrupted and `cron.job_run_details` will record relevant error messages. The default timeout is 15s, which is determined by `cron.task_running_timeout`. This parameter can only take effect when the database is started.

See `lt_cron` for more details.

- Adding new GUC parameters `pg_prewarm.lt_autoprewarm_dbs`, `pg_prewarm.lt_autoprewarm_tables` and `pg_prewarm.lt_autoprewarm_indexes` for `pg_prewarm` extension, which are used to selectively prewarm the specified database, table and index automatically when LightDB is started. See `lt_prewarm` for more details.
- Canopy extension is enabled by default now.
- New extension `pg_show_plans` is integrated and disabled by default. See `lt_show_plans` for more details.
- Automatically ANALYZE when execute CREATE INDEX to collect statistics.
- UPDATE and DELETE statement allow use LIMIT clause to limit the rows will be updated and deleted, for example:

```
UPDATE mytable SET column = value LIMIT n;
DELETE FROM mytable WHERE column > value LIMIT m, n;
```

See UPDATE and DELETE for more details.

- If you use function(include built-in function and user defined function) to specify the default value of a column in CREATE TABLE statement, the function parameters can be other column names, variable names, and expressions containing other column names and variable names, for example:

```
CREATE FUNCTION myfunc(v integer)
RETURNS integer AS $$
BEGIN
    RETURN v + 10;
END;
$$ LANGUAGE plpgsql;

CREATE TABLE mytable (
    id    int    default 10,
    key   int    default myfunc(id),
    v1    int    default key,
    v2    int    default key + myfunc(key)
);
```

See CREATE TABLE for more details.

- When using "CREATE TABLE AS SELECT colname AS alias" to create a table, ltapk is not allowed as the alias. See CREATE TABLE for more details.
- `lt_standby_forward` (EXPERIMENTAL) is a module which forwards SQL statements from a hot standby to primary, providing a facility to reduce loading of primary and allow clients query from standby. For example, client can send INSERT, CREATE to a hot standby. See `lt_standby_forward` for more details.
- The sqlprompt format of ltsql is adjusted to `username@database`.

## E.9. Release 13.3-21.3

**Release date:** 2021-12-31

This release contains a variety of changes from LightDB 13.3-21.2.

- WAL (Write-Ahead Log) can be placed on Intel Optane PMEM, achieving significant improvements in recovery time and performance. To enable this feature, set GUC option `wal_sync_method` to `pmem_drain`. See `wal_sync_method` for details.
- MySQL compatibility enhancements
  - functions support: `find_in_set()`, `group_concat()`, `if()`, `truncate()`, `datediff()`, `locate()` and `database()`. See `myfce` for details.
  - longtext data type support
  - LIMIT(m, n) syntax support. See Section 7.6 for details.
- Oracle compatibility enhancements, including data type implicit conversion between number (such as `int2`, `int4`, `int8`, `float4`, `float8` and `numeric`) and string (such as `char`, `varchar`, `text` and `unknow`). See Chapter 10 for details.
- Autovacuum when setting a table read only. No more manual execution.
- Wildcards '%' can be used when viewing GUC parameters with SHOW statement. For example, you can use it like "SHOW max%", "SHOW %timeout" and "SHOW %vacuum%". See SHOW for details.
- Alias can be used when updating a single table with UPDATE statement. For example, you can use it like "UPDATE mytable AS t SET t.colname = value WHERE t.id = 1".
- Support automatic cleaning of archived WAL and log files according to specified rules. See Section 17.5.3 for details.
  - Archived WAL: clean up archived wal files in archive dir (`lightdb_archive_dir`) older than (`checkpoint file - lightdb_archive_retention_size`) when archive wal success. For example: `lightdb_archive_retention_size = 2`. checkpoint file is `000000010000000000000008`, will remove the file older than `000000010000000000000006`.
  - log files: by setting `lightdb_log_retention_age` to N Mins (usually set to `xxx` to remove file `xxx` days ago) to remove files older than N Mins. Execute when switching to a new file. The time depends on file modification time.
- COPY and `pg_bulkload` support multi character separators (at most three) for text. See COPY for details.

```
COPY country TO STDOUT (DELIMITER 'ABC');
```



- Modify default search\_path to contains oracle schema. This means functions and data types in orafce extension can be used anywhere directly.
- integrate Citus extension, but not enabled by default.
- integrate pg\_pathman extension and enabled by default.
- Enhance pg\_profile, adding database time statistics in LightDB profile report(PWR). See pgprofile for details.
- Enhance pg\_hint\_plan, including multi hint support, hint scope qualification, qb\_name syntax support and no\_merge hint syntax support. Now you can use hint only for sub query. See lthint\_plan for details.
- Enhance pg\_cron, including second level timed task support and one time scheduled task support. In addition, the default time zone of the task is adjusted to UTC/GMT+08:00. See lt\_cron for details.
- Enhance system\_stats, adding a new function lt\_get\_sys\_kernel\_settings() to get linux kernel parameters.
- lt\_initdb command line parameters support specifying non default port number(-p). For example: lt\_initdb -p xxx -D xxx. See lt\_initdb for details.
- Support ROWNUM. ROWNUM is a pseudocolumn like oracle ROWNUM. Each row returns by a query, the ROWNUM pseudocolumn returns a number indicating the order in which LightDB selects the row from a table or a set of joined rows.

Now ROWNUM supports using with order by, group by, subquery, join, union and partition table. However, it is not supported in update or deletion, and it is not supported in column expression(like selecting rownum + 1 from xxx ). See Section 7.9 for details.

- The following extensions is removed from LightDB.
  - pg\_wait\_sampling
  - timescaledb

## E.10. Release 13.3-21.2

**Release date:** 2021-10-24

This release contains a variety of changes from LightDB 13.3-21.1.

- This version contains a database monitor and management platform, the LightDB Enterprise Manager (LightDB-EM) embedded version, provides monitoring and management solution for LightDB.
- New Installation Wizard, with GUI and CLI mode. Allows you to simply and easily install standalone or high-available deployment LightDB, including the LightDB-EM.
- Enhance PWR and ASH, especially wait-event. Helping you to find out most resource-consuming activities and top SQL in your LightDB databases.
- Enhance Oracle compatilby, as following: Function. rowid, sysdate, nvl function supports numeric, real, integer, text, varchar, bpchar, bit conversion. guid function. DataTypee. clob, blob, varchar2, number, rowid.
- Enhance MySQL compatilby, as following: Function. uuid function. DataTypee. datetime. Syntax and features. Supporting AUTO\_INCREMENT, ON UPDATE CURRENT\_TIMESTAMP.

- Add a new GUC parameter `lightdb_keep_temp_file`, for debug purpose. Allowing temporary files, such as sort and hash temporary files, be retained.
- Add Ordered optimizer hint, which is equivalent to Leading optimizer hint.
- To Improve database design and best practice, LightDB introduce design checking through DDL. Five kinds of checkings are supporting now: `keyword_not_allowed`, `bad_datatype`, `must_have_pk`, `must_have_gmt`, `no_more_100cols`. these rules can enable all or enable as needed, like MySQL's `sql-mode`. GUC parameters `lightdb_best_practice_mode` and `lightdb_best_practice_level` used for controlling the rule. Existing object all not affected.
- To improve legacy system pull-mode incremental-sync speed, LightDB support hidden auto-increment primary key column and hidden update timestamp column. Add `WITH PRIMARY KEY` to create an implicit column `ltapk`, which will be incremented automatically when a new row is inserted. Add `WITH UPDATE CURRENT_TIMESTAMP` to create an implicit column `ltau`, which will be updated automatically when row a is inserted or modified.
- The following built-in extensions are auto enabled by default in every database, user don't need to perform `CREATE EXTENSION` manually.
  - `pg_log_long_xact`, `pl/pgsql` function to log long running transactions
  - `pg_bulkload`, `pg_bulkload` is a high speed data loading utility for LightDB, an replacement for `COPY` command
  - `system_stats`, system statistic functions for LightDB
  - `timescaledb`, enables scalable inserts and complex queries for time-series data
  - `zhparser`, a parser for full-text search of Chinese. The default configuration name is `zhcfg`
  - `rum`, RUM index access method, a faster full text search implementation.
  - `tsvector2`, a extended format of `tsvector`, a better space usage datatype for full text search.
- The following extensions are also built-in but not enabled by default, perform `CREATE EXTENSION` before using them.
  - `mysql_fdw`, a Foreign Data Wrapper (FDW) for MySQL
  - `oracle_fdw`, a Foreign Data Wrapper for Oracle

## E.11. Release 13.3-21.1

**Release date:** 2021-08-17

This is the first GA release of LightDB.

- The default values of some GUC parameters have been modified for better performance for modern hardware.
- The native partition can be declared in clause statement of `CREATE TABLE`, which supports list, range and hash syntax.
- Add `lightdb_explain_no_runtime_pruned_partition` parameter to control whether partitions pruned at runtime are shown in `EXPLAIN ANALYZE` output.
- Built-in `pg_hint_plan`, which can control the execution plan with hinting phrases in comment of special form.

- Built-in `pg_wait_sampling`, which provides sampling based statistics of wait events.
- Built-in `pg_profile`, which can help you to find out most resource-consuming activities in your LightDB databases.
- Built-in `pg_cron`, a simple cron-based job scheduler that runs inside the database. It uses the same syntax as regular cron, but it allows you to schedule LightDB commands directly from the database.
- Built-in `pg_cheat_funcs`, which provides a set of cheat(but useful) functions on LightDB.
- Built-in `pgfincore`, which provides a set of functions to handle low-level management of relations using mincore to explore cache memory.
- Built-in `orafce`, an Oracle's compatibility functions and packages.
- Built-in `pgaudit`, which provides detailed session and/or object audit logging via the standard LightDB logging facility.
- Built-in `pg_probackup`, which manages backup and recovery of LightDB database clusters.
- The following built-in extensions are auto enabled by default in every database(Except `dblink`, `pg_profile` and `pg_cron`, which is only available in postgres database), you don't need to perform `CREATE EXTENSION` manually.
  - `pg_stat_statements`
  - `auto_explain`
  - `tablefunc`
  - `dblink`
  - `uuid-oss`
  - `pg_hint_plan`
  - `pg_wait_sampling`
  - `pg_profile`
  - `pg_cron`
  - `pgfincore`
  - `orafce`
  - `pgaudit`

Specially, a `pg_cron` job named "take\_sample\_every\_10min" will be created automatically by default in postgres database. This job will call `take_sample()` every 10 minutes (`take_sample()` is provided by `pg_profile` extension).

---

# Appendix F. Additional Supplied Modules

This appendix and the next one contain information regarding the modules that can be found in the `contrib` directory of the LightDB distribution. These include porting tools, analysis utilities, and plug-in features that are not part of the core LightDB system, mainly because they address a limited audience or are too experimental to be part of the main source tree. This does not preclude their usefulness.

This appendix covers extensions and other server plug-in modules found in `contrib`. Appendix G covers utility programs.

If you are using a pre-packaged version of LightDB, these modules are typically made available as a separate subpackage, such as `lightdb-contrib`.

Many modules supply new user-defined functions, operators, or types. To make use of one of these modules, after you have installed the code you need to register the new SQL objects in the database system. This is done by executing a `CREATE EXTENSION` command. In a fresh database, you can simply do

```
CREATE EXTENSION module_name;
```

This command registers the new SQL objects in the current database only, so you need to run it in each database that you want the module's facilities to be available in. Alternatively, run it in database `template1` so that the extension will be copied into subsequently-created databases by default.

For all these modules, `CREATE EXTENSION` must be run by a database superuser, unless the module is considered “trusted”, in which case it can be run by any user who has `CREATE` privilege on the current database. Modules that are trusted are identified as such in the sections that follow. Generally, trusted modules are ones that cannot provide access to outside-the-database functionality.

Many modules allow you to install their objects in a schema of your choice. To do that, add `SCHEMA schema_name` to the `CREATE EXTENSION` command. By default, the objects will be placed in your current creation target schema, which in turn defaults to `public`.

Note, however, that some of these modules are not “extensions” in this sense, but are loaded into the server in some other way, for instance by way of `shared_preload_libraries`. See the documentation of each module for details.

## F.1. adminpack

`adminpack` provides a number of support functions which pgAdmin and other administration and management tools can use to provide additional functionality, such as remote management of server log files. Use of all these functions is only allowed to the superuser by default but may be allowed to other users by using the `GRANT` command.

The functions shown in Table F.1 provide write access to files on the machine hosting the server. (See also the functions in Table 9.96, which provide read-only access.) Only files within the database cluster directory can be accessed, unless the user is a superuser or given one of the `pg_read_server_files`, or `pg_write_server_files` roles, as appropriate for the function, but either a relative or absolute path is allowable.

**Table F.1. adminpack Functions**

Function	Description
<code>pg_catalog.pg_file_write ( filename text, data text, append boolean ) → bigint</code>	Writes, or appends to, a text file.
<code>pg_catalog.pg_file_sync ( filename text ) → void</code>	Flushes a file or directory to disk.
<code>pg_catalog.pg_file_rename ( oldname text, newname text [, archivename text ] ) → boolean</code>	Renames a file.
<code>pg_catalog.pg_file_unlink ( filename text ) → boolean</code>	Removes a file.
<code>pg_catalog.pg_logdir_ls () → setof record</code>	Lists the log files in the <code>log_directory</code> directory.

`pg_file_write` writes the specified *data* into the file named by *filename*. If *append* is false, the file must not already exist. If *append* is true, the file can already exist, and will be appended to if so. Returns the number of bytes written.

`pg_file_sync` fsyncs the specified file or directory named by *filename*. An error is thrown on failure (e.g., the specified file is not present). Note that `data_sync_retry` has no effect on this function, and therefore a PANIC-level error will not be raised even on failure to flush database files.

`pg_file_rename` renames a file. If *archivename* is omitted or NULL, it simply renames *oldname* to *newname* (which must not already exist). If *archivename* is provided, it first renames *newname* to *archivename* (which must not already exist), and then renames *oldname* to *newname*. In event of failure of the second rename step, it will try to rename *archivename* back to *newname* before reporting the error. Returns true on success, false if the source file(s) are not present or not writable; other cases throw errors.

`pg_file_unlink` removes the specified file. Returns true on success, false if the specified file is not present or the `unlink()` call fails; other cases throw errors.

`pg_logdir_ls` returns the start timestamps and path names of all the log files in the `log_directory` directory. The `log_filename` parameter must have its default setting (`lightdb-%Y-%m-%d_%H%M%S.log`) to use this function.

## F.2. amcheck

The `amcheck` module provides functions that allow you to verify the logical consistency of the structure of relations. If the structure appears to be valid, no error is raised.

The functions verify various *invariants* in the structure of the representation of particular relations. The correctness of the access method functions behind index scans and other important operations relies on these invariants always holding. For example, certain functions verify, among other things, that all B-Tree pages have items in “logical” order (e.g., for B-Tree indexes on `text`, index tuples should be in collated lexical order). If that particular invariant somehow fails to hold, we can expect

binary searches on the affected page to incorrectly guide index scans, resulting in wrong answers to SQL queries.

Verification is performed using the same procedures as those used by index scans themselves, which may be user-defined operator class code. For example, B-Tree index verification relies on comparisons made with one or more B-Tree support function 1 routines. See Section 36.16.3 for details of operator class support functions.

amcheck functions may only be used by superusers.

## F.2.1. Functions

`bt_index_check(index regclass, heapallindexed boolean)` returns void

`bt_index_check` tests that its target, a B-Tree index, respects a variety of invariants. Example usage:

```
test=# SELECT bt_index_check(index => c.oid, heapallindexed =>
      i.indisunique),
      c.relname,
      c.relpages
FROM pg_index i
JOIN pg_opclass op ON i.indclass[0] = op.oid
JOIN pg_am am ON op.opcmethod = am.oid
JOIN pg_class c ON i.indexrelid = c.oid
JOIN pg_namespace n ON c.relnamespace = n.oid
WHERE am.amname = 'btree' AND n.nspname = 'pg_catalog'
-- Don't check temp tables, which may be from another session:
AND c.relpersistence != 't'
-- Function may throw an error when this is omitted:
AND c.relkind = 'i' AND i.indisready AND i.indisvalid
ORDER BY c.relpages DESC LIMIT 10;
```

bt_index_check	relname	relpages
	pg_depend_reference_index	43
	pg_depend_depender_index	40
	pg_proc_proname_args_nsp_index	31
	pg_description_o_c_o_index	21
	pg_attribute_relid_attnam_index	14
	pg_proc_oid_index	10
	pg_attribute_relid_attnum_index	9
	pg_amproc_fam_proc_index	5
	pg_amop_opr_fam_index	5
	pg_amop_fam_strat_index	5

(10 rows)

This example shows a session that performs verification of the 10 largest catalog indexes in the database “test”. Verification of the presence of heap tuples as index tuples is requested for the subset that are unique indexes. Since no error is raised, all indexes tested appear to be logically consistent. Naturally, this query could easily be changed to call `bt_index_check` for every index in the database where verification is supported.

`bt_index_check` acquires an `AccessShareLock` on the target index and the heap relation it belongs to. This lock mode is the same lock mode acquired on relations by simple `SELECT` statements. `bt_index_check` does not verify invariants that span child/parent relationships, but will verify the presence of all heap tuples as index tuples within the index when `heapallindexed` is `true`. When a routine, lightweight test for corruption is required in a live production environment, using `bt_index_check` often provides the best trade-off between thoroughness of verification and limiting the impact on application performance and availability.

```
bt_index_parent_check(index regclass, heapallindexed boolean,
rootdescend boolean) returns void
```

`bt_index_parent_check` tests that its target, a B-Tree index, respects a variety of invariants. Optionally, when the *heapallindexed* argument is `true`, the function verifies the presence of all heap tuples that should be found within the index. When the optional *rootdescend* argument is `true`, verification re-finds tuples on the leaf level by performing a new search from the root page for each tuple. The checks that can be performed by `bt_index_parent_check` are a superset of the checks that can be performed by `bt_index_check`. `bt_index_parent_check` can be thought of as a more thorough variant of `bt_index_check`: unlike `bt_index_check`, `bt_index_parent_check` also checks invariants that span parent/child relationships, including checking that there are no missing downlinks in the index structure. `bt_index_parent_check` follows the general convention of raising an error if it finds a logical inconsistency or other problem.

A `ShareLock` is required on the target index by `bt_index_parent_check` (a `ShareLock` is also acquired on the heap relation). These locks prevent concurrent data modification from `INSERT`, `UPDATE`, and `DELETE` commands. The locks also prevent the underlying relation from being concurrently processed by `VACUUM`, as well as all other utility commands. Note that the function holds locks only while running, not for the entire transaction.

`bt_index_parent_check`'s additional verification is more likely to detect various pathological cases. These cases may involve an incorrectly implemented B-Tree operator class used by the index that is checked, or, hypothetically, undiscovered bugs in the underlying B-Tree index access method code. Note that `bt_index_parent_check` cannot be used when Hot Standby mode is enabled (i.e., on read-only physical replicas), unlike `bt_index_check`.

### Tip

`bt_index_check` and `bt_index_parent_check` both output log messages about the verification process at `DEBUG1` and `DEBUG2` severity levels. These messages provide detailed information about the verification process that may be of interest to LightDB developers. Advanced users may also find this information helpful, since it provides additional context should verification actually detect an inconsistency. Running:

```
SET client_min_messages = DEBUG1;
```

in an interactive `lsql` session before running a verification query will display messages about the progress of verification with a manageable level of detail.

## F.2.2. Optional *heapallindexed* Verification

When the *heapallindexed* argument to verification functions is `true`, an additional phase of verification is performed against the table associated with the target index relation. This consists of a “dummy” `CREATE INDEX` operation, which checks for the presence of all hypothetical new index tuples against a temporary, in-memory summarizing structure (this is built when needed during the basic first phase of verification). The summarizing structure “fingerprints” every tuple found within the target index. The high level principle behind *heapallindexed* verification is that a new index that is equivalent to the existing, target index must only have entries that can be found in the existing structure.

The additional *heapallindexed* phase adds significant overhead: verification will typically take several times longer. However, there is no change to the relation-level locks acquired when *heapallindexed* verification is performed.

The summarizing structure is bound in size by `maintenance_work_mem`. In order to ensure that there is no more than a 2% probability of failure to detect an inconsistency for each heap tuple that should be represented in the index, approximately 2 bytes of memory are needed per tuple. As less memory is made available per tuple, the probability of missing an inconsistency slowly increases. This approach limits the overhead of verification significantly, while only slightly reducing the probability of detecting a problem, especially for installations where verification is treated as a routine maintenance task. Any single absent or malformed tuple has a new opportunity to be detected with each new verification attempt.

### F.2.3. Using `amcheck` Effectively

`amcheck` can be effective at detecting various types of failure modes that data page checksums will always fail to catch. These include:

- Structural inconsistencies caused by incorrect operator class implementations.

This includes issues caused by the comparison rules of operating system collations changing. Comparisons of datums of a collatable type like `text` must be immutable (just as all comparisons used for B-Tree index scans must be immutable), which implies that operating system collation rules must never change. Though rare, updates to operating system collation rules can cause these issues. More commonly, an inconsistency in the collation order between a master server and a standby server is implicated, possibly because the *major* operating system version in use is inconsistent. Such inconsistencies will generally only arise on standby servers, and so can generally only be detected on standby servers.

If a problem like this arises, it may not affect each individual index that is ordered using an affected collation, simply because *indexed* values might happen to have the same absolute ordering regardless of the behavioral inconsistency. See Section 21.1 and Section 21.2 for further details about how LightDB uses operating system locales and collations.

- Structural inconsistencies between indexes and the heap relations that are indexed (when *heapallindexed* verification is performed).

There is no cross-checking of indexes against their heap relation during normal operation. Symptoms of heap corruption can be subtle.

- Corruption caused by hypothetical undiscovered bugs in the underlying LightDB access method code, sort code, or transaction management code.

Automatic verification of the structural integrity of indexes plays a role in the general testing of new or proposed LightDB features that could plausibly allow a logical inconsistency to be introduced. Verification of table structure and associated visibility and transaction status information plays a similar role. One obvious testing strategy is to call `amcheck` functions continuously when running the standard regression tests. See Section 30.1 for details on running the tests.

- File system or storage subsystem faults where checksums happen to simply not be enabled.

Note that `amcheck` examines a page as represented in some shared memory buffer at the time of verification if there is only a shared buffer hit when accessing the block. Consequently, `amcheck` does not necessarily examine data read from the file system at the time of verification. Note that when checksums are enabled, `amcheck` may raise an error due to a checksum failure when a corrupt block is read into a buffer.

- Corruption caused by faulty RAM, or the broader memory subsystem.

LightDB does not protect against correctable memory errors and it is assumed you will operate using RAM that uses industry standard Error Correcting Codes (ECC) or better protection. However, ECC memory is typically only immune to single-bit errors, and should not be assumed to provide *absolute* protection against failures that result in memory corruption.



When *heapallindexed* verification is performed, there is generally a greatly increased chance of detecting single-bit errors, since strict binary equality is tested, and the indexed attributes within the heap are tested.

In general, `amcheck` can only prove the presence of corruption; it cannot prove its absence.

## F.2.4. Repairing Corruption

No error concerning corruption raised by `amcheck` should ever be a false positive. `amcheck` raises errors in the event of conditions that, by definition, should never happen, and so careful analysis of `amcheck` errors is often required.

There is no general method of repairing problems that `amcheck` detects. An explanation for the root cause of an invariant violation should be sought. `pageinspect` may play a useful role in diagnosing corruption that `amcheck` detects. A `REINDEX` may not be effective in repairing corruption.

## F.3. `auth_delay`

`auth_delay` causes the server to pause briefly before reporting authentication failure, to make brute-force attacks on database passwords more difficult. Note that it does nothing to prevent denial-of-service attacks, and may even exacerbate them, since processes that are waiting before reporting authentication failure will still consume connection slots.

In order to function, this module must be loaded via `shared_preload_libraries` in `lightdb.conf`.

### F.3.1. Configuration Parameters

`auth_delay.milliseconds` (int)

The number of milliseconds to wait before reporting an authentication failure. The default is 0.

These parameters must be set in `lightdb.conf`. Typical usage might be:

```
# lightdb.conf
shared_preload_libraries = 'auth_delay'

auth_delay.milliseconds = '500'
```

### F.3.2. Author

KaiGai Kohei <kaigai@ak.jp.nec.com>

## F.4. `auto_explain`

The `auto_explain` module provides a means for logging execution plans of slow statements automatically, without having to run `EXPLAIN` by hand. This is especially helpful for tracking down un-optimized queries in large applications.

The module provides no SQL-accessible functions. To use it, simply load it into the server. You can load it into an individual session:

```
LOAD 'auto_explain';
```

(You must be superuser to do that.) More typical usage is to preload it into some or all sessions by including `auto_explain` in `session_preload_libraries` or `shared_preload_libraries` in

`lightdb.conf`. Then you can track unexpectedly slow queries no matter when they happen. Of course there is a price in overhead for that.

The `auto_explain` module will also generate a separate log file which called slow log. A slow log file has the same basename as the default log file and a ".slow" suffix. The format of slow log is always json.

## F.4.1. Configuration Parameters

There are several configuration parameters that control the behavior of `auto_explain`. Note that the default behavior is to do nothing, so you must set at least `auto_explain.log_min_duration` if you want any results.

`auto_explain.log_min_duration` (integer)

`auto_explain.log_min_duration` is the minimum statement execution time, in milliseconds, that will cause the statement's plan to be logged. Setting this to 0 logs all plans. -1 (the default) disables logging of plans. For example, if you set it to 250ms then all statements that run 250ms or longer will be logged. Only superusers can change this setting.

`auto_explain.log_analyze` (boolean)

`auto_explain.log_analyze` causes `EXPLAIN ANALYZE` output, rather than just `EXPLAIN` output, to be printed when an execution plan is logged. This parameter is off by default. Only superusers can change this setting.

### Note

When this parameter is on, per-plan-node timing occurs for all statements executed, whether or not they run long enough to actually get logged. This can have an extremely negative impact on performance. Turning off `auto_explain.log_timing` ameliorates the performance cost, at the price of obtaining less information.

`auto_explain.log_buffers` (boolean)

`auto_explain.log_buffers` controls whether buffer usage statistics are printed when an execution plan is logged; it's equivalent to the `BUFFERS` option of `EXPLAIN`. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_wal` (boolean)

`auto_explain.log_wal` controls whether WAL usage statistics are printed when an execution plan is logged; it's equivalent to the `WAL` option of `EXPLAIN`. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_timing` (boolean)

`auto_explain.log_timing` controls whether per-node timing information is printed when an execution plan is logged; it's equivalent to the `TIMING` option of `EXPLAIN`. The overhead of repeatedly reading the system clock can slow down queries significantly on some systems, so it may be useful to set this parameter to off when only actual row counts, and not exact times, are needed. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is on by default. Only superusers can change this setting.

`auto_explain.log_triggers` (boolean)

`auto_explain.log_triggers` causes trigger execution statistics to be included when an execution plan is logged. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_verbose` (boolean)

`auto_explain.log_verbose` controls whether verbose details are printed when an execution plan is logged; it's equivalent to the `VERBOSE` option of `EXPLAIN`. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_settings` (boolean)

`auto_explain.log_settings` controls whether information about modified configuration options is printed when an execution plan is logged. Only options affecting query planning with value different from the built-in default value are included in the output. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_format` (enum)

`auto_explain.log_format` selects the `EXPLAIN` output format to be used. The allowed values are `text`, `xml`, `json`, and `yaml`. The default is `text`. Only superusers can change this setting.

`auto_explain.log_level` (enum)

`auto_explain.log_level` selects the log level at which `auto_explain` will log the query plan. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, `INFO`, `NOTICE`, `WARNING`, and `LOG`. The default is `LOG`. Only superusers can change this setting.

`auto_explain.log_nested_statements` (boolean)

`auto_explain.log_nested_statements` causes nested statements (statements executed inside a function) to be considered for logging. When it is off, only top-level query plans are logged. This parameter is off by default. Only superusers can change this setting.

`auto_explain.sample_rate` (real)

`auto_explain.sample_rate` causes `auto_explain` to only explain a fraction of the statements in each session. The default is 1, meaning explain all the queries. In case of nested statements, either all will be explained or none. Only superusers can change this setting.

In ordinary usage, these parameters are set in `lightdb.conf`, although superusers can alter them on-the-fly within their own sessions. Typical usage might be:

```
# lightdb.conf
session_preload_libraries = 'auto_explain'

auto_explain.log_min_duration = '3s'
```

## F.4.2. Example

```
lightdb@postgres=# LOAD 'auto_explain';
lightdb@postgres=# SET auto_explain.log_min_duration = 0;
lightdb@postgres=# SET auto_explain.log_analyze = true;
lightdb@postgres=# SELECT count(*)
```

```
FROM pg_class, pg_index
WHERE oid = indrelid AND indisunique;
```

This might produce log output such as:

```
LOG: duration: 3.651 ms plan:
Query Text: SELECT count(*)
           FROM pg_class, pg_index
           WHERE oid = indrelid AND indisunique;
Aggregate (cost=16.79..16.80 rows=1 width=0) (actual
time=3.626..3.627 rows=1 loops=1)
  -> Hash Join (cost=4.17..16.55 rows=92 width=0) (actual
time=3.349..3.594 rows=92 loops=1)
    Hash Cond: (pg_class.oid = pg_index.indrelid)
    -> Seq Scan on pg_class (cost=0.00..9.55 rows=255
width=4) (actual time=0.016..0.140 rows=255 loops=1)
    -> Hash (cost=3.02..3.02 rows=92 width=4) (actual
time=3.238..3.238 rows=92 loops=1)
      Buckets: 1024 Batches: 1 Memory Usage: 4kB
      -> Seq Scan on pg_index (cost=0.00..3.02 rows=92
width=4) (actual time=0.008..3.187 rows=92 loops=1)
    Filter: indisunique
```

## F.4.3. Author

Takahiro Itagaki <itagaki.takahiro@oss.ntt.co.jp>

## F.5. bloom

`bloom` provides an index access method based on Bloom filters<sup>1</sup>.

A Bloom filter is a space-efficient data structure that is used to test whether an element is a member of a set. In the case of an index access method, it allows fast exclusion of non-matching tuples via signatures whose size is determined at index creation.

A signature is a lossy representation of the indexed attribute(s), and as such is prone to reporting false positives; that is, it may be reported that an element is in the set, when it is not. So index search results must always be rechecked using the actual attribute values from the heap entry. Larger signatures reduce the odds of a false positive and thus reduce the number of useless heap visits, but of course also make the index larger and hence slower to scan.

This type of index is most useful when a table has many attributes and queries test arbitrary combinations of them. A traditional btree index is faster than a bloom index, but it can require many btree indexes to support all possible queries where one needs only a single bloom index. Note however that bloom indexes only support equality queries, whereas btree indexes can also perform inequality and range searches.

### F.5.1. Parameters

A bloom index accepts the following parameters in its `WITH` clause:

`length`

Length of each signature (index entry) in bits. It is rounded up to the nearest multiple of 16. The default is 80 bits and the maximum is 4096.

---

<sup>1</sup> [https://en.wikipedia.org/wiki/Bloom\\_filter](https://en.wikipedia.org/wiki/Bloom_filter)

col1 - col32

Number of bits generated for each index column. Each parameter's name refers to the number of the index column that it controls. The default is 2 bits and the maximum is 4095. Parameters for index columns not actually used are ignored.

## F.5.2. Examples

This is an example of creating a bloom index:

```
CREATE INDEX bloomidx ON tbloom USING bloom (i1,i2,i3)
    WITH (length=80, col1=2, col2=2, col3=4);
```

The index is created with a signature length of 80 bits, with attributes i1 and i2 mapped to 2 bits, and attribute i3 mapped to 4 bits. We could have omitted the length, col1, and col2 specifications since those have the default values.

Here is a more complete example of bloom index definition and usage, as well as a comparison with equivalent btree indexes. The bloom index is considerably smaller than the btree index, and can perform better.

```
=# CREATE TABLE tbloom AS
    SELECT
        (random() * 1000000)::int as i1,
        (random() * 1000000)::int as i2,
        (random() * 1000000)::int as i3,
        (random() * 1000000)::int as i4,
        (random() * 1000000)::int as i5,
        (random() * 1000000)::int as i6
    FROM
        generate_series(1,10000000);
SELECT 10000000
```

A sequential scan over this large table takes a long time:

```
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
    123451;
```

QUERY PLAN

```
-----
Seq Scan on tbloom (cost=0.00..2137.14 rows=3 width=24) (actual
time=15.480..15.480 rows=0 loops=1)
  Filter: ((i2 = 898732) AND (i5 = 123451))
  Rows Removed by Filter: 100000
Planning Time: 0.340 ms
Execution Time: 15.501 ms
(5 rows)
```

Even with the btree index defined the result will still be a sequential scan:

```
=# CREATE INDEX btreeidx ON tbloom (i1, i2, i3, i4, i5, i6);
CREATE INDEX
=# SELECT pg_size_pretty(pg_relation_size('btreeidx'));
pg_size_pretty
```

```
-----
3976 kB
(1 row)
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
123451;
```

QUERY PLAN

```
-----
Seq Scan on tbloom (cost=0.00..2137.00 rows=2 width=24) (actual
time=12.604..12.604 rows=0 loops=1)
  Filter: ((i2 = 898732) AND (i5 = 123451))
  Rows Removed by Filter: 100000
Planning Time: 0.155 ms
Execution Time: 12.617 ms
(5 rows)
```

Having the bloom index defined on the table is better than btree in handling this type of search:

```
=# CREATE INDEX bloomidx ON tbloom USING bloom (i1, i2, i3, i4, i5,
i6);
CREATE INDEX
=# SELECT pg_size_pretty(pg_relation_size('bloomidx'));
pg_size_pretty
```

```
-----
1584 kB
(1 row)
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
123451;
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tbloom (cost=1792.00..1799.69 rows=2
width=24) (actual time=0.384..0.384 rows=0 loops=1)
  Recheck Cond: ((i2 = 898732) AND (i5 = 123451))
  Rows Removed by Index Recheck: 26
  Heap Blocks: exact=26
  -> Bitmap Index Scan on bloomidx (cost=0.00..1792.00 rows=2
width=0) (actual time=0.350..0.350 rows=26 loops=1)
    Index Cond: ((i2 = 898732) AND (i5 = 123451))
Planning Time: 0.122 ms
Execution Time: 0.407 ms
(8 rows)
```

Now, the main problem with the btree search is that btree is inefficient when the search conditions do not constrain the leading index column(s). A better strategy for btree is to create a separate index on each column. Then the planner will choose something like this:

```
=# CREATE INDEX btreeidx1 ON tbloom (i1);
CREATE INDEX
=# CREATE INDEX btreeidx2 ON tbloom (i2);
CREATE INDEX
=# CREATE INDEX btreeidx3 ON tbloom (i3);
CREATE INDEX
=# CREATE INDEX btreeidx4 ON tbloom (i4);
CREATE INDEX
```

```

=# CREATE INDEX btreeidx5 ON tbloom (i5);
CREATE INDEX
=# CREATE INDEX btreeidx6 ON tbloom (i6);
CREATE INDEX
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
  123451;

```

QUERY PLAN

```

-----
Bitmap Heap Scan on tbloom (cost=24.34..32.03 rows=2 width=24)
(actual time=0.032..0.033 rows=0 loops=1)
  Recheck Cond: ((i5 = 123451) AND (i2 = 898732))
    -> BitmapAnd (cost=24.34..24.34 rows=2 width=0) (actual
time=0.029..0.030 rows=0 loops=1)
      -> Bitmap Index Scan on btreeidx5 (cost=0.00..12.04
rows=500 width=0) (actual time=0.029..0.029 rows=0 loops=1)
        Index Cond: (i5 = 123451)
      -> Bitmap Index Scan on btreeidx2 (cost=0.00..12.04
rows=500 width=0) (never executed)
        Index Cond: (i2 = 898732)
Planning Time: 0.537 ms
Execution Time: 0.064 ms
(9 rows)

```

Although this query runs much faster than with either of the single indexes, we pay a penalty in index size. Each of the single-column btree indexes occupies 2 MB, so the total space needed is 12 MB, eight times the space used by the bloom index.

### F.5.3. Operator Class Interface

An operator class for bloom indexes requires only a hash function for the indexed data type and an equality operator for searching. This example shows the operator class definition for the `text` data type:

```

CREATE OPERATOR CLASS text_ops
DEFAULT FOR TYPE text USING bloom AS
  OPERATOR      1      =(text, text),
  FUNCTION      1      hashtext(text);

```

### F.5.4. Limitations

- Only operator classes for `int4` and `text` are included with the module.
- Only the `=` operator is supported for search. But it is possible to add support for arrays with union and intersection operations in the future.
- bloom access method doesn't support `UNIQUE` indexes.
- bloom access method doesn't support searching for `NULL` values.

### F.5.5. Authors

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## F.6. btree\_gin

`btree_gin` provides sample GIN operator classes that implement B-tree equivalent behavior for the data types `int2`, `int4`, `int8`, `float4`, `float8`, `timestamp with time zone`, `timestamp without time zone`, `time with time zone`, `time without time zone`, `date`, `interval`, `oid`, `money`, `"char"`, `varchar`, `text`, `bytea`, `bit`, `varbit`, `macaddr`, `macaddr8`, `inet`, `cidr`, `uuid`, `name`, `bool`, `bpchar`, and all enum types.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they are useful for GIN testing and as a base for developing other GIN operator classes. Also, for queries that test both a GIN-indexable column and a B-tree-indexable column, it might be more efficient to create a multicolumn GIN index that uses one of these operator classes than to create two separate indexes that would have to be combined via bitmap ANDing.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

### F.6.1. Example Usage

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING GIN (a);
-- query
SELECT * FROM test WHERE a < 10;
```

### F.6.2. Authors

Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megera/oddmuse/index.cgi/Gin> for additional information.

## F.7. btree\_gist

`btree_gist` provides GiST index operator classes that implement B-tree equivalent behavior for the data types `int2`, `int4`, `int8`, `float4`, `float8`, `numeric`, `timestamp with time zone`, `timestamp without time zone`, `time with time zone`, `time without time zone`, `date`, `interval`, `oid`, `money`, `char`, `varchar`, `text`, `bytea`, `bit`, `varbit`, `macaddr`, `macaddr8`, `inet`, `cidr`, `uuid`, and all enum types.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they provide some other features that are not available with a B-tree index, as described below. Also, these operator classes are useful when a multicolumn GiST index is needed, wherein some of the columns are of data types that are only indexable with GiST but other columns are just simple data types. Lastly, these operator classes are useful for GiST testing and as a base for developing other GiST operator classes.

In addition to the typical B-tree search operators, `btree_gist` also provides index support for `<>` (“not equals”). This may be useful in combination with an exclusion constraint, as described below.

Also, for data types for which there is a natural distance metric, `btree_gist` defines a distance operator `<->`, and provides GiST index support for nearest-neighbor searches using this operator. Distance operators are provided for `int2`, `int4`, `int8`, `float4`, `float8`, `timestamp with`



time zone, timestamp without time zone, time without time zone, date, interval, oid, and money.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

## F.7.1. Example Usage

Simple example using `btree_gist` instead of `btree`:

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING GIST (a);
-- query
SELECT * FROM test WHERE a < 10;
-- nearest-neighbor search: find the ten entries closest to "42"
SELECT *, a <-> 42 AS dist FROM test ORDER BY a <-> 42 LIMIT 10;
```

Use an exclusion constraint to enforce the rule that a cage at a zoo can contain only one kind of animal:

```
=> CREATE TABLE zoo (
    cage    INTEGER,
    animal  TEXT,
    EXCLUDE USING GIST (cage WITH =, animal WITH <>)
);

=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'lion');
ERROR:  conflicting key value violates exclusion constraint
        "zoo_cage_animal_excl"
DETAIL:  Key (cage, animal)=(123, lion) conflicts with existing key
        (cage, animal)=(123, zebra).
=> INSERT INTO zoo VALUES(124, 'lion');
INSERT 0 1
```

## F.7.2. Authors

Teodor Sigaev (<teodor@stack.net>), Oleg Bartunov (<oleg@sai.msu.su>), Janko Richter (<jankorichter@yahoo.de>), and Paul Jungwirth (<pj@illuminatedcomputing.com>). See <http://www.sai.msu.su/~megeera/postgres/gist/> for additional information.

## F.8. canopy

See `canopy`<sup>2</sup> for more details.

## F.9. citext

The `citext` module provides a case-insensitive character string type, `citext`. Essentially, it internally calls `lower` when comparing values. Otherwise, it behaves almost exactly like `text`.

---

<sup>2</sup> <http://www.light-pg.com/docs/canopy/13.8-23.4/index.html>

**Tip**

Consider using *nondeterministic collations* (see Section 21.2.2.4) instead of this module. They can be used for case-insensitive comparisons, accent-insensitive comparisons, and other combinations, and they handle more Unicode special cases correctly.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

## F.9.1. Rationale

The standard approach to doing case-insensitive matches in LightDB has been to use the `lower` function when comparing values, for example

```
SELECT * FROM tab WHERE lower(col) = LOWER(?);
```

This works reasonably well, but has a number of drawbacks:

- It makes your SQL statements verbose, and you always have to remember to use `lower` on both the column and the query value.
- It won't use an index, unless you create a functional index using `lower`.
- If you declare a column as `UNIQUE` or `PRIMARY KEY`, the implicitly generated index is case-sensitive. So it's useless for case-insensitive searches, and it won't enforce uniqueness case-insensitively.

The `citext` data type allows you to eliminate calls to `lower` in SQL queries, and allows a primary key to be case-insensitive. `citext` is locale-aware, just like `text`, which means that the matching of upper case and lower case characters is dependent on the rules of the database's `LC_CTYPE` setting. Again, this behavior is identical to the use of `lower` in queries. But because it's done transparently by the data type, you don't have to remember to do anything special in your queries.

## F.9.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE users (  
    nick CITEXT PRIMARY KEY,  
    pass TEXT NOT NULL  
);  
  
INSERT INTO users VALUES ( 'larry',  
    sha256(random)::text::bytea );  
INSERT INTO users VALUES ( 'Tom',  
    sha256(random)::text::bytea );  
INSERT INTO users VALUES ( 'Damian',  
    sha256(random)::text::bytea );  
INSERT INTO users VALUES ( 'NEAL',  
    sha256(random)::text::bytea );  
INSERT INTO users VALUES ( 'Bjørn',  
    sha256(random)::text::bytea );
```

```
SELECT * FROM users WHERE nick = 'Larry';
```

The `SELECT` statement will return one tuple, even though the `nick` column was set to `larry` and the query was for `Larry`.

### F.9.3. String Comparison Behavior

`citext` performs comparisons by converting each string to lower case (as though `lower` were called) and then comparing the results normally. Thus, for example, two strings are considered equal if `lower` would produce identical results for them.

In order to emulate a case-insensitive collation as closely as possible, there are `citext`-specific versions of a number of string-processing operators and functions. So, for example, the regular expression operators `~` and `~*` exhibit the same behavior when applied to `citext`: they both match case-insensitively. The same is true for `!~` and `!~*`, as well as for the `LIKE` operators `~~` and `~~*`, and `!~~` and `!~~*`. If you'd like to match case-sensitively, you can cast the operator's arguments to `text`.

Similarly, all of the following functions perform matching case-insensitively if their arguments are `citext`:

- `regexp_match()`
- `regexp_matches()`
- `regexp_replace()`
- `regexp_split_to_array()`
- `regexp_split_to_table()`
- `replace()`
- `split_part()`
- `strpos()`
- `translate()`

For the `regexp` functions, if you want to match case-sensitively, you can specify the “`c`” flag to force a case-sensitive match. Otherwise, you must cast to `text` before using one of these functions if you want case-sensitive behavior.

### F.9.4. Limitations

- `citext`'s case-folding behavior depends on the `LC_CTYPE` setting of your database. How it compares values is therefore determined when the database is created. It is not truly case-insensitive in the terms defined by the Unicode standard. Effectively, what this means is that, as long as you're happy with your collation, you should be happy with `citext`'s comparisons. But if you have data in different languages stored in your database, users of one language may find their query results are not as expected if the collation is for another language.
- As of LightDB 9.1, you can attach a `COLLATE` specification to `citext` columns or data values. Currently, `citext` operators will honor a non-default `COLLATE` specification while comparing case-folded strings, but the initial folding to lower case is always done according to the database's `LC_CTYPE` setting (that is, as though `COLLATE "default"` were given). This may be changed in a future release so that both steps follow the input `COLLATE` specification.
- `citext` is not as efficient as `text` because the operator functions and the B-tree comparison functions must make copies of the data and convert it to lower case for comparisons. Also, only

`text` can support B-Tree deduplication. However, `citext` is slightly more efficient than using `lower` to get case-insensitive matching.

- `citext` doesn't help much if you need data to compare case-sensitively in some contexts and case-insensitively in other contexts. The standard answer is to use the `text` type and manually use the `lower` function when you need to compare case-insensitively; this works all right if case-insensitive comparison is needed only infrequently. If you need case-insensitive behavior most of the time and case-sensitive infrequently, consider storing the data as `citext` and explicitly casting the column to `text` when you want case-sensitive comparison. In either situation, you will need two indexes if you want both types of searches to be fast.
- The schema containing the `citext` operators must be in the current `search_path` (typically `public`); if it is not, the normal case-sensitive `text` operators will be invoked instead.
- The approach of lower-casing strings for comparison does not handle some Unicode special cases correctly, for example when one upper-case letter has two lower-case letter equivalents. Unicode distinguishes between *case mapping* and *case folding* for this reason. Use nondeterministic collations instead of `citext` to handle that correctly.

## F.9.5. Author

David E. Wheeler <david@kineticcode.com>

Inspired by the original `citext` module by Donald Fraser.

## F.10. cube

This module implements a data type `cube` for representing multidimensional cubes.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.10.1. Syntax

Table F.2 shows the valid external representations for the `cube` type. `x`, `y`, etc. denote floating-point numbers.

**Table F.2. Cube External Representations**

External Syntax	Meaning
<code>x</code>	A one-dimensional point (or, zero-length one-dimensional interval)
<code>(x)</code>	Same as above
<code>x1, x2, . . . , xn</code>	A point in n-dimensional space, represented internally as a zero-volume cube
<code>(x1, x2, . . . , xn)</code>	Same as above
<code>(x), (y)</code>	A one-dimensional interval starting at <code>x</code> and ending at <code>y</code> or vice versa; the order does not matter
<code>[(x), (y)]</code>	Same as above
<code>(x1, . . . , xn), (y1, . . . , yn)</code>	An n-dimensional cube represented by a pair of its diagonally opposite corners
<code>[(x1, . . . , xn), (y1, . . . , yn)]</code>	Same as above

It does not matter which order the opposite corners of a cube are entered in. The `cube` functions automatically swap values if needed to create a uniform “lower left — upper right” internal representation. When the corners coincide, `cube` stores only one corner along with an “is point” flag to avoid wasting space.

White space is ignored on input, so `[ ( x ) , ( y ) ]` is the same as `[ ( x ) , ( y ) ]`.

## F.10.2. Precision

Values are stored internally as 64-bit floating point numbers. This means that numbers with more than about 16 significant digits will be truncated.

## F.10.3. Usage

Table F.3 shows the specialized operators provided for type `cube`.

**Table F.3. Cube Operators**

Operator	Description
<code>cube &amp;&amp; cube</code>	<code>→ boolean</code> Do the cubes overlap?
<code>cube @&gt; cube</code>	<code>→ boolean</code> Does the first cube contain the second?
<code>cube &lt;@ cube</code>	<code>→ boolean</code> Is the first cube contained in the second?
<code>cube -&gt; integer</code>	<code>→ float8</code> Extracts the $n$ -th coordinate of the cube (counting from 1).
<code>cube ~&gt; integer</code>	<code>→ float8</code> Extracts the $n$ -th coordinate of the cube, counting in the following way: $n = 2 * k - 1$ means lower bound of $k$ -th dimension, $n = 2 * k$ means upper bound of $k$ -th dimension. Negative $n$ denotes the inverse value of the corresponding positive coordinate. This operator is designed for KNN-GiST support.
<code>cube &lt;-&gt; cube</code>	<code>→ float8</code> Computes the Euclidean distance between the two cubes.
<code>cube &lt;#&gt; cube</code>	<code>→ float8</code> Computes the taxicab (L-1 metric) distance between the two cubes.
<code>cube &lt;=&gt; cube</code>	<code>→ float8</code> Computes the Chebyshev (L-inf metric) distance between the two cubes.

(Before LightDB 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

In addition to the above operators, the usual comparison operators shown in Table 9.1 are available for type `cube`. These operators first compare the first coordinates, and if those are equal, compare the second coordinates, etc. They exist mainly to support the b-tree index operator class for `cube`, which can be useful for example if you would like a `UNIQUE` constraint on a `cube` column. Otherwise, this ordering is not of much practical use.

The `cube` module also provides a GiST index operator class for `cube` values. A `cube` GiST index can be used to search for values using the `=`, `&&`, `@>`, and `<@` operators in `WHERE` clauses.

In addition, a cube GiST index can be used to find nearest neighbors using the metric operators <->, <#>, and <=> in ORDER BY clauses. For example, the nearest neighbor of the 3-D point (0.5, 0.5, 0.5) could be found efficiently with:

```
SELECT c FROM test ORDER BY c <-> cube(array[0.5,0.5,0.5]) LIMIT 1;
```

The ~> operator can also be used in this way to efficiently retrieve the first few values sorted by a selected coordinate. For example, to get the first few cubes ordered by the first coordinate (lower left corner) ascending one could use the following query:

```
SELECT c FROM test ORDER BY c ~> 1 LIMIT 5;
```

And to get 2-D cubes ordered by the first coordinate of the upper right corner descending:

```
SELECT c FROM test ORDER BY c ~> 3 DESC LIMIT 5;
```

Table F.4 shows the available functions.

**Table F.4. Cube Functions**

Function	Description	Example(s)
<code>cube ( float8 )</code>	→ cube Makes a one dimensional cube with both coordinates the same.	<code>cube(1) → (1)</code>
<code>cube ( float8, float8 )</code>	→ cube Makes a one dimensional cube.	<code>cube(1,2) → (1), (2)</code>
<code>cube ( float8[] )</code>	→ cube Makes a zero-volume cube using the coordinates defined by the array.	<code>cube(ARRAY[1,2,3]) → (1, 2, 3)</code>
<code>cube ( float8[], float8[] )</code>	→ cube Makes a cube with upper right and lower left coordinates as defined by the two arrays, which must be of the same length.	<code>cube(ARRAY[1,2], ARRAY[3,4]) → (1, 2), (3, 4)</code>
<code>cube ( cube, float8 )</code>	→ cube Makes a new cube by adding a dimension on to an existing cube, with the same values for both endpoints of the new coordinate. This is useful for building cubes piece by piece from calculated values.	<code>cube('(1,2),(3,4)::cube, 5) → (1, 2, 5), (3, 4, 5)</code>
<code>cube ( cube, float8, float8 )</code>	→ cube Makes a new cube by adding a dimension on to an existing cube. This is useful for building cubes piece by piece from calculated values.	<code>cube('(1,2),(3,4)::cube, 5, 6) → (1, 2, 5), (3, 4, 6)</code>
<code>cube_dim ( cube )</code>	→ integer Returns the number of dimensions of the cube.	<code>cube_dim('(1,2),(3,4)') → 2</code>

Function	Description	Example(s)
<code>cube_ll_coord</code>	<code>cube_ll_coord ( cube, integer ) → float8</code> Returns the <i>n</i> -th coordinate value for the lower left corner of the cube.	<code>cube_ll_coord( '(1,2),(3,4)', 2) → 2</code>
<code>cube_ur_coord</code>	<code>cube_ur_coord ( cube, integer ) → float8</code> Returns the <i>n</i> -th coordinate value for the upper right corner of the cube.	<code>cube_ur_coord( '(1,2),(3,4)', 2) → 4</code>
<code>cube_is_point</code>	<code>cube_is_point ( cube ) → boolean</code> Returns true if the cube is a point, that is, the two defining corners are the same.	<code>cube_is_point(cube(1,1)) → t</code>
<code>cube_distance</code>	<code>cube_distance ( cube, cube ) → float8</code> Returns the distance between two cubes. If both cubes are points, this is the normal distance function.	<code>cube_distance( '(1,2)', '(3,4)' ) → 2.8284271247461903</code>
<code>cube_subset</code>	<code>cube_subset ( cube, integer[] ) → cube</code> Makes a new cube from an existing cube, using a list of dimension indexes from an array. Can be used to extract the endpoints of a single dimension, or to drop dimensions, or to reorder them as desired.	<code>cube_subset(cube( '(1,3,5),(6,7,8)' ), ARRAY[2]) → (3),(7)</code> <code>cube_subset(cube( '(1,3,5),(6,7,8)' ), ARRAY[3,2,1,1]) → (5, 3, 1, 1),(8, 7, 6, 6)</code>
<code>cube_union</code>	<code>cube_union ( cube, cube ) → cube</code> Produces the union of two cubes.	<code>cube_union( '(1,2)', '(3,4)' ) → (1, 2),(3, 4)</code>
<code>cube_inter</code>	<code>cube_inter ( cube, cube ) → cube</code> Produces the intersection of two cubes.	<code>cube_inter( '(1,2)', '(3,4)' ) → (3, 4),(1, 2)</code>
<code>cube_enlarge</code>	<code>cube_enlarge ( c cube, r double, n integer ) → cube</code> Increases the size of the cube by the specified radius <i>r</i> in at least <i>n</i> dimensions. If the radius is negative the cube is shrunk instead. All defined dimensions are changed by the radius <i>r</i> . Lower-left coordinates are decreased by <i>r</i> and upper-right coordinates are increased by <i>r</i> . If a lower-left coordinate is increased to more than the corresponding upper-right coordinate (this can only happen when <i>r</i> < 0) then both coordinates are set to their average. If <i>n</i> is greater than the number of defined dimensions and the cube is being enlarged ( <i>r</i> > 0), then extra dimensions are added to make <i>n</i> altogether; 0 is used as the initial value for the extra coordinates. This function is useful for creating bounding boxes around a point for searching for nearby points.	<code>cube_enlarge( '(1,2),(3,4)', 0.5, 3) → (0.5, 1.5, -0.5),(3.5, 4.5, 0.5)</code>

## F.10.4. Defaults

I believe this union:

```
select cube_union('(0,5,2),(2,3,1)', '0');
cube_union
```

```
-----  
(0, 0, 0), (2, 5, 2)  
(1 row)
```

does not contradict common sense, neither does the intersection

```
select cube_inter('(0,-1),(1,1)', '(-2),(2)');  
cube_inter  
-----  
(0, 0), (1, 0)  
(1 row)
```

In all binary operations on differently-dimensional cubes, I assume the lower-dimensional one to be a Cartesian projection, i. e., having zeroes in place of coordinates omitted in the string representation. The above examples are equivalent to:

```
cube_union('(0,5,2),(2,3,1)', '(0,0,0),(0,0,0)');  
cube_inter('(0,-1),(1,1)', '(-2,0),(2,0)');
```

The following containment predicate uses the point syntax, while in fact the second argument is internally represented by a box. This syntax makes it unnecessary to define a separate point type and functions for (box,point) predicates.

```
select cube_contains('(0,0),(1,1)', '0.5,0.5');  
cube_contains  
-----  
t  
(1 row)
```

## F.10.5. Notes

For examples of usage, see the regression test `sql/cube.sql`.

To make it harder for people to break things, there is a limit of 100 on the number of dimensions of cubes. This is set in `cubedata.h` if you need something bigger.

## F.10.6. Credits

Original author: Gene Selkov, Jr. <selkovjr@mcs.anl.gov>, Mathematics and Computer Science Division, Argonne National Laboratory.

My thanks are primarily to Prof. Joe Hellerstein (<https://dsf.berkeley.edu/jmh/>) for elucidating the gist of the GiST (<http://gist.cs.berkeley.edu/>), and to his former student Andy Dong for his example written for Illustra. I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

Minor updates to this package were made by Bruno Wolff III <bruno@wolff.to> in August/September of 2002. These include changing the precision from single precision to double precision and adding some new functions.

Additional updates were made by Joshua Reich <josh@root.net> in July 2006. These include `cube(float8[], float8[])` and cleaning up the code to use the V1 call protocol instead of the deprecated V0 protocol.

## F.11. dblink



`dblink` is a module that supports connections to other LightDB databases from within a database session.

**Note**

See also `postgres_fdw`, which provides roughly the same functionality using a more modern and standards-compliant infrastructure.

## dblink\_connect

`dblink_connect` — opens a persistent connection to a remote database

### Synopsis

```
dblink_connect(text connstr) returns text
dblink_connect(text connname, text connstr) returns text
```

### Description

`dblink_connect()` establishes a connection to a remote LightDB database. The server and database to be contacted are identified through a standard libpq connection string. Optionally, a name can be assigned to the connection. Multiple named connections can be open at once, but only one unnamed connection is permitted at a time. The connection will persist until closed or until the database session is ended.

The connection string may also be the name of an existing foreign server. It is recommended to use the foreign-data wrapper `dblink_fdw` when defining the foreign server. See the example below, as well as `CREATE SERVER` and `CREATE USER MAPPING`.

### Arguments

*connname*

The name to use for this connection; if omitted, an unnamed connection is opened, replacing any existing unnamed connection.

*connstr*

libpq-style connection info string, for example `hostaddr=127.0.0.1 port=5432 dbname=mydb user=lightdb password=mypasswd options=-csearch_path=`. For details see Section 32.1.1. Alternatively, the name of a foreign server.

### Return Value

Returns status, which is always OK (since any error causes the function to throw an error instead of returning).

### Notes

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from `search_path`. One could, for example, add `options=-csearch_path=` to *connstr*. This consideration is not specific to `dblink`; it applies to every interface for executing arbitrary SQL commands.

Only superusers may use `dblink_connect` to create non-password-authenticated connections. If non-superusers need this capability, use `dblink_connect_u` instead.

It is unwise to choose connection names that contain equal signs, as this opens a risk of confusion with connection info strings in other `dblink` functions.

### Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
dblink_connect
-----
```

```
OK
(1 row)
```

```
SELECT dblink_connect('myconn', 'dbname=postgres options=-
csearch_path=');
dblink_connect
```

```
-----
OK
(1 row)
```

```
-- FOREIGN DATA WRAPPER functionality
-- Note: local connection must require password authentication for
-- this to work properly
-- Otherwise, you will receive the following error from
-- dblink_connect():
-- ERROR: password is required
-- DETAIL: Non-superuser cannot connect if the server does
-- not request a password.
-- HINT: Target server's authentication method must be
-- changed.
```

```
CREATE SERVER fdtest FOREIGN DATA WRAPPER dblink_fdw OPTIONS
(hostaddr '127.0.0.1', dbname 'contrib_regression');
```

```
CREATE USER regress_dblink_user WITH PASSWORD 'secret';
CREATE USER MAPPING FOR regress_dblink_user SERVER fdtest OPTIONS
(user 'regress_dblink_user', password 'secret');
GRANT USAGE ON FOREIGN SERVER fdtest TO regress_dblink_user;
GRANT SELECT ON TABLE foo TO regress_dblink_user;
```

```
\set ORIGINAL_USER :USER
\c - regress_dblink_user
SELECT dblink_connect('myconn', 'fdtest');
dblink_connect
```

```
-----
OK
(1 row)
```

```
SELECT * FROM dblink('myconn', 'SELECT * FROM foo') AS t(a int, b
text, c text[]);
```

```
 a | b | c
-----+-----
 0 | a | {a0,b0,c0}
 1 | b | {a1,b1,c1}
 2 | c | {a2,b2,c2}
 3 | d | {a3,b3,c3}
 4 | e | {a4,b4,c4}
 5 | f | {a5,b5,c5}
 6 | g | {a6,b6,c6}
 7 | h | {a7,b7,c7}
 8 | i | {a8,b8,c8}
 9 | j | {a9,b9,c9}
10 | k | {a10,b10,c10}
(11 rows)
```

```
\c - :ORIGINAL_USER
REVOKE USAGE ON FOREIGN SERVER fdtest FROM regress_dblink_user;
REVOKE SELECT ON TABLE foo FROM regress_dblink_user;
```

```
DROP USER MAPPING FOR regress_dblink_user SERVER fdtest;  
DROP USER regress_dblink_user;  
DROP SERVER fdtest;
```

## **dblink\_connect\_u**

`dblink_connect_u` — opens a persistent connection to a remote database, insecurely

### **Synopsis**

```
dblink_connect_u(text connstr) returns text  
dblink_connect_u(text connname, text connstr) returns text
```

### **Description**

`dblink_connect_u()` is identical to `dblink_connect()`, except that it will allow non-superusers to connect using any authentication method.

If the remote server selects an authentication method that does not involve a password, then impersonation and subsequent escalation of privileges can occur, because the session will appear to have originated from the user as which the local LightDB server runs. Also, even if the remote server does demand a password, it is possible for the password to be supplied from the server environment, such as a `~/ .pgpass` file belonging to the server's user. This opens not only a risk of impersonation, but the possibility of exposing a password to an untrustworthy remote server. Therefore, `dblink_connect_u()` is initially installed with all privileges revoked from `PUBLIC`, making it un-callable except by superusers. In some situations it may be appropriate to grant `EXECUTE` permission for `dblink_connect_u()` to specific users who are considered trustworthy, but this should be done with care. It is also recommended that any `~/ .pgpass` file belonging to the server's user *not* contain any records specifying a wildcard host name.

For further details see `dblink_connect()`.

## dblink\_disconnect

`dblink_disconnect` — closes a persistent connection to a remote database

### Synopsis

```
dblink_disconnect() returns text
dblink_disconnect(text connname) returns text
```

### Description

`dblink_disconnect()` closes a connection previously opened by `dblink_connect()`. The form with no arguments closes an unnamed connection.

### Arguments

*connname*

The name of a named connection to be closed.

### Return Value

Returns status, which is always OK (since any error causes the function to throw an error instead of returning).

### Examples

```
SELECT dblink_disconnect();
 dblink_disconnect
-----
      OK
(1 row)

SELECT dblink_disconnect('myconn');
 dblink_disconnect
-----
      OK
(1 row)
```

## dblink

`dblink` — executes a query in a remote database

## Synopsis

```
dblink(text connname, text sql [, bool fail_on_error]) returns
  setof record
dblink(text connstr, text sql [, bool fail_on_error]) returns setof
  record
dblink(text sql [, bool fail_on_error]) returns setof record
```

## Description

`dblink` executes a query (usually a `SELECT`, but it can be any SQL statement that returns rows) in a remote database.

When two `text` arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for `dblink_connect`, and the indicated connection is made just for the duration of this command.

## Arguments

*connname*

Name of the connection to use; omit this parameter to use the unnamed connection.

*connstr*

A connection info string, as previously described for `dblink_connect`.

*sql*

The SQL query that you wish to execute in the remote database, for example `select * from foo`.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a `NOTICE`, and the function returns no rows.

## Return Value

The function returns the row(s) produced by the query. Since `dblink` can be used with any query, it is declared to return `record`, rather than specifying any particular set of columns. This means that you must specify the expected set of columns in the calling query — otherwise `LightDB` would not know what to expect. Here is an example:

```
SELECT *
FROM dblink('dbname=mydb options=-csearch_path=',
            'select proname, prosrc from pg_proc')
AS t1(proname name, prosrc text)
WHERE proname LIKE 'bytea%';
```

The “alias” part of the FROM clause must specify the column names and types that the function will return. (Specifying column names in an alias is actually standard SQL syntax, but specifying column types is a LightDB extension.) This allows the system to understand what \* should expand to, and what pronomine in the WHERE clause refers to, in advance of trying to execute the function. At run time, an error will be thrown if the actual query result from the remote database does not have the same number of columns shown in the FROM clause. The column names need not match, however, and dblink does not insist on exact type matches either. It will succeed so long as the returned data strings are valid input for the column type declared in the FROM clause.

## Notes

A convenient way to use dblink with predetermined queries is to create a view. This allows the column type information to be buried in the view, instead of having to spell it out in every query. For example,

```
CREATE VIEW myremote_pg_proc AS
  SELECT *
    FROM dblink('dbname=postgres options=-csearch_path=',
                'select pronomine, prosrc from pg_proc')
  AS t1(pronomine name, prosrc text);

SELECT * FROM myremote_pg_proc WHERE pronomine LIKE 'bytea%';
```

## Examples

```
SELECT * FROM dblink('dbname=postgres options=-csearch_path=',
                    'select pronomine, prosrc from pg_proc')
  AS t1(pronomine name, prosrc text) WHERE pronomine LIKE 'bytea%';
 pronomine |   prosrc
-----+-----
 byteacat  | byteacat
 byteaeq   | byteaeq
 bytealt   | bytealt
 byteale   | byteale
 byteagt   | byteagt
 byteage   | byteage
 byteane   | byteane
 byteacmp  | byteacmp
 bytealike | bytealike
 byteanlike | byteanlike
 byteain   | byteain
 byteaout  | byteaout
(12 rows)
```

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
 dblink_connect
-----
 OK
(1 row)
```

```
SELECT * FROM dblink('select pronomine, prosrc from pg_proc')
  AS t1(pronomine name, prosrc text) WHERE pronomine LIKE 'bytea%';
 pronomine |   prosrc
-----+-----
 byteacat  | byteacat
 byteaeq   | byteaeq
```



```

bytealt      | bytealt
byteale      | byteale
byteagt      | byteagt
byteage      | byteage
byteane      | byteane
byteacmp     | byteacmp
bytealike    | bytealike
byteanlike   | byteanlike
byteain      | byteain
byteaout     | byteaout
(12 rows)

```

```

SELECT dblink_connect('myconn', 'dbname=regression options=-
csearch_path=');
 dblink_connect
-----
OK
(1 row)

```

```

SELECT * FROM dblink('myconn', 'select proname, prosrc from
pg_proc')
 AS t1(proname name, prosrc text) WHERE proname LIKE 'bytea%';
 proname      |   prosrc
-----+-----
bytearecv     | bytearecv
byteasend     | byteasend
byteale       | byteale
byteagt       | byteagt
byteage       | byteage
byteane       | byteane
byteacmp      | byteacmp
bytealike     | bytealike
byteanlike    | byteanlike
byteacat      | byteacat
byteaeq       | byteaeq
bytealt       | bytealt
byteain       | byteain
byteaout      | byteaout
(14 rows)

```

## dblink\_exec

`dblink_exec` — executes a command in a remote database

## Synopsis

```
dblink_exec(text connname, text sql [, bool fail_on_error]) returns
  text
dblink_exec(text connstr, text sql [, bool fail_on_error]) returns
  text
dblink_exec(text sql [, bool fail_on_error]) returns text
```

## Description

`dblink_exec` executes a command (that is, any SQL statement that doesn't return rows) in a remote database.

When two `text` arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for `dblink_connect`, and the indicated connection is made just for the duration of this command.

## Arguments

*connname*

Name of the connection to use; omit this parameter to use the unnamed connection.

*connstr*

A connection info string, as previously described for `dblink_connect`.

*sql*

The SQL command that you wish to execute in the remote database, for example `insert into foo values(0, 'a', '{"a0","b0","c0"}')`.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to `ERROR`.

## Return Value

Returns status, either the command's status string or `ERROR`.

## Examples

```
SELECT dblink_connect('dbname=dblink_test_standby');
 dblink_connect
-----
OK
(1 row)
```

```
SELECT dblink_exec('insert into foo values(21, 'z',
  '{"a0","b0","c0"}');');
  dblink_exec
-----
INSERT 943366 1
(1 row)

SELECT dblink_connect('myconn', 'dbname=regression');
  dblink_connect
-----
OK
(1 row)

SELECT dblink_exec('myconn', 'insert into foo values(21, 'z',
  '{"a0","b0","c0"}');');
  dblink_exec
-----
INSERT 6432584 1
(1 row)

SELECT dblink_exec('myconn', 'insert into pg_class values
  ('foo'),false);
NOTICE:  sql error
DETAIL:  ERROR:  null value in column "relnamespace" violates not-
null constraint

  dblink_exec
-----
ERROR
(1 row)
```

## dblink\_open

`dblink_open` — opens a cursor in a remote database

### Synopsis

```
dblink_open(text cursorname, text sql [, bool fail_on_error])
  returns text
dblink_open(text connname, text cursorname, text sql [, bool
  fail_on_error]) returns text
```

### Description

`dblink_open()` opens a cursor in a remote database. The cursor can subsequently be manipulated with `dblink_fetch()` and `dblink_close()`.

### Arguments

*connname*

Name of the connection to use; omit this parameter to use the unnamed connection.

*cursorname*

The name to assign to this cursor.

*sql*

The `SELECT` statement that you wish to execute in the remote database, for example `select * from pg_class`.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a `NOTICE`, and the function's return value is set to `ERROR`.

### Return Value

Returns status, either `OK` or `ERROR`.

### Notes

Since a cursor can only persist within a transaction, `dblink_open` starts an explicit transaction block (`BEGIN`) on the remote side, if the remote side was not already within a transaction. This transaction will be closed again when the matching `dblink_close` is executed. Note that if you use `dblink_exec` to change data between `dblink_open` and `dblink_close`, and then an error occurs or you use `dblink_disconnect` before `dblink_close`, your change *will be lost* because the transaction will be aborted.

### Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
dblink_connect
```

-----

OK  
(1 row)

```
SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');  
dblink_open
```

-----

OK  
(1 row)

## dblink\_fetch

`dblink_fetch` — returns rows from an open cursor in a remote database

## Synopsis

```
dblink_fetch(text cursorname, int howmany [, bool fail_on_error])
  returns setof record
dblink_fetch(text connname, text cursorname, int howmany [, bool
  fail_on_error]) returns setof record
```

## Description

`dblink_fetch` fetches rows from a cursor previously established by `dblink_open`.

## Arguments

*connname*

Name of the connection to use; omit this parameter to use the unnamed connection.

*cursorname*

The name of the cursor to fetch from.

*howmany*

The maximum number of rows to retrieve. The next *howmany* rows are fetched, starting at the current cursor position, moving forward. Once the cursor has reached its end, no more rows are produced.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

## Return Value

The function returns the row(s) fetched from the cursor. To use this function, you will need to specify the expected set of columns, as previously discussed for `dblink`.

## Notes

On a mismatch between the number of return columns specified in the FROM clause, and the actual number of columns returned by the remote cursor, an error will be thrown. In this event, the remote cursor is still advanced by as many rows as it would have been if the error had not occurred. The same is true for any other error occurring in the local query after the remote FETCH has been done.

## Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
dblink_connect
-----
```

```
OK
(1 row)
```

```
SELECT dblink_open('foo', 'select proname, prosrc from pg_proc
where proname like ''bytea%'');
dblink_open
```

```
-----
OK
(1 row)
```

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

```
funcname | source
-----+-----
byteacat | byteacat
byteacmp | byteacmp
byteaeq  | byteaeq
byteage  | byteage
byteagt  | byteagt
(5 rows)
```

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

```
funcname | source
-----+-----
byteain  | byteain
byteale  | byteale
bytealike| bytealike
bytealt  | bytealt
byteane  | byteane
(5 rows)
```

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

```
funcname | source
-----+-----
byteanlike| byteanlike
byteaout  | byteaout
(2 rows)
```

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

```
funcname | source
-----+-----
(0 rows)
```

## dblink\_close

`dblink_close` — closes a cursor in a remote database

## Synopsis

```
dblink_close(text cursorname [, bool fail_on_error]) returns text
dblink_close(text connname, text cursorname [, bool fail_on_error])
returns text
```

## Description

`dblink_close` closes a cursor previously opened with `dblink_open`.

## Arguments

*connname*

Name of the connection to use; omit this parameter to use the unnamed connection.

*cursorname*

The name of the cursor to close.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to ERROR.

## Return Value

Returns status, either OK or ERROR.

## Notes

If `dblink_open` started an explicit transaction block, and this is the last remaining open cursor in this connection, `dblink_close` will issue the matching COMMIT.

## Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
 dblink_connect
-----
OK
(1 row)

SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');
 dblink_open
-----
OK
(1 row)

SELECT dblink_close('foo');
```



dblink\_close

-----  
OK  
(1 row)

## **dblink\_get\_connections**

`dblink_get_connections` — returns the names of all open named dblink connections

### **Synopsis**

```
dblink_get_connections() returns text[]
```

### **Description**

`dblink_get_connections` returns an array of the names of all open named dblink connections.

### **Return Value**

Returns a text array of connection names, or NULL if none.

### **Examples**

```
SELECT dblink_get_connections();
```

## **dblink\_error\_message**

`dblink_error_message` — gets last error message on the named connection

### **Synopsis**

```
dblink_error_message(text connname) returns text
```

### **Description**

`dblink_error_message` fetches the most recent remote error message for a given connection.

### **Arguments**

*connname*

Name of the connection to use.

### **Return Value**

Returns last error message, or OK if there has been no error in this connection.

### **Notes**

When asynchronous queries are initiated by `dblink_send_query`, the error message associated with the connection might not get updated until the server's response message is consumed. This typically means that `dblink_is_busy` or `dblink_get_result` should be called prior to `dblink_error_message`, so that any error generated by the asynchronous query will be visible.

### **Examples**

```
SELECT dblink_error_message('dtest1');
```

## **dblink\_send\_query**

`dblink_send_query` — sends an async query to a remote database

### **Synopsis**

```
dblink_send_query(text connname, text sql) returns int
```

### **Description**

`dblink_send_query` sends a query to be executed asynchronously, that is, without immediately waiting for the result. There must not be an async query already in progress on the connection.

After successfully dispatching an async query, completion status can be checked with `dblink_is_busy`, and the results are ultimately collected with `dblink_get_result`. It is also possible to attempt to cancel an active async query using `dblink_cancel_query`.

### **Arguments**

*connname*

Name of the connection to use.

*sql*

The SQL statement that you wish to execute in the remote database, for example `select * from pg_class`.

### **Return Value**

Returns 1 if the query was successfully dispatched, 0 otherwise.

### **Examples**

```
SELECT dblink_send_query('dtest1', 'SELECT * FROM foo WHERE f1 < 3');
```

## **dblink\_is\_busy**

`dblink_is_busy` — checks if connection is busy with an async query

### **Synopsis**

```
dblink_is_busy(text connname) returns int
```

### **Description**

`dblink_is_busy` tests whether an async query is in progress.

### **Arguments**

*connname*

Name of the connection to check.

### **Return Value**

Returns 1 if connection is busy, 0 if it is not busy. If this function returns 0, it is guaranteed that `dblink_get_result` will not block.

### **Examples**

```
SELECT dblink_is_busy('dtest1');
```

## dblink\_get\_notify

dblink\_get\_notify — retrieve async notifications on a connection

### Synopsis

```
dblink_get_notify() returns setof (notify_name text, be_pid int,
  extra text)
dblink_get_notify(text connname) returns setof (notify_name text,
  be_pid int, extra text)
```

### Description

dblink\_get\_notify retrieves notifications on either the unnamed connection, or on a named connection if specified. To receive notifications via dblink, LISTEN must first be issued, using dblink\_exec. For details see LISTEN and NOTIFY.

### Arguments

*connname*

The name of a named connection to get notifications on.

### Return Value

Returns setof (notify\_name text, be\_pid int, extra text), or an empty set if none.

### Examples

```
SELECT dblink_exec('LISTEN virtual');
dblink_exec
-----
LISTEN
(1 row)

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-----+-----+-----
(0 rows)

NOTIFY virtual;
NOTIFY

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-----+-----+-----
 virtual    | 1229  |
(1 row)
```

## dblink\_get\_result

`dblink_get_result` — gets an async query result

### Synopsis

```
dblink_get_result(text connname [, bool fail_on_error]) returns
  setof record
```

### Description

`dblink_get_result` collects the results of an asynchronous query previously sent with `dblink_send_query`. If the query is not already completed, `dblink_get_result` will wait until it is.

### Arguments

*connname*

Name of the connection to use.

*fail\_on\_error*

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

### Return Value

For an async query (that is, a SQL statement returning rows), the function returns the row(s) produced by the query. To use this function, you will need to specify the expected set of columns, as previously discussed for `dblink`.

For an async command (that is, a SQL statement not returning rows), the function returns a single row with a single text column containing the command's status string. It is still necessary to specify that the result will have a single text column in the calling FROM clause.

### Notes

This function *must* be called if `dblink_send_query` returned 1. It must be called once for each query sent, and one additional time to obtain an empty set result, before the connection can be used again.

When using `dblink_send_query` and `dblink_get_result`, `dblink` fetches the entire remote query result before returning any of it to the local query processor. If the query returns a large number of rows, this can result in transient memory bloat in the local session. It may be better to open such a query as a cursor with `dblink_open` and then fetch a manageable number of rows at a time. Alternatively, use plain `dblink()`, which avoids memory bloat by spooling large result sets to disk.

### Examples

```
contrib_regression=# SELECT dblink_connect('dtest1',
  'dbname=contrib_regression');
dblink_connect
-----
```

OK  
(1 row)

```
contrib_regression=# SELECT * FROM
contrib_regression=# dblink_send_query('dtest1', 'select * from foo
where f1 < 3') AS t1;
t1
```

```
----
 1
(1 row)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
t1(f1 int, f2 text, f3 text[]);
f1 | f2 |      f3
```

```
----+-----+-----
 0 | a  | {a0,b0,c0}
 1 | b  | {a1,b1,c1}
 2 | c  | {a2,b2,c2}
(3 rows)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
t1(f1 int, f2 text, f3 text[]);
f1 | f2 | f3
```

```
----+-----+-----
(0 rows)
```

```
contrib_regression=# SELECT * FROM
contrib_regression=# dblink_send_query('dtest1', 'select * from foo
where f1 < 3; select * from foo where f1 > 6') AS t1;
t1
```

```
----
 1
(1 row)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
t1(f1 int, f2 text, f3 text[]);
f1 | f2 |      f3
```

```
----+-----+-----
 0 | a  | {a0,b0,c0}
 1 | b  | {a1,b1,c1}
 2 | c  | {a2,b2,c2}
(3 rows)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
t1(f1 int, f2 text, f3 text[]);
f1 | f2 |      f3
```

```
----+-----+-----
 7 | h  | {a7,b7,c7}
 8 | i  | {a8,b8,c8}
 9 | j  | {a9,b9,c9}
10 | k  | {a10,b10,c10}
(4 rows)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
t1(f1 int, f2 text, f3 text[]);
f1 | f2 | f3
```

```
----+-----+-----
(0 rows)
```



## **dblink\_cancel\_query**

`dblink_cancel_query` — cancels any active query on the named connection

### **Synopsis**

```
dblink_cancel_query(text connname) returns text
```

### **Description**

`dblink_cancel_query` attempts to cancel any query that is in progress on the named connection. Note that this is not certain to succeed (since, for example, the remote query might already have finished). A cancel request simply improves the odds that the query will fail soon. You must still complete the normal query protocol, for example by calling `dblink_get_result`.

### **Arguments**

*connname*

Name of the connection to use.

### **Return Value**

Returns OK if the cancel request has been sent, or the text of an error message on failure.

### **Examples**

```
SELECT dblink_cancel_query('dtest1');
```

## dblink\_get\_pkey

`dblink_get_pkey` — returns the positions and field names of a relation's primary key fields

## Synopsis

```
dblink_get_pkey(text relname) returns setof dblink_pkey_results
```

## Description

`dblink_get_pkey` provides information about the primary key of a relation in the local database. This is sometimes useful in generating queries to be sent to remote databases.

## Arguments

*relname*

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

## Return Value

Returns one row for each primary key field, or no rows if the relation has no primary key. The result row type is defined as

```
CREATE TYPE dblink_pkey_results AS (position int, colname text);
```

The `position` column simply runs from 1 to *N*; it is the number of the field within the primary key, not the number within the table's columns.

## Examples

```
CREATE TABLE foobar (  
    f1 int,  
    f2 int,  
    f3 int,  
    PRIMARY KEY (f1, f2, f3)  
);  
CREATE TABLE  
  
SELECT * FROM dblink_get_pkey('foobar');  
 position | colname  
-----+-----  
         1 | f1  
         2 | f2  
         3 | f3  
(3 rows)
```

## dblink\_build\_sql\_insert

`dblink_build_sql_insert` — builds an INSERT statement using a local tuple, replacing the primary key field values with alternative supplied values

### Synopsis

```
dblink_build_sql_insert(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] src_pk_att_vals_array,  
                        text[] tgt_pk_att_vals_array) returns text
```

### Description

`dblink_build_sql_insert` can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL INSERT command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.)

### Arguments

*relname*

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

*primary\_key\_attnums*

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

*num\_primary\_key\_atts*

The number of primary key fields.

*src\_pk\_att\_vals\_array*

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

*tgt\_pk\_att\_vals\_array*

Values of the primary key fields to be placed in the resulting INSERT command. Each field is represented in text form.

### Return Value

Returns the requested SQL statement as text.

### Notes

As of LightDB 9.0, the attribute numbers in *primary\_key\_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous

versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

## Examples

```
SELECT dblink_build_sql_insert('foo', '1 2', 2, '{"1", "a"}',
    '{"1", "b'a"}');
          dblink_build_sql_insert
-----
INSERT INTO foo(f1,f2,f3) VALUES('1','b'a','1')
(1 row)
```

## dblink\_build\_sql\_delete

`dblink_build_sql_delete` — builds a DELETE statement using supplied values for primary key field values

### Synopsis

```
dblink_build_sql_delete(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] tgt_pk_att_vals_array) returns text
```

### Description

`dblink_build_sql_delete` can be useful in doing selective replication of a local table to a remote database. It builds a SQL DELETE command that will delete the row with the given primary key values.

### Arguments

*relname*

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

*primary\_key\_attnums*

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

*num\_primary\_key\_atts*

The number of primary key fields.

*tgt\_pk\_att\_vals\_array*

Values of the primary key fields to be used in the resulting DELETE command. Each field is represented in text form.

### Return Value

Returns the requested SQL statement as text.

### Notes

As of LightDB 9.0, the attribute numbers in *primary\_key\_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

### Examples

```
SELECT dblink_build_sql_delete('"MyFoo"', '1 2', 2, '{"1", "b"}');  
      dblink_build_sql_delete
```

```
-----  
DELETE FROM "MyFoo" WHERE f1='1' AND f2='b'  
(1 row)
```

## dblink\_build\_sql\_update

`dblink_build_sql_update` — builds an UPDATE statement using a local tuple, replacing the primary key field values with alternative supplied values

### Synopsis

```
dblink_build_sql_update(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] src_pk_att_vals_array,  
                        text[] tgt_pk_att_vals_array) returns text
```

### Description

`dblink_build_sql_update` can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL UPDATE command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.) The UPDATE command always assigns all fields of the row — the main difference between this and `dblink_build_sql_insert` is that it's assumed that the target row already exists in the remote table.

### Arguments

*relname*

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

*primary\_key\_attnums*

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

*num\_primary\_key\_atts*

The number of primary key fields.

*src\_pk\_att\_vals\_array*

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

*tgt\_pk\_att\_vals\_array*

Values of the primary key fields to be placed in the resulting UPDATE command. Each field is represented in text form.

### Return Value

Returns the requested SQL statement as text.

### Notes

As of LightDB 9.0, the attribute numbers in *primary\_key\_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

## Examples

```
SELECT dblink_build_sql_update('foo', '1 2', 2, '{"1", "a"}',
    '{"1", "b"}');
          dblink_build_sql_update
-----
UPDATE foo SET f1='1',f2='b',f3='1' WHERE f1='1' AND f2='b'
(1 row)
```

## F.12. dict\_int

`dict_int` is an example of an add-on dictionary template for full-text search. The motivation for this example dictionary is to control the indexing of integers (signed and unsigned), allowing such numbers to be indexed while preventing excessive growth in the number of unique words, which greatly affects the performance of searching.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.12.1. Configuration

The dictionary accepts three options:

- The `maxlen` parameter specifies the maximum number of digits allowed in an integer word. The default value is 6.
- The `rejectlong` parameter specifies whether an overlength integer should be truncated or ignored. If `rejectlong` is `false` (the default), the dictionary returns the first `maxlen` digits of the integer. If `rejectlong` is `true`, the dictionary treats an overlength integer as a stop word, so that it will not be indexed. Note that this also means that such an integer cannot be searched for.
- The `absval` parameter specifies whether leading “+” or “-” signs should be removed from integer words. The default is `false`. When `true`, the sign is removed before `maxlen` is applied.

### F.12.2. Usage

Installing the `dict_int` extension creates a text search template `intdict_template` and a dictionary `intdict` based on it, with the default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY intdict (MAXLEN = 4, REJECTLONG
= true);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb# select ts_lexize('intdict', '12345678');
      ts_lexize
-----
{123456}
```

but real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:



```
ALTER TEXT SEARCH CONFIGURATION english
ALTER MAPPING FOR int, uint WITH intdict;
```

## F.13. dict\_xsyn

`dict_xsyn` (Extended Synonym Dictionary) is an example of an add-on dictionary template for full-text search. This dictionary type replaces words with groups of their synonyms, and so makes it possible to search for a word using any of its synonyms.

### F.13.1. Configuration

A `dict_xsyn` dictionary accepts the following options:

- `matchorig` controls whether the original word is accepted by the dictionary. Default is `true`.
- `matchsynonyms` controls whether the synonyms are accepted by the dictionary. Default is `false`.
- `keeporig` controls whether the original word is included in the dictionary's output. Default is `true`.
- `keepsynonyms` controls whether the synonyms are included in the dictionary's output. Default is `true`.
- `rules` is the base name of the file containing the list of synonyms. This file must be stored in `$(SHAREDIR)/tsearch_data/` (where `$(SHAREDIR)` means the LightDB installation's shared-data directory). Its name must end in `.rules` (which is not to be included in the `rules` parameter).

The rules file has the following format:

- Each line represents a group of synonyms for a single word, which is given first on the line. Synonyms are separated by whitespace, thus:

```
word syn1 syn2 syn3
```

- The sharp (#) sign is a comment delimiter. It may appear at any position in a line. The rest of the line will be skipped.

Look at `xsyn_sample.rules`, which is installed in `$(SHAREDIR)/tsearch_data/`, for an example.

### F.13.2. Usage

Installing the `dict_xsyn` extension creates a text search template `xsyn_template` and a dictionary `xsyn` based on it, with default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
KEEPORIG=false);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb=# SELECT ts_lexize('xsyn', 'word');
       ts_lexize
-----
{syn1,syn2,syn3}
```

```

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
      KEEPORIG=true);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'word');
      ts_lexize
-----
 {word,syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
      KEEPORIG=false, MATCHSYNONYMS=true);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
      ts_lexize
-----
 {syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
      KEEPORIG=true, MATCHORIG=false, KEEPSYNONYMS=false);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
      ts_lexize
-----
 {word}

```

Real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:

```

ALTER TEXT SEARCH CONFIGURATION english
      ALTER MAPPING FOR word, asciiword WITH xsyn, english_stem;

```

## F.14. file\_fdw

The `file_fdw` module provides the foreign-data wrapper `file_fdw`, which can be used to access data files in the server's file system, or to execute programs on the server and read their output. The data file or program output must be in a format that can be read by `COPY FROM`; see `COPY` for details. Access to data files is currently read-only.

A foreign table created using this wrapper can have the following options:

`filename`

Specifies the file to be read. Relative paths are relative to the data directory. Either `filename` or `program` must be specified, but not both.

`program`

Specifies the command to be executed. The standard output of this command will be read as though `COPY FROM PROGRAM` were used. Either `program` or `filename` must be specified, but not both.

`format`

Specifies the data format, the same as `COPY`'s `FORMAT` option.

`header`

Specifies whether the data has a header line, the same as `COPY`'s `HEADER` option.

`delimiter`

Specifies the data delimiter character, the same as COPY's DELIMITER option.

`quote`

Specifies the data quote character, the same as COPY's QUOTE option.

`escape`

Specifies the data escape character, the same as COPY's ESCAPE option.

`null`

Specifies the data null string, the same as COPY's NULL option.

`encoding`

Specifies the data encoding, the same as COPY's ENCODING option.

Note that while COPY allows options such as HEADER to be specified without a corresponding value, the foreign table option syntax requires a value to be present in all cases. To activate COPY options typically written without a value, you can pass the value TRUE, since all such options are Booleans.

A column of a foreign table created using this wrapper can have the following options:

`force_not_null`

This is a Boolean option. If true, it specifies that values of the column should not be matched against the null string (that is, the table-level null option). This has the same effect as listing the column in COPY's FORCE\_NOT\_NULL option.

`force_null`

This is a Boolean option. If true, it specifies that values of the column which match the null string are returned as NULL even if the value is quoted. Without this option, only unquoted values matching the null string are returned as NULL. This has the same effect as listing the column in COPY's FORCE\_NULL option.

COPY's FORCE\_QUOTE option is currently not supported by `file_fdw`.

These options can only be specified for a foreign table or its columns, not in the options of the `file_fdw` foreign-data wrapper, nor in the options of a server or user mapping using the wrapper.

Changing table-level options requires being a superuser or having the privileges of the default role `pg_read_server_files` (to use a filename) or the default role `pg_execute_server_program` (to use a program), for security reasons: only certain users should be able to control which file is read or which program is run. In principle regular users could be allowed to change the other options, but that's not supported at present.

When specifying the `program` option, keep in mind that the option string is executed by the shell. If you need to pass any arguments to the command that come from an untrusted source, you must be careful to strip or escape any characters that might have special meaning to the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in it.

For a foreign table using `file_fdw`, EXPLAIN shows the name of the file to be read or program to be run. For a file, unless `COSTS OFF` is specified, the file size (in bytes) is shown as well.

### **Example F.1. Create a Foreign Table for LightDB CSV Logs**

One of the obvious uses for `file_fdw` is to make the LightDB activity log available as a table for querying. To do this, first you must be logging to a CSV file, which here we will call `ltlog.csv`. First, install `file_fdw` as an extension:

```
CREATE EXTENSION file_fdw;
```

Then create a foreign server:

```
CREATE SERVER ltlog FOREIGN DATA WRAPPER file_fdw;
```

Now you are ready to create the foreign data table. Using the `CREATE FOREIGN TABLE` command, you will need to define the columns for the table, the CSV file name, and its format:

```
CREATE FOREIGN TABLE ltlog (  
  log_time timestamp(3) with time zone,  
  user_name text,  
  database_name text,  
  process_id integer,  
  connection_from text,  
  session_id text,  
  session_line_num bigint,  
  command_tag text,  
  session_start_time timestamp with time zone,  
  virtual_transaction_id text,  
  transaction_id bigint,  
  error_severity text,  
  sql_state_code text,  
  message text,  
  detail text,  
  hint text,  
  internal_query text,  
  internal_query_pos integer,  
  context text,  
  query text,  
  query_pos integer,  
  location text,  
  application_name text,  
  backend_type text  
) SERVER ltlog  
OPTIONS ( filename 'log/ltlog.csv', format 'csv' );
```

That's it — now you can query your log directly. In production, of course, you would need to define some way to deal with log rotation.

## F.15. fuzzystmatch

The `fuzzystmatch` module provides several functions to determine similarities and distance between strings.

### Caution

At present, the `soundex`, `metaphone`, `dmetaphone`, and `dmetaphone_alt` functions do not work well with multibyte encodings (such as UTF-8).

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

## F.15.1. Soundex

The Soundex system is a method of matching similar-sounding names by converting them to the same code. It was initially used by the United States Census in 1880, 1900, and 1910. Note that Soundex is not very useful for non-English names.

The `fuzzystrmatch` module provides two functions for working with Soundex codes:

```
soundex(text) returns text  
difference(text, text) returns int
```

The `soundex` function converts a string to its Soundex code. The `difference` function converts two strings to their Soundex codes and then reports the number of matching code positions. Since Soundex codes have four characters, the result ranges from zero to four, with zero being no match and four being an exact match. (Thus, the function is misnamed — `similarity` would have been a better name.)

Here are some usage examples:

```
SELECT soundex('hello world!');  
  
SELECT soundex('Anne'), soundex('Ann'), difference('Anne', 'Ann');  
SELECT soundex('Anne'), soundex('Andrew'), difference('Anne',  
  'Andrew');  
SELECT soundex('Anne'), soundex('Margaret'), difference('Anne',  
  'Margaret');  
  
CREATE TABLE s (nm text);  
  
INSERT INTO s VALUES ('john');  
INSERT INTO s VALUES ('joan');  
INSERT INTO s VALUES ('wobbly');  
INSERT INTO s VALUES ('jack');  
  
SELECT * FROM s WHERE soundex(nm) = soundex('john');  
  
SELECT * FROM s WHERE difference(s.nm, 'john') > 2;
```

## F.15.2. Levenshtein

This function calculates the Levenshtein distance between two strings:

```
levenshtein(text source, text target, int ins_cost, int del_cost,  
  int sub_cost) returns int  
levenshtein(text source, text target) returns int  
levenshtein_less_equal(text source, text target, int ins_cost, int  
  del_cost, int sub_cost, int max_d) returns int  
levenshtein_less_equal(text source, text target, int max_d) returns  
  int
```

Both `source` and `target` can be any non-null string, with a maximum of 255 characters. The cost parameters specify how much to charge for a character insertion, deletion, or substitution, respectively. You can omit the cost parameters, as in the second version of the function; in that case they all default to 1.

`levenshtein_less_equal` is an accelerated version of the Levenshtein function for use when only small distances are of interest. If the actual distance is less than or equal to `max_d`, then `levenshtein_less_equal` returns the correct distance; otherwise it returns some value greater than `max_d`. If `max_d` is negative then the behavior is the same as `levenshtein`.

Examples:

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL');
 levenshtein
-----
                2
(1 row)
```

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL', 2, 1, 1);
 levenshtein
-----
                3
(1 row)
```

```
test=# SELECT levenshtein_less_equal('extensive', 'exhaustive', 2);
 levenshtein_less_equal
-----
                                3
(1 row)
```

```
test=# SELECT levenshtein_less_equal('extensive', 'exhaustive', 4);
 levenshtein_less_equal
-----
                                4
(1 row)
```

### F.15.3. Metaphone

Metaphone, like Soundex, is based on the idea of constructing a representative code for an input string. Two strings are then deemed similar if they have the same codes.

This function calculates the metaphone code of an input string:

`metaphone(text source, int max_output_length)` returns `text`

`source` has to be a non-null string with a maximum of 255 characters. `max_output_length` sets the maximum length of the output metaphone code; if longer, the output is truncated to this length.

Example:

```
test=# SELECT metaphone('GUMBO', 4);
 metaphone
-----
        KM
(1 row)
```

### F.15.4. Double Metaphone

The Double Metaphone system computes two “sounds like” strings for a given input string — a “primary” and an “alternate”. In most cases they are the same, but for non-English names especially

they can be a bit different, depending on pronunciation. These functions compute the primary and alternate codes:

```
dmetaphone(text source) returns text
dmetaphone_alt(text source) returns text
```

There is no length limit on the input strings.

Example:

```
test=# SELECT dmetaphone('gumbo');
 dmetaphone
-----
      KMP
(1 row)
```

## F.16. hstore

This module implements the `hstore` data type for storing sets of key/value pairs within a single LightDB value. This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data. Keys and values are simply text strings.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.16.1. hstore External Representation

The text representation of an `hstore`, used for input and output, includes zero or more *key => value* pairs separated by commas. Some examples:

```
k => v
foo => bar, baz => whatever
"1-a" => "anything at all"
```

The order of the pairs is not significant (and may not be reproduced on output). Whitespace between pairs or around the `=>` sign is ignored. Double-quote keys and values that include whitespace, commas, `=`s or `>`s. To include a double quote or a backslash in a key or value, escape it with a backslash.

Each key in an `hstore` is unique. If you declare an `hstore` with duplicate keys, only one will be stored in the `hstore` and there is no guarantee as to which will be kept:

```
SELECT 'a=>1,a=>2'::hstore;
 hstore
-----
"a"=>"1"
```

A value (but not a key) can be an SQL `NULL`. For example:

```
key => NULL
```

The `NULL` keyword is case-insensitive. Double-quote the `NULL` to treat it as the ordinary string “`NULL`”.

**Note**

Keep in mind that the `hstore` text format, when used for input, applies *before* any required quoting or escaping. If you are passing an `hstore` literal via a parameter, then no additional processing is needed. But if you're passing it as a quoted literal constant, then any single-quote characters and (depending on the setting of the `standard_conforming_strings` configuration parameter) backslash characters need to be escaped correctly. See Section 4.1.2.1 for more on the handling of string constants.

On output, double quotes always surround keys and values, even when it's not strictly necessary.

**F.16.2. hstore Operators and Functions**

The operators provided by the `hstore` module are shown in Table F.5, the functions in Table F.6.

**Table F.5. hstore Operators**

<b>Operator</b>	<b>Description</b>	<b>Example(s)</b>
<code>hstore -&gt; text → text</code>	Returns value associated with given key, or NULL if not present.	<code>'a=&gt;x, b=&gt;y'::hstore -&gt; 'a' → x</code>
<code>hstore -&gt; text[] → text[]</code>	Returns values associated with given keys, or NULL if not present.	<code>'a=&gt;x, b=&gt;y, c=&gt;z'::hstore -&gt; ARRAY['c','a'] → {"z","x"}</code>
<code>hstore    hstore → hstore</code>	Concatenates two <code>hstore</code> s.	<code>'a=&gt;b, c=&gt;d'::hstore    'c=&gt;x, d=&gt;q'::hstore → "a"=&gt;"b", "c"=&gt;"x", "d"=&gt;"q"</code>
<code>hstore ? text → boolean</code>	Does <code>hstore</code> contain key?	<code>'a=&gt;1'::hstore ? 'a' → t</code>
<code>hstore ?&amp; text[] → boolean</code>	Does <code>hstore</code> contain all the specified keys?	<code>'a=&gt;1,b=&gt;2'::hstore ?&amp; ARRAY['a','b'] → t</code>
<code>hstore ?  text[] → boolean</code>	Does <code>hstore</code> contain any of the specified keys?	<code>'a=&gt;1,b=&gt;2'::hstore ?  ARRAY['b','c'] → t</code>
<code>hstore @&gt; hstore → boolean</code>	Does left operand contain right?	<code>'a=&gt;b, b=&gt;1, c=&gt;NULL'::hstore @&gt; 'b=&gt;1' → t</code>
<code>hstore &lt;@ hstore → boolean</code>	Is left operand contained in right?	<code>'a=&gt;c'::hstore &lt;@ 'a=&gt;b, b=&gt;1, c=&gt;NULL' → f</code>
<code>hstore - text → hstore</code>		



<b>Operator</b>	<b>Description</b> <b>Example(s)</b>
	Deletes key from left operand. <code>'a=&gt;1, b=&gt;2, c=&gt;3'::hstore - 'b'::text → "a"=&gt;"1", "c"=&gt;"3"</code>
<code>hstore - text[] → hstore</code>	Deletes keys from left operand. <code>'a=&gt;1, b=&gt;2, c=&gt;3'::hstore - ARRAY['a','b'] → "c"=&gt;"3"</code>
<code>hstore - hstore → hstore</code>	Deletes pairs from left operand that match pairs in the right operand. <code>'a=&gt;1, b=&gt;2, c=&gt;3'::hstore - 'a=&gt;4, b=&gt;2'::hstore → "a"=&gt;"1", "c"=&gt;"3"</code>
<code>anyelement #= hstore → anyelement</code>	Replaces fields in the left operand (which must be a composite type) with matching values from hstore. <code>ROW(1,3) #= 'f1=&gt;11'::hstore → (11,3)</code>
<code>%% hstore → text[]</code>	Converts hstore to an array of alternating keys and values. <code>%% 'a=&gt;foo, b=&gt;bar'::hstore → {a,foo,b,bar}</code>
<code>%# hstore → text[]</code>	Converts hstore to a two-dimensional key/value array. <code>%# 'a=&gt;foo, b=&gt;bar'::hstore → {{a,foo},{b,bar}}</code>

**Note**

Prior to LightDB 8.2, the containment operators @> and <@ were called @ and ~, respectively. These names are still available, but are deprecated and will eventually be removed. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!

**Table F.6. hstore Functions**

<b>Function</b>	<b>Description</b> <b>Example(s)</b>
<code>hstore ( record ) → hstore</code>	Constructs an hstore from a record or row. <code>hstore(ROW(1,2)) → "f1"=&gt;"1", "f2"=&gt;"2"</code>
<code>hstore ( text[] ) → hstore</code>	Constructs an hstore from an array, which may be either a key/value array, or a two-dimensional array. <code>hstore(ARRAY['a','1','b','2']) → "a"=&gt;"1", "b"=&gt;"2"</code> <code>hstore(ARRAY[['c','3'],['d','4']]) → "c"=&gt;"3", "d"=&gt;"4"</code>
<code>hstore ( text[], text[] ) → hstore</code>	Constructs an hstore from separate key and value arrays. <code>hstore(ARRAY['a','b'], ARRAY['1','2']) → "a"=&gt;"1", "b"=&gt;"2"</code>

<b>Function</b>	<b>Description</b>	<b>Example(s)</b>
<code>hstore ( text, text ) → hstore</code>	Makes a single-item hstore.	<code>hstore( 'a', 'b' ) → "a"=&gt;"b"</code>
<code>akeys ( hstore ) → text [ ]</code>	Extracts an hstore's keys as an array.	<code>akeys( 'a=&gt;1,b=&gt;2' ) → {a,b}</code>
<code>skeys ( hstore ) → setof text</code>	Extracts an hstore's keys as a set.	<code>skeys( 'a=&gt;1,b=&gt;2' ) →</code>  <code>a</code> <code>b</code>
<code>avals ( hstore ) → text [ ]</code>	Extracts an hstore's values as an array.	<code>avals( 'a=&gt;1,b=&gt;2' ) → {1,2}</code>
<code>svals ( hstore ) → setof text</code>	Extracts an hstore's values as a set.	<code>svals( 'a=&gt;1,b=&gt;2' ) →</code>  <code>1</code> <code>2</code>
<code>hstore_to_array ( hstore ) → text [ ]</code>	Extracts an hstore's keys and values as an array of alternating keys and values.	<code>hstore_to_array( 'a=&gt;1,b=&gt;2' ) → {a,1,b,2}</code>
<code>hstore_to_matrix ( hstore ) → text [ ]</code>	Extracts an hstore's keys and values as a two-dimensional array.	<code>hstore_to_matrix( 'a=&gt;1,b=&gt;2' ) → {{a,1},{b,2}}</code>
<code>hstore_to_json ( hstore ) → json</code>	Converts an hstore to a json value, converting all non-null values to JSON strings. This function is used implicitly when an hstore value is cast to json.	<code>hstore_to_json( "a key"=&gt;1, b=&gt;t, c=&gt;null, d=&gt;12345, e=&gt;012345, f=&gt;1.234, g=&gt;2.345e+4' ) → {"a key": "1", "b": "t", "c": null, "d": "12345", "e": "012345", "f": "1.234", "g": "2.345e+4"}</code>
<code>hstore_to_jsonb ( hstore ) → jsonb</code>	Converts an hstore to a jsonb value, converting all non-null values to JSON strings. This function is used implicitly when an hstore value is cast to jsonb.	<code>hstore_to_jsonb( "a key"=&gt;1, b=&gt;t, c=&gt;null, d=&gt;12345, e=&gt;012345, f=&gt;1.234, g=&gt;2.345e+4' ) → {"a key": "1", "b": "t", "c": null, "d": "12345", "e": "012345", "f": "1.234", "g": "2.345e+4"}</code>
<code>hstore_to_json_loose ( hstore ) → json</code>		

Function	Description	Example(s)						
	Converts an hstore to a json value, but attempts to distinguish numerical and Boolean values so they are unquoted in the JSON.	<pre>hstore_to_json_loose('"a key"=&gt;1, b=&gt;t, c=&gt;null, d=&gt;12345, e=&gt;012345, f=&gt;1.234, g=&gt;2.345e+4') → {"a key": 1, "b": true, "c": null, "d": 12345, "e": "012345", "f": 1.234, "g": 2.345e+4}</pre>						
	Converts an hstore to a jsonb value, but attempts to distinguish numerical and Boolean values so they are unquoted in the JSON.	<pre>hstore_to_jsonb_loose('"a key"=&gt;1, b=&gt;t, c=&gt;null, d=&gt;12345, e=&gt;012345, f=&gt;1.234, g=&gt;2.345e+4') → {"a key": 1, "b": true, "c": null, "d": 12345, "e": "012345", "f": 1.234, "g": 2.345e+4}</pre>						
	Extracts a subset of an hstore containing only the specified keys.	<pre>slice('a=&gt;1,b=&gt;2,c=&gt;3'::hstore, ARRAY['b','c','x']) → "b"=&gt;"2", "c"=&gt;"3"</pre>						
	Extracts an hstore's keys and values as a set of records.	<pre>select * from each('a=&gt;1,b=&gt;2') →</pre> <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>key</th> <th>value</th> </tr> </thead> <tbody> <tr> <td>a</td> <td>1</td> </tr> <tr> <td>b</td> <td>2</td> </tr> </tbody> </table>	key	value	a	1	b	2
key	value							
a	1							
b	2							
	Does hstore contain key?	<pre>exist('a=&gt;1', 'a') → t</pre>						
	Does hstore contain a non-NULL value for key?	<pre>defined('a=&gt;NULL', 'a') → f</pre>						
	Deletes pair with matching key.	<pre>delete('a=&gt;1,b=&gt;2', 'b') → "a"=&gt;"1"</pre>						
	Deletes pairs with matching keys.	<pre>delete('a=&gt;1,b=&gt;2,c=&gt;3', ARRAY['a','b']) → "c"=&gt;"3"</pre>						
	Deletes pairs matching those in the second argument.	<pre>delete('a=&gt;1,b=&gt;2', 'a=&gt;4,b=&gt;2'::hstore) → "a"=&gt;"1"</pre>						
	Replaces fields in the left operand (which must be a composite type) with matching values from hstore.	<pre>populate_record( anyelement, hstore ) → anyelement</pre>						

Function
<b>Description</b> <b>Example(s)</b>
<code>populate_record(ROW(1,2), 'f1=&gt;42'::hstore) → (42,2)</code>

## F.16.3. Indexes

`hstore` has GiST and GIN index support for the `@>`, `?`, `?&` and `?|` operators. For example:

```
CREATE INDEX hidx ON testhstore USING GIST (h);
```

```
CREATE INDEX hidx ON testhstore USING GIN (h);
```

`gist_hstore_ops` GiST opclass approximates a set of key/value pairs as a bitmap signature. Its optional integer parameter `siglen` determines the signature length in bytes. The default length is 16 bytes. Valid values of signature length are between 1 and 2024 bytes. Longer signatures lead to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

Example of creating such an index with a signature length of 32 bytes:

```
CREATE INDEX hidx ON testhstore USING GIST (h
gist_hstore_ops(siglen=32));
```

`hstore` also supports `btree` or `hash` indexes for the `=` operator. This allows `hstore` columns to be declared `UNIQUE`, or to be used in `GROUP BY`, `ORDER BY` or `DISTINCT` expressions. The sort ordering for `hstore` values is not particularly useful, but these indexes may be useful for equivalence lookups. Create indexes for `=` comparisons as follows:

```
CREATE INDEX hidx ON testhstore USING BTREE (h);
```

```
CREATE INDEX hidx ON testhstore USING HASH (h);
```

## F.16.4. Examples

Add a key, or update an existing key with a new value:

```
UPDATE tab SET h = h || hstore('c', '3');
```

Delete a key:

```
UPDATE tab SET h = delete(h, 'k1');
```

Convert a record to an `hstore`:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');
```

```
SELECT hstore(t) FROM test AS t;
           hstore
```

```
-----
"col1"=>"123", "col2"=>"foo", "col3"=>"bar"
(1 row)
```

Convert an hstore to a predefined record type:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);

SELECT * FROM populate_record(null::test,
                              '"col1"=>"456", "col2"=>"zzz"');

 col1 | col2 | col3
-----+-----+-----
  456 | zzz  |
(1 row)
```

Modify an existing record using the values from an hstore:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');

SELECT (r).* FROM (SELECT t #= '"col3"=>"baz"' AS r FROM test t) s;

 col1 | col2 | col3
-----+-----+-----
  123 | foo  | baz
(1 row)
```

## F.16.5. Statistics

The hstore type, because of its intrinsic liberality, could contain a lot of different keys. Checking for valid keys is the task of the application. The following examples demonstrate several techniques for checking keys and obtaining statistics.

Simple example:

```
SELECT * FROM each('aaa=>bq, b=>NULL, ""=>1');
```

Using a table:

```
SELECT (each(h)).key, (each(h)).value INTO stat FROM testhstore;
```

Online statistics:

```
SELECT key, count(*) FROM
  (SELECT (each(h)).key FROM testhstore) AS stat
GROUP BY key
ORDER BY count DESC, key;

 key      | count
-----+-----
 line     |    883
 query    |    207
 pos      |    203
 node     |    202
 space    |    197
 status   |    195
 public   |    194
 title    |    190
 org      |    189
.....
```

## F.16.6. Compatibility

As of LightDB 9.0, `hstore` uses a different internal representation than previous versions. This presents no obstacle for dump/restore upgrades since the text representation (used in the dump) is unchanged.

In the event of a binary upgrade, upward compatibility is maintained by having the new code recognize old-format data. This will entail a slight performance penalty when processing data that has not yet been modified by the new code. It is possible to force an upgrade of all values in a table column by doing an `UPDATE` statement as follows:

```
UPDATE tablename SET hstorecol = hstorecol || '';
```

Another way to do it is:

```
ALTER TABLE tablename ALTER hstorecol TYPE hstore USING hstorecol  
|| '';
```

The `ALTER TABLE` method requires an `ACCESS EXCLUSIVE` lock on the table, but does not result in bloating the table with old row versions.

## F.16.7. Transforms

<p style="text-align: center;"><b>Caution</b></p> <p>It is strongly recommended that the transform extensions be installed in the same schema as <code>hstore</code>. Otherwise there are installation-time security hazards if a transform extension's schema contains objects defined by a hostile user.</p>
--

## F.16.8. Authors

Oleg Bartunov <oleg@sai.msu.su>, Moscow, Moscow University, Russia

Teodor Sigaev <teodor@sigaev.ru>, Moscow, Delta-Soft Ltd., Russia

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## F.17. intagg

The `intagg` module provides an integer aggregator and an enumerator. `intagg` is now obsolete, because there are built-in functions that provide a superset of its capabilities. However, the module is still provided as a compatibility wrapper around the built-in functions.

### F.17.1. Functions

The aggregator is an aggregate function `int_array_aggregate(integer)` that produces an integer array containing exactly the integers it is fed. This is a wrapper around `array_agg`, which does the same thing for any array type.

The enumerator is a function `int_array_enum(integer[])` that returns `setof integer`. It is essentially the reverse operation of the aggregator: given an array of integers, expand it into a set of rows. This is a wrapper around `unnest`, which does the same thing for any array type.

## F.17.2. Sample Uses

Many database systems have the notion of a one to many table. Such a table usually sits between two indexed tables, for example:

```
CREATE TABLE left (id INT PRIMARY KEY, ...);
CREATE TABLE right (id INT PRIMARY KEY, ...);
CREATE TABLE one_to_many(left INT REFERENCES left, right INT
  REFERENCES right);
```

It is typically used like this:

```
SELECT right.* from right JOIN one_to_many ON (right.id =
  one_to_many.right)
  WHERE one_to_many.left = item;
```

This will return all the items in the right hand table for an entry in the left hand table. This is a very common construct in SQL.

Now, this methodology can be cumbersome with a very large number of entries in the `one_to_many` table. Often, a join like this would result in an index scan and a fetch for each right hand entry in the table for a particular left hand entry. If you have a very dynamic system, there is not much you can do. However, if you have some data which is fairly static, you can create a summary table with the aggregator.

```
CREATE TABLE summary AS
  SELECT left, int_array_aggregate(right) AS right
  FROM one_to_many
  GROUP BY left;
```

This will create a table with one row per left item, and an array of right items. Now this is pretty useless without some way of using the array; that's why there is an array enumerator. You can do

```
SELECT left, int_array_enum(right) FROM summary WHERE left = item;
```

The above query using `int_array_enum` produces the same results as

```
SELECT left, right FROM one_to_many WHERE left = item;
```

The difference is that the query against the summary table has to get only one row from the table, whereas the direct query against `one_to_many` must index scan and fetch a row for each entry.

On one system, an EXPLAIN showed a query with a cost of 8488 was reduced to a cost of 329. The original query was a join involving the `one_to_many` table, which was replaced by:

```
SELECT right, count(right) FROM
  ( SELECT left, int_array_enum(right) AS right
    FROM summary JOIN (SELECT left FROM left_table WHERE left
  = item) AS lefts
    ON (summary.left = lefts.left)
  ) AS list
  GROUP BY right
  ORDER BY count DESC;
```

## F.18. intarray

The `intarray` module provides a number of useful functions and operators for manipulating null-free arrays of integers. There is also support for indexed searches using some of the operators.

All of these operations will throw an error if a supplied array contains any NULL elements.

Many of these operations are only sensible for one-dimensional arrays. Although they will accept input arrays of more dimensions, the data is treated as though it were a linear array in storage order.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

### F.18.1. intarray Functions and Operators

The functions provided by the `intarray` module are shown in Table F.7, the operators in Table F.8.

**Table F.7. intarray Functions**

Function	Description	Example(s)
<code>icount ( integer[] )</code>	<code>→ integer</code> Returns the number of elements in the array.	<code>icount ( '{1,2,3}' :: integer[] ) → 3</code>
<code>sort ( integer[], dir text )</code>	<code>→ integer[]</code> Sorts the array in either ascending or descending order. <i>dir</i> must be <i>asc</i> or <i>desc</i> .	<code>sort ( '{1,3,2}' :: integer[], 'desc' ) → {3,2,1}</code>
<code>sort ( integer[] )</code>	<code>→ integer[]</code>	
<code>sort_asc ( integer[] )</code>	<code>→ integer[]</code> Sorts in ascending order.	<code>sort ( array[11,77,44] ) → {11,44,77}</code>
<code>sort_desc ( integer[] )</code>	<code>→ integer[]</code> Sorts in descending order.	<code>sort_desc ( array[11,77,44] ) → {77,44,11}</code>
<code>uniq ( integer[] )</code>	<code>→ integer[]</code> Removes adjacent duplicates. Often used with <code>sort</code> to remove all duplicates.	<code>uniq ( '{1,2,2,3,1,1}' :: integer[] ) → {1,2,3,1}</code> <code>uniq ( sort ( '{1,2,3,2,1}' :: integer[] ) ) → {1,2,3}</code>
<code>idx ( integer[], item integer )</code>	<code>→ integer</code> Returns index of the first array element matching <i>item</i> , or 0 if no match.	<code>idx ( array[11,22,33,22,11], 22 ) → 2</code>
<code>subarray ( integer[], start integer, len integer )</code>	<code>→ integer[]</code> Extracts the portion of the array starting at position <i>start</i> , with <i>len</i> elements.	<code>subarray ( '{1,2,3,2,1}' :: integer[], 2, 3 ) → {2,3,2}</code>
<code>subarray ( integer[], start integer )</code>	<code>→ integer[]</code> Extracts the portion of the array starting at position <i>start</i> .	<code>subarray ( '{1,2,3,2,1}' :: integer[], 2 ) → {2,3,2,1}</code>
<code>intset ( integer )</code>	<code>→ integer[]</code>	



<b>Function</b>
<b>Description</b> <b>Example(s)</b>
Makes a single-element array. <code>intset(42) → {42}</code>

**Table F.8. intarray Operators**

<b>Operator</b>
<b>Description</b>
<code>integer[] &amp;&amp; integer[] → boolean</code> Do arrays overlap (have at least one element in common)?
<code>integer[] @&gt; integer[] → boolean</code> Does left array contain right array?
<code>integer[] &lt;@ integer[] → boolean</code> Is left array contained in right array?
<code># integer[] → integer</code> Returns the number of elements in the array.
<code>integer[] # integer → integer</code> Returns index of the first array element matching the right argument, or 0 if no match. (Same as <code>idx</code> function.)
<code>integer[] + integer → integer[]</code> Adds element to end of array.
<code>integer[] + integer[] → integer[]</code> Concatenates the arrays.
<code>integer[] - integer → integer[]</code> Removes entries matching the right argument from the array.
<code>integer[] - integer[] → integer[]</code> Removes elements of the right array from the left array.
<code>integer[]   integer → integer[]</code> Computes the union of the arguments.
<code>integer[]   integer[] → integer[]</code> Computes the union of the arguments.
<code>integer[] &amp; integer[] → integer[]</code> Computes the intersection of the arguments.
<code>integer[] @@ query_int → boolean</code> Does array satisfy query? (see below)
<code>query_int ~~ integer[] → boolean</code> Does array satisfy query? (commutator of @@)

(Before LightDB 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The operators `&&`, `@>` and `<@` are equivalent to LightDB's built-in operators of the same names, except that they work only on integer arrays that do not contain nulls, while the built-in operators work for any array type. This restriction makes them faster than the built-in operators in many cases.

The @@ and ~~ operators test whether an array satisfies a *query*, which is expressed as a value of a specialized data type `query_int`. A *query* consists of integer values that are checked against the elements of the array, possibly combined using the operators & (AND), | (OR), and ! (NOT). Parentheses can be used as needed. For example, the query `1 & (2 | 3)` matches arrays that contain 1 and also contain either 2 or 3.

## F.18.2. Index Support

`intarray` provides index support for the &&, @>, <@, and @@ operators, as well as regular array equality.

Two parameterized GiST index operator classes are provided: `gist__int_ops` (used by default) is suitable for small- to medium-size data sets, while `gist__intbig_ops` uses a larger signature and is more suitable for indexing large data sets (i.e., columns containing a large number of distinct array values). The implementation uses an RD-tree data structure with built-in lossy compression.

`gist__int_ops` approximates an integer set as an array of integer ranges. Its optional integer parameter `numranges` determines the maximum number of ranges in one index key. The default value of `numranges` is 100. Valid values are between 1 and 253. Using larger arrays as GiST index keys leads to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

`gist__intbig_ops` approximates an integer set as a bitmap signature. Its optional integer parameter `siglen` determines the signature length in bytes. The default signature length is 16 bytes. Valid values of signature length are between 1 and 2024 bytes. Longer signatures lead to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

There is also a non-default GIN operator class `gin__int_ops` supporting the same operators.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere.

## F.18.3. Example

```
-- a message can be in one or more "sections"
CREATE TABLE message (mid INT PRIMARY KEY, sections INT[], ...);

-- create specialized index with signature length of 32 bytes
CREATE INDEX message_rdtree_idx ON message USING GIST (sections
  gist__intbig_ops (siglen = 32));

-- select messages in section 1 OR 2 - OVERLAP operator
SELECT message.mid FROM message WHERE message.sections && '{1,2}';

-- select messages in sections 1 AND 2 - CONTAINS operator
SELECT message.mid FROM message WHERE message.sections @> '{1,2}';

-- the same, using QUERY operator
SELECT message.mid FROM message WHERE message.sections @@
  '1&2'::query_int;
```

## F.18.4. Benchmark

The source directory `contrib/intarray/bench` contains a benchmark test suite, which can be run against an installed LightDB server. (It also requires `DBD:Pg` to be installed.) To run:

```
cd ../contrib/intarray/bench
```

```
createdb TEST
ltsql -c "CREATE EXTENSION intarray" TEST
./create_test.pl | ltsql TEST
./bench.pl
```

The `bench.pl` script has numerous options, which are displayed when it is run without any arguments.

## F.18.5. Authors

All work was done by Teodor Sigaev (<teodor@sigaev.ru>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megeera/postgres/gist/> for additional information. Andrey Oktyabrski did a great work on adding new functions and operations.

## F.19. isn

The `isn` module provides data types for the following international product numbering standards: EAN13, UPC, ISBN (books), ISMN (music), and ISSN (serials). Numbers are validated on input according to a hard-coded list of prefixes; this list of prefixes is also used to hyphenate numbers on output. Since new prefixes are assigned from time to time, the list of prefixes may be out of date. It is hoped that a future version of this module will obtain the prefix list from one or more tables that can be easily updated by users as needed; however, at present, the list can only be updated by modifying the source code and recompiling. Alternatively, prefix validation and hyphenation support may be dropped from a future version of this module.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.19.1. Data Types

Table F.9 shows the data types provided by the `isn` module.

**Table F.9. isn Data Types**

Data Type	Description
EAN13	European Article Numbers, always displayed in the EAN13 display format
ISBN13	International Standard Book Numbers to be displayed in the new EAN13 display format
ISMN13	International Standard Music Numbers to be displayed in the new EAN13 display format
ISSN13	International Standard Serial Numbers to be displayed in the new EAN13 display format
ISBN	International Standard Book Numbers to be displayed in the old short display format
ISMN	International Standard Music Numbers to be displayed in the old short display format
ISSN	International Standard Serial Numbers to be displayed in the old short display format
UPC	Universal Product Codes

Some notes:

1. ISBN13, ISMN13, ISSN13 numbers are all EAN13 numbers.
2. EAN13 numbers aren't always ISBN13, ISMN13 or ISSN13 (some are).

3. Some ISBN13 numbers can be displayed as ISBN.
4. Some ISMN13 numbers can be displayed as ISMN.
5. Some ISSN13 numbers can be displayed as ISSN.
6. UPC numbers are a subset of the EAN13 numbers (they are basically EAN13 without the first 0 digit).
7. All UPC, ISBN, ISMN and ISSN numbers can be represented as EAN13 numbers.

Internally, all these types use the same representation (a 64-bit integer), and all are interchangeable. Multiple types are provided to control display formatting and to permit tighter validity checking of input that is supposed to denote one particular type of number.

The ISBN, ISMN, and ISSN types will display the short version of the number (ISxN 10) whenever it's possible, and will show ISxN 13 format for numbers that do not fit in the short version. The EAN13, ISBN13, ISMN13 and ISSN13 types will always display the long version of the ISxN (EAN13).

## F.19.2. Casts

The `isn` module provides the following pairs of type casts:

- ISBN13 <=> EAN13
- ISMN13 <=> EAN13
- ISSN13 <=> EAN13
- ISBN <=> EAN13
- ISMN <=> EAN13
- ISSN <=> EAN13
- UPC <=> EAN13
- ISBN <=> ISBN13
- ISMN <=> ISMN13
- ISSN <=> ISSN13

When casting from EAN13 to another type, there is a run-time check that the value is within the domain of the other type, and an error is thrown if not. The other casts are simply relabelings that will always succeed.

## F.19.3. Functions and Operators

The `isn` module provides the standard comparison operators, plus B-tree and hash indexing support for all these data types. In addition there are several specialized functions; shown in Table F.10. In this table, `isn` means any one of the module's data types.

**Table F.10. `isn` Functions**

Function	Description
<code>isn_weak ( boolean ) → boolean</code>	Sets the weak input mode, and returns new setting.
<code>isn_weak () → boolean</code>	Returns the current status of the weak mode.

Function	Description
<code>make_valid(isn) → isn</code>	Validates an invalid number (clears the invalid flag).
<code>is_valid(isn) → boolean</code>	Checks for the presence of the invalid flag.

*Weak* mode is used to be able to insert invalid data into a table. Invalid means the check digit is wrong, not that there are missing numbers.

Why would you want to use the weak mode? Well, it could be that you have a huge collection of ISBN numbers, and that there are so many of them that for weird reasons some have the wrong check digit (perhaps the numbers were scanned from a printed list and the OCR got the numbers wrong, perhaps the numbers were manually captured... who knows). Anyway, the point is you might want to clean the mess up, but you still want to be able to have all the numbers in your database and maybe use an external tool to locate the invalid numbers in the database so you can verify the information and validate it more easily; so for example you'd want to select all the invalid numbers in the table.

When you insert invalid numbers in a table using the weak mode, the number will be inserted with the corrected check digit, but it will be displayed with an exclamation mark (!) at the end, for example 0-11-000322-5!. This invalid marker can be checked with the `is_valid` function and cleared with the `make_valid` function.

You can also force the insertion of invalid numbers even when not in the weak mode, by appending the ! character at the end of the number.

Another special feature is that during input, you can write ? in place of the check digit, and the correct check digit will be inserted automatically.

## F.19.4. Examples

```
--Using the types directly:
SELECT isbn('978-0-393-04002-9');
SELECT isbn13('0901690546');
SELECT issn('1436-4522');

--Casting types:
-- note that you can only cast from ean13 to another type when the
-- number would be valid in the realm of the target type;
-- thus, the following will NOT work: select
  isbn(ean13('0220356483481'));
-- but these will:
SELECT upc(ean13('0220356483481'));
SELECT ean13(upc('220356483481'));

--Create a table with a single column to hold ISBN numbers:
CREATE TABLE test (id isbn);
INSERT INTO test VALUES('9780393040029');

--Automatically calculate check digits (observe the '?'):
INSERT INTO test VALUES('220500896?');
INSERT INTO test VALUES('978055215372?');

SELECT issn('3251231?');
SELECT ismn('979047213542?');
```

```
--Using the weak mode:
SELECT isn_weak(true);
INSERT INTO test VALUES('978-0-11-000533-4');
INSERT INTO test VALUES('9780141219307');
INSERT INTO test VALUES('2-205-00876-X');
SELECT isn_weak(false);

SELECT id FROM test WHERE NOT is_valid(id);
UPDATE test SET id = make_valid(id) WHERE id = '2-205-00876-X!';

SELECT * FROM test;

SELECT isbn13(id) FROM test;
```

## F.19.5. Bibliography

The information to implement this module was collected from several sites, including:

- <https://www.isbn-international.org/>
- <https://www.issn.org/>
- <https://www.ismn-international.org/>
- <https://www.wikipedia.org/>

The prefixes used for hyphenation were also compiled from:

- <https://www.gs1.org/standards/id-keys>
- [https://en.wikipedia.org/wiki/List\\_of\\_ISBN\\_identifier\\_groups](https://en.wikipedia.org/wiki/List_of_ISBN_identifier_groups)
- <https://www.isbn-international.org/content/isbn-users-manual>
- [https://en.wikipedia.org/wiki/International\\_Standard\\_Music\\_Number](https://en.wikipedia.org/wiki/International_Standard_Music_Number)
- <https://www.ismn-international.org/ranges.html>

Care was taken during the creation of the algorithms and they were meticulously verified against the suggested algorithms in the official ISBN, ISMN, ISSN User Manuals.

## F.19.6. Author

Germán Méndez Bravo (Kronuz), 2004–2006

This module was inspired by Garrett A. Wollman's `isbn_issn` code.

## F.20. lo

The `lo` module provides support for managing Large Objects (also called LOs or BLOBs). This includes a data type `lo` and a trigger `lo_manage`.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.20.1. Rationale

One of the problems with the JDBC driver (and this affects the ODBC driver also), is that the specification assumes that references to BLOBs (Binary Large Objects) are stored within a table, and if that entry is changed, the associated BLOB is deleted from the database.

As LightDB stands, this doesn't occur. Large objects are treated as objects in their own right; a table entry can reference a large object by OID, but there can be multiple table entries referencing the same large object OID, so the system doesn't delete the large object just because you change or remove one such entry.

Now this is fine for LightDB-specific applications, but standard code using JDBC or ODBC won't delete the objects, resulting in orphan objects — objects that are not referenced by anything, and simply occupy disk space.

The `lo` module allows fixing this by attaching a trigger to tables that contain LO reference columns. The trigger essentially just does a `lo_unlink` whenever you delete or modify a value referencing a large object. When you use this trigger, you are assuming that there is only one database reference to any large object that is referenced in a trigger-controlled column!

The module also provides a data type `lo`, which is really just a domain of the `oid` type. This is useful for differentiating database columns that hold large object references from those that are OIDs of other things. You don't have to use the `lo` type to use the trigger, but it may be convenient to use it to keep track of which columns in your database represent large objects that you are managing with the trigger. It is also rumored that the ODBC driver gets confused if you don't use `lo` for BLOB columns.

## F.20.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE image (title text, raster lo);

CREATE TRIGGER t_raster BEFORE UPDATE OR DELETE ON image
    FOR EACH ROW EXECUTE FUNCTION lo_manage(raster);
```

For each column that will contain unique references to large objects, create a `BEFORE UPDATE OR DELETE` trigger, and give the column name as the sole trigger argument. You can also restrict the trigger to only execute on updates to the column by using `BEFORE UPDATE OF column_name`. If you need multiple `lo` columns in the same table, create a separate trigger for each one, remembering to give a different name to each trigger on the same table.

## F.20.3. Limitations

- Dropping a table will still orphan any objects it contains, as the trigger is not executed. You can avoid this by preceding the `DROP TABLE` with `DELETE FROM table`.

`TRUNCATE` has the same hazard.

If you already have, or suspect you have, orphaned large objects, see the `vacuumlo` module to help you clean them up. It's a good idea to run `vacuumlo` occasionally as a back-stop to the `lo_manage` trigger.

- Some frontends may create their own tables, and will not create the associated trigger(s). Also, users may not remember (or know) to create the triggers.

## F.20.4. Author

Peter Mount <peter@retep.org.uk>

## F.21. `lt_buffercache`

The `lt_buffercache` module provides a means for examining what's happening in the shared buffer cache in real time.

The module provides a C function `pg_buffercache_pages` that returns a set of records, plus a view `pg_buffercache` that wraps the function for convenient use.

By default, use is restricted to superusers and members of the `pg_monitor` role. Access may be granted to others using `GRANT`.

## F.21.1. The `pg_buffercache` View

The definitions of the columns exposed by the view are shown in Table F.11.

**Table F.11. `pg_buffercache` Columns**

Column Type	Description
<code>bufferid integer</code>	ID, in the range <code>1..shared_buffers</code>
<code>relfilenode oid (references pg_class.relfilenode)</code>	Filenode number of the relation
<code>reltablespace oid (references pg_tablespace.oid)</code>	Tablespace OID of the relation
<code>reldatabase oid (references pg_database.oid)</code>	Database OID of the relation
<code>relforknumber smallint</code>	Fork number within the relation; see <code>include/common/relpath.h</code>
<code>relblocknumber bigint</code>	Page number within the relation
<code>isdirty boolean</code>	Is the page dirty?
<code>usagecount smallint</code>	Clock-sweep access count
<code>pinning_backends integer</code>	Number of backends pinning this buffer

There is one row for each buffer in the shared cache. Unused buffers are shown with all fields null except `bufferid`. Shared system catalogs are shown as belonging to database zero.

Because the cache is shared by all the databases, there will normally be pages from relations not belonging to the current database. This means that there may not be matching join rows in `pg_class` for some rows, or that there could even be incorrect joins. If you are trying to join against `pg_class`, it's a good idea to restrict the join to rows having `reldatabase` equal to the current database's OID or zero.

Since buffer manager locks are not taken to copy the buffer state data that the view will display, accessing `pg_buffercache` view has less impact on normal buffer activity but it doesn't provide a consistent set of results across all buffers. However, we ensure that the information of each buffer is self-consistent.

## F.21.2. Sample Output

```
regression=# SELECT n.nspname, c.relname, count(*) AS buffers
              FROM pg_buffercache b JOIN pg_class c
              ON b.relfilenode = pg_relation_filenode(c.oid) AND
                 b.reldatabase IN (0, (SELECT oid FROM pg_database
```



```

WHERE datname =
current_database()))
JOIN pg_namespace n ON n.oid = c.relnamespace
GROUP BY n.nspname, c.relname
ORDER BY 3 DESC
LIMIT 9;

```

nspname	relname	buffers
public	delete_test_table	593
public	delete_test_table_pkey	494
pg_catalog	pg_attribute	472
public	quad_poly_tbl	353
public	tenk2	349
public	tenk1	349
public	gin_test_idx	306
pg_catalog	pg_largeobject	206
public	gin_test_tbl	188

(9 rows)

## F.21.3. Authors

Mark Kirkwood <markir@paradise.net.nz>

Design suggestions: Neil Conway <neilc@samurai.com>

Debugging advice: Tom Lane <tgl@sss.pgh.pa.us>

## F.22. It\_bulkload

It\_bulkload is a high speed data loading tool for LightDB.

It\_bulkload is designed to load huge amount of data to a database. You can load data to table bypassing LightDB shared buffers.

It\_bulkload also has some ETL features; input data validation and data transformation.

### F.22.1. Synopsis

```
It_bulkload [ OPTIONS ] [ controlfile ]
```

### F.22.2. Description

It\_bulkload is designed to load huge amount of data to a database. You can choose whether database constraints are checked and how many errors are ignored during the loading. For example, you can skip integrity checks for performance when you copy data from another database to LightDB. On the other hand, you can enable constraint checks when loading unclean data.

It\_bulkload can convert the load data into the binary file which can be used as an input file of It\_bulkload. If you check whether the load data is valid when converting it into the binary file, you can skip the check when loading it from the binary file to a table.

### F.22.3. Usage

You can use It\_bulkload by the following three steps:

1. Edit control file "sample\_csv.ctl" or "sample\_bin.ctl" that includes settings for data loading. You can specify table name, absolute path for input file, description of the input file, and so on.

2. Assume there is a directory \$LTDATA/lt\_bulkload, in that load status files are created.
3. Execute command with a control file as argument. Relative path is available for the argument.

```
$ lt_bulkload sample_csv.ctl
NOTICE: BULK LOAD START
NOTICE: BULK LOAD END
 0 Rows skipped.
 8 Rows successfully loaded.
 0 Rows not loaded due to parse errors.
 0 Rows not loaded due to duplicate errors.
 0 Rows replaced with new rows.
```

## F.22.4. Options

lt\_bulkload has the following command line options:

### F.22.4.1. Load Options

```
-i INPUT
--input=INPUT
--infile=INPUT
Source to load data from. Same as "INPUT" in
control files.
-O OUTPUT
--output=OUTPUT
Destination to load data to. Same as "OUTPUT" in
control files.
-l LOGFILE
--logfile=LOGFILE
A path to write the result log. Same as "LOGFILE"
in control files.
-P PARSE_BADFILE
--parse-badfile=PARSE_BADFILE
A path to write bad records that cannot be parsed
correctly. Same as "PARSE_BADFILE" in control files.
-u DUPLICATE_BADFILE
--duplicate-badfile=DUPLICATE_BADFILE
A path to write bad records that conflict
with unique constraints during index rebuild. Same as
"DUPLICATE_BADFILE" in control files.
-o "key=val"
--option="key=val"
Any options available in the control file. You can
pass multiple options.
```

### F.22.4.2. Connection Options

Options to connect to servers.

```
-d dbname
--dbname dbname
Specifies the name of the database to be connected.
If this is not specified, the database name is read from the
```

environment variable `LTDATABASE`. If that is not set, the user name specified for the connection is used.

`-h host`

`--host host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`

`--port port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`

`--username username`

User name to connect as.

`-W`

`--password`

Force `lt_bulkload` to prompt for a password before connecting to a database.

This option is never essential, since `lt_bulkload` will automatically prompt for a password if the server demands password authentication. However, `vacuumdb` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

### F.22.4.3. Generic Options

`-e`

`--echo`

Echo commands sent to server.

`-E`

`--elevel`

Choose the output message level from `DEBUG`, `INFO`, `NOTICE`, `WARNING`, `ERROR`, `LOG`, `FATAL`, and `PANIC`. The default is `INFO`.

`--help`

Show usage of the program.

`--version`

Show the version number of the program.

## F.22.5. Control Files

You can specify the following load options. Control files can be specified with an absolute path or a relative path. If you specify it by a relative path, it will be relative to the current working directory executing `lt_bulkload` command. If you don't specify a control file, you should pass required options through command line arguments for `lt_bulkload`.

Following parameters are available in control files. Characters after `"#"` are ignored as comments in each line.

### F.22.5.1. Common

`TYPE = CSV | BINARY | FIXED | FUNCTION`

The type of input data. The default is `CSV`.

- `CSV` : load from a text file in `CSV` format

- **BINARY | FIXED** : load from a fixed binary file
- **FUNCTION** : load from a result set from a function.

If you use it, **INPUT** must be an expression to call a function.

**INPUT | INFILE** = path | stdin | [ schemaname. ] function\_name (argvalue, ...)

Source to load data from. Always required. The value is treated as following depending on the **TYPE** option:

- **A file in the server**: This is a file path in server. If it is a relative path, it will be relative from the control file when specified in the control file, or will be relative from current working directory when specified in command line arguments. The user of LightDB server must have read permission to the file. It is available only when "**TYPE=CSV**" or "**TYPE=BINARY**".
- **Standard input to It\_bulkload command**: "**INPUT=stdin**" means It\_bulkload will read data from the standard input of It\_bulkload client program through network. You should use this form when the input file and database is in different servers. It is available only when "**TYPE=CSV**" or "**TYPE=BINARY**".
- **A SQL function**: Specify a SQL function with arguments that returns set of input data. It is available only when "**TYPE=FUNCTION**". You can use not only build-in functions but also any user-defined functions. The defined functions should return the type as **SETOF sometype**, or as **RETURNS TABLE(columns)**. Note that you specify attributes types if you use sometype. Because there is a case that assignment cast to cstring type which It\_bulkload uses internally, doesn't be permitted. Note that you might need to develop those function with C language instead of PL/pgSQL because the function must use **SFRM\_ValuePerCall** mode for streaming loading.

Here is an example of user-defined function.

```

                                $ CREATE TYPE sample_type AS (sum
integer, name char(10));
                                $ CREATE FUNCTION sample_function()
RETURNS SETOF sample_type
                                AS $$ SELECT id1 + id2,
upper(name) FROM INPUT_TABLE $$
                                LANGUAGE SQL;

```

Here is an example of a control file.

```

TABLE = sample_table
TYPE = FUNCTION
WRITER = DIRECT
INPUT = sample_function()      #
if to use the user-defined function
                                #INPUT = generate_series(1, 1000)
# if to use the build-in function, which generate sequential
numbers from 1 to 1000

```

**WRITER | LOADER** = **DIRECT | BUFFERED | BINARY | PARALLEL**

The method to load data. The default is **DIRECT**.

- **DIRECT** : Load data directly to table. Bypass the shared buffers and skip WAL logging, but need the own recovery procedure. This is the default, and original older version's mode.

- **BUFFERED** : Load data to table via shared buffers. Use shared buffers, write WALs, and use the original LightDB WAL recovery.
- **BINARY** : Convert data into the binary file which can be used as an input file to load from. Create a sample of the control file necessary to load the output binary file. This sample file is created in the same directory as the binary file.
- **PARALLEL** : Same as "WRITER=DIRECT" and "MULTI\_PROCESS=YES". If PARALLEL is specified, MULTI\_PROCESS is ignored. If password authentication is configured to the database to load, you have to set up the password file. See Restrictions for details.

OUTPUT | TABLE = { [ schema\_name. ] table\_name | outfile }

Destination to load data to. Always required. The value is treated as following depending on the WRITER (or LOADER) option:

- A table to load to: Specify the table to load to. If schema\_name is omitted, the first matching table in the search\_path is used. You can load data to a table only if WRITER is DIRECT, BUFFERED or PARALLEL.
- A file in the server: Specify the path of the output file in the server. If it's a relative path, it will be interpreted in the same way as INPUT option. The OS user running LightDB must have write permission to the parent directory of the specified file. You can load (convert) data to a file only if WRITER is BINARY.

SKIP | OFFSET = n

The number of skip input rows. The default is 0. You must not specify both "TYPE=FUNCTION" and SKIP at the same time.

LIMIT | LOAD = n

The number of rows to load. The default is INFINITE, i.e., all of data will be loaded. This option is available even if you use TYPE=FUNCTION.

ENCODING = encoding

Specify the encoding of the input data. Check whether the specified encoding is valid, and convert the input data to the database encoding if needed. By default, the encoding of the input data is neither verified nor converted. If you can be sure that the input data is encoded in the database encoding, you can reduce the load time by not specifying this option, and by skipping encoding verification and conversion. Note that client\_encoding is used as the encoding of the input data by default only if INPUT is stdin. You must not specify both "TYPE=FUNCTION" and ENCODING at the same time.

Here are option values and actual behaviors:

			DB
encoding			
SQL_ASCII	not specified	non-SQL_ASCII	neither
checked nor converted	SQL_ASCII	checked nor converted	neither
checked nor converted	only checked		
DB only checked	non-SQL_ASCII,		same as
checked	non-SQL_ASCII, different from DB	checked and converted	only

`FILTER = [ schema_name. ] function_name [ (argtype, ... ) ]`

Specify the filter function to convert each row in the input file. You can omit definitions of argtype as long as the function name is unique in the database. If not specified, the input data are directly parsed as the load-target table. See also How to write FILTER functions to make FILTER functions.

You must not specify both "TYPE=FUNCTION" and FILTER at the same time. Also, FORCE\_NOT\_NULL in CSV option cannot be used with FILTER option.

`CHECK_CONSTRAINTS = YES | NO`

Specify whether CHECK constraints are checked during the loading. The default is NO. You must not specify both "WRITER=BINARY" and CHECK\_CONSTRAINTS at the same time.

`PARSE_ERRORS = n`

The number of ingored tuples that throw errors during parsing, encoding checks, encoding conversion, FILTER function, CHECK constraint checks, NOT NULL checks, or data type conversion. Invalid input tuples are not loaded and recorded in the PARSE BADFILE. The default is 0. If there are equal or more parse errors than the value, already loaded data is committed and the remaining tuples are not loaded. 0 means to allow no errors, and -1 and INFINITE mean to ignore all errors.

`DUPLICATE_ERRORS = n`

The number of ingored tuples that violate unique constraints. Conflicted tuples are removed from the table and recorded in the DUPLICATE BADFILE. The default is 0. If there are equal or more unique violations than the value, the whole load is rolled back. 0 means to allow no violations, and -1 and INFINITE mean to ignore all violations. You must not specify both "WRITER=BINARY" and DUPLICATE\_ERRORS at the same time.

`ON_DUPLICATE_KEEP = NEW | OLD`

Specify how to handle tuples that violate unique constraints. The removed tuples are recorded in the BAD file. The default is NEW. You also need to set DUPLICATE\_ERRORS to more than 0 if you enable the option. You must not specify both "WRITER=BINARY" and ON\_DUPLICATE\_KEEP at the same time.

- NEW : Keep tuples in the input data, and remove corresponding existing tuples. When both violated tuples are in the data, keep the latter one.
- OLD : Keep existing tuples and remove tuples in the input data.

`LOGFILE = path`

A path to write the result log. If specified by a relative path, it is treated as same as INPUT. The default is \$LTDATA/lt\_bulkload/timestamp\_dbname\_schema\_table.log.

`PARSE_BADFILE = path`

A path to the BAD file logging invalid records which caused an error during parsing, encoding checks, encoding conversion, FILTER function, CHECK constraint checks, NOT NULL checks, or data type conversion. The format of the file is same as the input source file. If specified by a relative path, it is treated as same as INPUT. The default is \$LTDATA/lt\_bulkload/timestamp\_dbname\_schema\_table.bad.extension-of-infile.

`DUPLICATE_BADFILE = path`

A path to write bad records that conflict with unique constraints during index rebuild. The format of the file is always CSV. If specified by a relative path, it is treated as same as INPUT. The default is \$LTDATA/lt\_bulkload/timestamp\_dbname\_schema\_table.dup.csv. You must not specify both "WRITER=BINARY" and DUPLICATE\_BADFILE at the same time.

TRUNCATE = YES | NO

If YES, delete all rows from the target table with TRUNCATE command. If NO, do nothing. The default is NO. You must not specify both "WRITER=BINARY" and TRUNCATE at the same time.

VERBOSE = YES | NO

If YES, write bad tuples also in server log. If NO, don't write them in serverlog. The default is NO.

MULTI\_PROCESS = YES | NO

If YES, we do data reading, parsing and writing in parallel by using multiple threads. If NO, we use only single thread for them instead of doing parallel processing. The default is NO. If WRITER is PARALLEL, MULTI\_PROCESS is ignored. If password authentication is configured to the database to load, you have to set up the password file. See Restrictions for details. Please make sure when enabling MULTI\_PROCESS that no other LightDB backend process is trying to modify the schema of the table, because it may cause the schema of the table as seen by the reader and the writer processes to differ and cause problems.

### F.22.5.2. CSV input format

DELIMITER = delimiter\_character

The single ASCII character that separates columns within each row (line) of the file. The default is comma. When you load a tab-separated format file (TSV), you can set DELIMITER to a tab character. Then, you need to double quote the tab:

```
DELIMITER=" " # a double-quoted tab
```

You can also specify DELIMITER as a command-line -o option with '\$\t' syntax.

```
$ lt_bulkload tsv.ct1 -o '$\t'
```

QUOTE = quote\_character

Specifies the ASCII quotation character. The default is double-quotation.

ESCAPE = escape\_character

Specifies the ASCII character that should appear before a QUOTE data character value. The default is double-quotation.

NULL = null\_string

The string that represents a null value. The default is a empty value with no quotes.

FORCE\_NOT\_NULL = column

Process each specified column as though it were not a NULL value. Multiple columns are available as needed. FILTER cannot be used together with this option.

### F.22.5.3. Binary input format

COL = type [ (size) ] [ NULLIF { 'null\_string' | null\_hex } ]

Column definitions of input file from left to right. The definitions consists of type name, offset, and length in bytes. CHAR and VARCHAR means input data is a text. Otherwise, it is a binary data. If binary, endian must match between server and data file.

- CHAR | CHARACTER : a string trimmed trailing spaces. The length is always required.
- VARCHAR | CHARACTER VARYING : a string keeping trailing spaces. The length is always required.
- SMALLINT | SHOFT : signed integer in 2 bytes.
- INTEGER | INT : signed integer in 2 or 4 or 8 bytes. The default is 4.
- BIGINT | LONG : signed integer in 8 bytes.
- UNSIGNED SMALLINT | SHORT : unsigned integer in 2 bytes.
- UNSIGNED INTEGER | INT : unsigned integer in 2 or 4 bytes. The default is 4.
- FLOAT | REAL : floating point number in 4 or 8 bytes. The default is 4.
- DOUBLE : floating point number in 8 bytes.

The length and offset of the type can be specified as follows:

- TYPE : TYPE with default length follows.
- TYPE(L) : TYPE with L bytes follows.
- TYPE(S+L) : L bytes, offset S bytes from the beginning of the line
- TYPE(S:E) : start at S bytes and end at E bytes.

The length and offset of the type can be specified as follows:

- NULLIF 'null\_string' : Specify the string expressing NULL when the type is CHAR or VARCHAR. The length of the string must be the same as that of the type.
- NULLIF null\_hex : Specify the hex value expressing NULL when the type is other than CHAR and VARCHAR. The length of the hex value must be the same as that of the type.

In addition, "COL N" is available, that is same as COL CHAR(N), for backward compatibility.

PRESERVE\_BLANKS = YES | NO

YES regards following "COL N" as "COL CHAR(N)" and NO as "COL VARCHAR(N)". Default is NO.

STRIDE = n

Length of one row. Use if you want to truncate the end of row. The default is whole of the row, which means the total of COLs.

#### F.22.5.4. Binary output format

OUT\_COL = type [ (size) ] [ NULLIF { 'null\_string' | null\_hex } ]

Column definitions of output file from left to right. The definitions consists of type name, offset, and length in bytes. CHAR and VARCHAR means input data is a text. Otherwise, it is a binary data. If binary, endian must match between server and data file.

- CHAR | CHARACTER : fixed-length string. The length must be specified. If the string to be stored is shorter than the declared length, values will be space-padded. "COL=CHAR(size)" will be output in the sample of control file.
- VARCHAR | CHARACTER VARYING : fixed-length string. The length must be specified. If the string to be stored is shorter than the declared length, values will be space-padded. "COL=VARCHAR(size)" will be output in the sample of control file.



- SMALLINT | SHOFT : signed integer in 2 bytes.
- INTEGER | INT : signed integer in 2 or 4 or 8 bytes. The default is 4.
- BIGINT | LONG : signed integer in 8 bytes.
- UNSIGNED SMALLINT | SHORT : unsigned integer in 2 bytes.
- UNSIGNED INTEGER | INT : unsigned integer in 2 or 4 bytes. The default is 4.
- FLOAT | REAL : floating point number in 4 or 8 bytes. The default is 4.
- DOUBLE : floating point number in 8 bytes.

The string expressing NULL can be specified as follows. If omitted but NULL is input, NULL is logged as an invalid data in PARSE\_BADFILE.

- NULLIF 'null\_string' : Specify the string expressing NULL when the type is CHAR or VARCHAR. The length of the string must be the same as that of the type.
- NULLIF null\_hex : Specify the hex value expressing NULL when the type is other than CHAR and VARCHAR. The length of the hex value must be the same as that of the type.

## F.22.6. Restrictions

### F.22.6.1. Exit code of lt\_bulkload

lt\_bulkload returns 0 when successfully loaded. It also returns 3 with a WARNING message when there are some parse errors or duplicate errors even if loading itself was finished. Note that skipped rows and replaced rows (with ON\_DUPLICATE\_KEEP = NEW) are not considered as an error; the exit code will be 0.

When there is a non-continuable error, the loader raises an ERROR message. The return code will be often 1 because many errors occur in the database server during loading data. The following table shows the codes that lt\_bulkload can return.

	Return code	Description
	0	Success
in LightDB	1	Error occurred during running SQL
	2	Failed to connect to LightDB
be loaded	3	Success, but some data could not

### F.22.6.2. On direct loading

If you use direct load mode (WRITER=DIRECT or PARALLEL), you have to be aware below:

#### F.22.6.2.1. LightDB startup sequence

When lt\_bulkload is crashed and some .loadstatus files are remained in \$LTDATA/lt\_bulkload, database must be recovered by lt\_bulkload own recovery with "lt\_bulkload -r" command before you invoke lt\_ctl start. You must start and stop LightDB using LightDB script, which invokes "lt\_bulkload -r" and "lt\_ctl start" correctly. We recommend not to use lt\_ctl directly.

If you use lt\_bulkload in Windows operating system, LightDB script is not included in a lt\_bulkload package. So you have to invoke "lt\_bulkload -r" manually.

### F.22.6.2.2. PITR/Replication

Because of bypassing WAL, archive recovery by PITR is not available. This does not mean that it can be done PITR without loaded tables data. If you would like to use PITR, take a full backup of the database after load via `lt_bulkload`. If you are using streaming replication, you need to re-create your standby based on the backup set which is taken after `lt_bulkload`.

### F.22.6.2.3. Load status file in `$LTDATA/lt_bulkload`

You must not remove the load status file (`*.loadstatus`) found in `$LTDATA/lt_bulkload` directory. This file is needed in `lt_bulkload` crash recovery.

### F.22.6.2.4. Do not use `kill -9`

Do not terminate `lt_bulkload` command using `"kill -9"` as much as possible. If you did this, you must invoke LightDB script to perform `lt_bulkload` recovery and restart LightDB to continue.

### F.22.6.2.5. Authentication can fail when `MULTI_PROCESS=YES`

When `MULTI_PROCESS=YES` and password is required to connect from localhost to the database to load, the authentication will fail even if you enter the password correctly in the prompt. To avoid this, configure either of the followings.

- Use "trust" method to authenticate the connection from localhost

In UNIX environment, the connection from localhost uses UNIX-domain socket, and in Windows, it uses TCP/IP loopback address. In UNIX, add the following line into `lt_hba.conf`.

```

                                # TYPE  DATABASE          USER
CIDR-ADDRESS                   METHOD [for UNIX]
                                local   all                foo
                                trust

```

In Windows, add the following line into `lt_hba.conf`.

```

                                # TYPE  DATABASE          USER
CIDR-ADDRESS                   METHOD [for Windows]
                                host    all                foo
127.0.0.1/32                   trust

```

- Specify the password in `.pgpass` file

If you don't want to use "trust" method for security reasons, use "md5" or "password" as an authentication method and specify the password in `.pgpass` file. Note that the `.pgpass` file must be in the home directory of the OS user (typically "LightDB" user) who ran LightDB server. For example, if `lt_bulkload` connects to the server that is running on port 5432 as the DB user "foo" whose password is "foopass", the administrator can add the following line to the `.pgpass` file:

```
localhost:5432:*:foo:foopass
```

- Specify the password in `.pgpass` file

Don't use `"WRITER=PARALLE"`

Use the loading method other than  
"WRITER=PARALLEL".

### F.22.6.3. Database Constraints

Only unique constraint and not-NULL constraint are enforced during data load in default. You can to set "CHECK\_CONSTRAINTS=YES" to check CHECK constraints. Foreign key constraints cannot be checked. It is user's responsibility to provide valid data set.

## F.22.7. Details

### F.22.7.1. How to write FILTER functions

There are some notes and warnings when you write FILTER functions:

- Records in the input file are passed to the FILTER function one-by-one.
- When an error occurs in the FILTER function, the passed record is not loaded and written into PARSE BADFILE.
- The FILTER function must return record type or some composite type. Also, the actual record type must match with the target table definition.
- If the FILTER function returns NULL, a record that has NULLs in all columns is loaded.
- Functions with default arguments are supported. If the input data has fewer columns than arguments of the function, default values will be used.
- VARIADIC functions are NOT supported.
- SETOF funtions are NOT supported.
- Functions that have generic types (any, anyelement etc.) are NOT supported.
- FILTER functions can be implemented with any languages. SQL, C, PLs are ok, but you should write functions as fast as possible because they are called many times.
- You can only specify one of FILTER or FORCE\_NOT\_NULL options. Please re-implement FORCE\_NOT\_NULL-compatible FILTER functions if you need the feature.

Here is an example of FILTER function.

```
CREATE FUNCTION sample_filter(integer, text, text,  
real DEFAULT 0.05) RETURNS record  
AS $$ SELECT $1 * $4, upper($3) $$  
LANGUAGE SQL;
```

## F.23. It\_cheat\_funcs

This extension provides cheat (but useful) functions on LightDB.

### F.23.1. Functions

Note that **CREATE EXTENSION It\_cheat\_funcs** needs to be executed in all the databases that you want to execute the functions that this extension provides.

```
=# CREATE EXTENSION lt_cheat_funcs;
```

### F.23.1.1. SETOF record pg\_stat\_get\_memory\_context()

Return statistics about all memory contexts. This function returns a record, shown in the table below.

Column Name	Data Type	Description
name	text	context name
parent	text	name of parent context
level	integer	distance from TopMemoryContext in context tree
total_bytes	bigint	total bytes requested from malloc
total_nblocks	bigint	total number of malloc blocks
free_bytes	bigint	free space in bytes
free_chunks	bigint	number of free chunks
used_bytes	bigint	used space in bytes

This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.2. void pg\_stat\_print\_memory\_context()

Cause statistics about all memory contexts to be logged. The format of log message for each memory context is:

```
[name]: [total_bytes] total in [total_nblocks] blocks; [free_bytes]
free ([free_chunks] chunks); [used_bytes] used
```

For descriptions of the above fields, please see pg\_stat\_get\_memory\_context().

This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.3. record pg\_cached\_plan\_source(stmt text)

Return information about cached plan source of the specified prepared statement. This function returns a record, shown in the table below.

Column Name	Data Type	Description
generic_cost	double precision	cost of generic plan, or -1 if not known
total_custom_cost	double precision	total cost of custom plans so far
num_custom_plans	integer	number of plans included in total
force_generic	boolean	force use of generic plan?
force_custom	boolean	force use of custom plan?

### F.23.1.4. void pg\_signal\_process(pid int, signame text)

Send a signal to LightDB server process. This function can signal to only postmaster, backend, walsender and walreceiver process. Valid signal names are HUP, INT, QUIT, ABRT, KILL, TERM, USR1, USR2, CONT, and STOP. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

For example, terminate walreceiver process:

```
=# SELECT pg_signal_process(pid, 'TERM') FROM pg_stat_wal_receiver;
```

### F.23.1.5. integer `pg_get_priority(pid int)`

Return the scheduling priority (“nice”) of the specified LightDB server process. This function can get the priority of only postmaster, backend, walsender and walreceiver process. See `getpriority(2)` man page for details about a scheduling priority. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.6. void `pg_set_priority(pid int, priority int)`

Set the scheduling priority (“nice”) of the specified LightDB server process to the specified value. This function can change the priority of only postmaster, backend, walsender and walreceiver process. See `getpriority(2)` man page for details about a scheduling priority. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.7. void `pg_segmentation_fault(treat_fatal_as_error boolean)`

Cause segmentation fault. If `lt_cheat_funcs.exit_on_segv` is enabled and `treat_fatal_as_error` is true, segmentation fault that this function causes will lead to ERROR instead of FATAL error. This is intended mainly for testing. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.8. void `pg_process_config_file()`

Read and process the configuration file. Note that, if an error occurs, it’s logged with DEBUG2 level. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.9. text `pg_xlogfile_name(location pg_lsn, recovery boolean)`

Convert transaction log location string to file name. This function is almost the same as `pg_xlogfile_name()` which LightDB core provides. The difference of them is whether there is a second parameter of type boolean. If false, this function always fails with an error during recovery. This is the same behavior as the core version of `pg_xlogfile_name()`. If true, this function can be executed even during recovery. But note that the first 8 digits of returned WAL filename (which represents the timeline ID) can be completely incorrect. That is, this function can return bogus WAL file name. For details of this conversion, please see Section 9.27.3.

### F.23.1.10. SETOF record `pg_stat_get_syncprep_waiters()`

Return statistics about all server processes waiting for synchronous replication. This function returns a record per server process waiting for synchronous replication, shown in the table below.

Column Name	Data Type	Description
pid	integer	Process ID of a server process
wait_lsn	pg_lsn	Transaction log position to wait for
wait_mode	text	Wait mode of this server process

Possible values of `wait_mode` are `write`, `flush` and `apply`.

This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.11. `void pg_wait_syncrep(location pg_lsn)`

Wait for synchronous replication. This function waits until the given transaction log location is acknowledged by synchronous standbys, based on the setting of `synchronous_commit`.

This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.12. `xid pg_set_next_xid(transactionid xid)`

Set and return the next transaction ID. Note that this function doesn't check if it's safe to assign the given transaction ID to the next one. The caller must carefully choose the safe transaction ID, e.g., which doesn't cause a transaction ID wraparound problem. This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.13. SETOF record `pg_xid_assignment()`

Return information about transaction ID assignment state. This function returns a record, shown in the table below.

Column Name	Data Type	Description
<code>next_xid</code>	<code>xid</code>	next transaction ID to assign
<code>oldest_xid</code>	<code>xid</code>	cluster-wide minimum <code>datfrozenxid</code>
<code>xid_vac_limit</code>	<code>xid</code>	start forcing autovacuum here
<code>xid_warn_limit</code>	<code>xid</code>	start complaining here
<code>xid_stop_limit</code>	<code>xid</code>	refuse to advance next transaction ID beyond here
<code>xid_wrap_limit</code>	<code>xid</code>	where the world ends
<code>oldest_xid_db</code>	<code>oid</code>	database with minimum <code>datfrozenxid</code>

This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.14. `xid pg_set_next_oid(objectid oid)`

Set and return the next object ID (OID). Note that the next OID is set to 16384 (`FirstNormalObjectId`) when the given OID is less than that number. This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.15. SETOF record `pg_oid_assignment()`

Return information about object ID (OID) assignment state. This function returns a record, shown in the table below.

Column Name	Data Type	Description
<code>next_oid</code>	<code>oid</code>	next object ID to assign
<code>oid_count</code>	<code>integer</code>	OIDs available before must do WAL work

This function is restricted to superusers by default, but other users can be granted `EXECUTE` to run the function.

### F.23.1.16. integer `pg_advance_vacuum_cleanup_age(integer)`

Specify the number of transactions by which VACUUM and HOT updates will advance cleanup of dead row versions. `vacuum_defer_cleanup_age` in the session calling this function is set to the negative value of that specified number. If the argument is omitted or NULL is specified, `vacuum_defer_cleanup_age` is reset to its original setting value specified in the configuration file. This function returns the vacuum cleanup age.

By advancing the cleanup age, VACUUM and HOT updates can clean up even dead tuples that were produced since oldest transaction had started. So this function is helpful to prevent the database from bloating due to unremovable dead tuples while long transaction is running.

Note that this is extremely dangerous function and can easily corrupt the database. Any important data may disappear and data consistency may be lost completely. This function must not be used for a purpose other than debug.

This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.17. void `pg_checkpoint(fast bool, wait bool, force bool)`

Perform a checkpoint. If `fast` is true (default), a checkpoint will finish as soon as possible. Otherwise, I/O required for a checkpoint will be spread out over a period of time, to minimize the impact on query processing. If `wait` is true (default), this function waits for a checkpoint to complete before returning. Otherwise, it just signals checkpointer to do it and returns. If `force` is true (default), this function forces a checkpoint even if no WAL activity has occurred since the last one. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.18. SETOF record `pg_recovery_settings()`

Return information about all parameter settings in `recovery.conf`. This function returns a record, shown in the table below.

Column Name	Data Type	Description
<code>name</code>	text	configuration parameter name
<code>setting</code>	text	value of the parameter

This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

### F.23.1.19. text `pg_show_primary_conninfo()`

Return the current value of `primary_conninfo` recovery parameter. If it's not set yet, NULL is returned. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function. For details of `primary_conninfo` parameter, please see `primary_conninfo`.

### F.23.1.20. integer `pg_postmaster_pid()`

Return the Process ID of the postmaster process.

### F.23.1.21. timestamp with time zone `pg_backend_start_time()`

Return the time when the server process attached to the current session was started.

### F.23.1.22. SETOF text `pg_list_relation_filepath(relation regclass)`

List the file path names of the specified relation.

**F.23.1.23. text pg\_tablespace\_version\_dirctry()**

Return the name of major-version-specific tablespace subdirectory.

**F.23.1.24. bigint pg\_file\_write\_binary(filepath text, data bytea)**

Write bytea data to the file. This function creates the file if it does not exist, and truncates it to zero length otherwise. Then this function writes the bytea data from the beginning of the file, and returns the number of bytes written. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

**F.23.1.25. void pg\_file\_fsync(filepath text)**

Try to fsync the file or directory. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.

**F.23.1.26. text to\_octal(integer or bigint)**

Convert number to its equivalent octal representation.

**F.23.1.27. text pg\_text\_to\_hex(str text)**

Convert text to its equivalent hexadecimal representation.

Here is an example of the conversion from text to hex:

```
=# SELECT pg_text_to_hex('LightDB');
   pg_text_to_hex
-----
4c696768744442
(1 row)
```

**F.23.1.28. text pg\_hex\_to\_text(hex text)**

Convert hexadecimal representation to its equivalent text.

Here is an example of the conversion from hex to text:

```
=# SELECT pg_hex_to_text('4c696768744442');
   pg_hex_to_text
-----
LightDB
(1 row)
```

**F.23.1.29. text pg\_chr(code integer)**

Return the character with the given code. This function is almost the same as chr() which LightDB core provides. The difference of them is that this function returns NULL instead of throwing an error when the requested character is too large or not valid. Note that valid Unicode code point stops at U+10FFFF (1114111), even though 4-byte UTF8 sequences can hold values up to U+1FFFFFF. Therefore this function returns NULL whenever the given code is larger than 1114111.

**F.23.1.30. text pg\_utf8(code integer)**

Alias of pg\_chr(code integer). function.



### F.23.1.31. SETOF record pg\_all\_utf8()

Return all valid UTF-8 characters. This function returns a record, shown in the table below.

Column Name	Data Type	Description
code	text	code of character
utf8	text	UTF-8 character

This function can be executed only under UTF-8 database encoding.

### F.23.1.32. text pg\_eucjp(code1 bit(8), code2 bit(8), code3 bit(8))

Return EUC\_JP character with the given codes. The following table shows the valid combination of the codes.

code1	code2	code3
x00 - x7f	-	-
x8e	xa1 - xdf	-
xa1 - xfe	xa1 - xfe	-
x8f	xa1 - xfe	xa1 - xfe

For example, return EUC\_JP character with “a1fa” (BLACK STAR):

```
=# SELECT pg_eucjp('xa1', 'xfa');
```

This function returns NULL when the requested character is invalid for EUC\_JP. This function can be executed only under EUC\_JP database encoding.

### F.23.1.33. SETOF record pg\_all\_eucjp()

Return all valid EUC\_JP characters. This function returns a record, shown in the table below.

Column Name	Data Type	Description
code1	text	first byte of character
code2	text	second byte of character (x00 means non-existence of this byte)
code3	text	third byte of character (x00 means non-existence of this byte)
eucjp	text	EUC_JP character

This function can be executed only under EUC\_JP database encoding.

### F.23.1.34. bytea pglz\_compress(data text)

Create and return a compressed version of text data. This function uses PGLZ (an implementation of LZ compression for LightDB) for the compression. If the compression fails (e.g., the compressed result is actually bigger than the original), this function returns the original data. Note that the return data may be 4-bytes bigger than the original even when the compression fails because 4-bytes extra information like the length of original data is always stored in it. The bytea data that this function returns needs to be decompressed by using pg\_lz\_decompress() to obtain the original text data.

### F.23.1.35. bytea pglz\_compress\_bytea(data bytea)

Create and return a compressed version of bytea data. This function uses PGLZ (an implementation of LZ compression for LightDB) for the compression. If the compression fails (e.g., the compressed

result is actually bigger than the original), this function returns the original data. Note that the return data may be 4-bytes bigger than the original even when the compression fails because 4-bytes extra information like the length of original data is always stored in it. The bytea data that this function returns needs to be decompressed by using `pg_lz_decompress_bytea()` to obtain the original bytea data.

### **F.23.1.36. text `pglz_decompress(data bytea)`**

Decompress a compressed version of bytea data into text. Note that the input of this function must be the bytea data that `pg_lz_compress()` or `pg_lz_compress_bytea()` returned. Otherwise this function may return a corrupted data.

### **F.23.1.37. bytea `pglz_decompress_bytea(data bytea)`**

Decompress a compressed version of bytea data into bytea. Note that the input of this function must be the bytea data that `pg_lz_compress()` or `pg_lz_compress_bytea()` returned. Otherwise this function may return a corrupted data.

### **F.23.1.38. text `pg_saslprep(input text)`**

Normalize an input string with SASLprep. SASLprep normalization is basically used to process a user-supplied password into canonical form for SCRAM authentication. Note that an error is raised if the input is not a valid UTF-8 string or the normalized string contains characters prohibited by the SASLprep profile.

### **F.23.1.39. `pg_advisory_xact_unlock(bigint)`**

Release a previously-acquired exclusive transaction-level advisory lock. Return true if the lock is successfully released. If the lock was not held, false is returned, and in addition, an SQL warning will be reported by the server.

### **F.23.1.40. `pg_advisory_xact_unlock_shared(bigint)`**

Release a previously-acquired shared transaction-level advisory lock. Return true if the lock is successfully released. If the lock was not held, false is returned, and in addition, an SQL warning will be reported by the server.

### **F.23.1.41. `pg_advisory_xact_unlock(integer, integer)`**

Same as `pg_advisory_xact_unlock(bigint)`.

### **F.23.1.42. `pg_advisory_xact_unlock_shared(integer, integer)`**

Same as `pg_advisory_xact_unlock_shared(bigint)`.

## **F.23.2. Encoding Conversions**

### **F.23.2.1. `pg_euc_jp_to_utf8`**

This is an encoding conversion from EUC\_JP to UTF-8. It uses two conversion maps; ordinary map and extra map. They are defined in `conv/euc_jp_to_utf8.map` and `conv/euc_jp_to_utf8.extra`, respectively. For each character, ordinary map is consulted first. If no match is found, extra map is consulted next. If still no match, an error is raised.

The content of ordinary map is the same as the map that `euc_jp_to_utf8` (default conversion map from EUC\_JP to UTF-8 that LightDB provides) uses. The extra map contains some mappings (e.g., the following mappings for Roman numerals and full-width symbols) that ordinary map doesn't have.

EUC_JP	UTF-8	Description
fcf1	e285b0 (U+2170)	SMALL ROMAN NUMERAL ONE
fcf2	e285b1 (U+2171)	SMALL ROMAN NUMERAL TWO
fcf3	e285b2 (U+2172)	SMALL ROMAN NUMERAL THREE
fcf4	e285b3 (U+2173)	SMALL ROMAN NUMERAL FOUR
fcf5	e285b4 (U+2174)	SMALL ROMAN NUMERAL FIVE
fcf6	e285b5 (U+2175)	SMALL ROMAN NUMERAL SIX
fcf7	e285b6 (U+2176)	SMALL ROMAN NUMERAL SEVEN
fcf8	e285b7 (U+2177)	SMALL ROMAN NUMERAL EIGHT
fcf9	e285b8 (U+2178)	SMALL ROMAN NUMERAL NINE
fcfa	e285b9 (U+2179)	SMALL ROMAN NUMERAL TEN
fcfb	efbfa2 (U+FFE2)	FULLWIDTH NOT SIGN
fcfc	efbfa4 (U+FFE4)	FULLWIDTH BROKEN BAR
fcfd	efbc87 (U+FF07)	FULLWIDTH APOSTROPHE
fcfe	efbc82 (U+FF02)	FULLWIDTH QUOTATION MARK

In order to use `pg_euc_jp_to_utf8` as the default conversion from EUC\_JP to UTF-8, its `pg_conversion.condefault` needs to be enabled. Also `condefault` for `euc_jp_to_utf8` (built-in conversion from EUC\_JP to UTF-8) needs to be disabled. Here is an example of these catalog updates:

```

=# BEGIN;
=# UPDATE pg_conversion SET condefault = 'f' WHERE conname =
  'euc_jp_to_utf8';
=# UPDATE pg_conversion SET condefault = 't' WHERE conname =
  'pg_euc_jp_to_utf8';
=# COMMIT;

```

It's possible to use the customized conversion map by modifying the map files directly and rebuilding `lt_cheap_funcs` module. Note that entries in a map file must be sorted in ascending order.

## F.23.3. Configuration Parameters

Note that `shared_preload_libraries` or `session_preload_libraries` must be set to `"lt_cheap_funcs"` in `lightdb.conf` if you want to use the configuration parameters which this extension provides.

### F.23.3.1. `lt_cheap_funcs.log_memory_context` (boolean)

Cause statistics about the memory contexts to be logged at the end of query execution. For details of log format, please see `pg_stat_print_memory_context()`. This parameter is off by default. Only superusers can change this setting.

### F.23.3.2. `lt_cheap_funcs.hide_appname` (boolean)

If true, client's `application_name` is ignored and its setting value is stored in `lt_cheap_funcs.hidden_appname` parameter. By default, this is set to false, so that the string that client specifies will be used as `application_name`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

### F.23.3.3. `lt_cheap_funcs.hidden_appname` (string)

Report client's `application_name` hidden from view. The default is an empty string. Any users can change this setting.

### F.23.3.4. `lt_cheap_funcs.log_session_start_options` (boolean)

Log options sent to the server at connection start. This parameter is off by default. Only superusers can change this parameter at session start, and it cannot be changed at all within a session.

### F.23.3.5. `lt_cheap_funcs.scheduling_priority` (integer)

Specify the scheduling priority ("nice") of LightDB server process. Valid values are between -20 and 19. Lower values cause more favorable scheduling. The default value is zero. Any users can change this setting. See `getpriority(2)` man page for details about a scheduling priority.

### F.23.3.6. `lt_cheap_funcs.exit_on_segv` (boolean)

If off, which is the default, segmentation fault will lead to the server crash. If on, only the current session causing segmentation fault will be terminated. Any users can change this setting.

## F.24. `ltcluster`

See `ltcluster`<sup>1</sup> for more details.

## F.25. `ltcron`

### F.25.1. What is `ltcron`?

`ltcron` is a simple cron-based job scheduler for LightDB that runs inside the database as an extension. It allows you to schedule LightDB commands directly from the database:

```
-- Vacuum on Saturday at 3:30am (East eight time zone)
SELECT cron.schedule('30 3 * * 6', 'VACUUM');
schedule
-----
42

-- Vacuum every day at 10:00am (East eight time zone)
SELECT cron.schedule('nightly-vacuum', '0 10 * * *',
'VACUUM');
schedule
-----
43
```

---

<sup>1</sup> <http://www.light-pg.com/docs/ltcluster/13.8-23.4/index.html>

```

-- Change to vacuum at 3:00am (East eight time zone)
SELECT cron.schedule('nightly-vacuum', '0 3 * * *',
'VACUUM');
  schedule
  -----
         43

-- Stop scheduling jobs
SELECT cron.unschedule('nightly-vacuum' );
  unschedule
  -----
  t
(1 row)

SELECT cron.unschedule(42);
  unschedule
  -----
  t

```

It\_cron can support second-level precision:

```

zone)
-- Vacuum every day at 10:00:30am (East eight time
SELECT cron.schedule('30 0 10 * * *', 'VACUUM');
  schedule
  -----
         45

-- Vacuum every second
SELECT cron.schedule('dayly-vacuum', '* * * * *',
'VACUUM');
  schedule
  -----
         46

-- Change to Vacuum every 10 seconds
SELECT cron.schedule('dayly-vacuum', '*/10 * * * * *',
'VACUUM');
  schedule
  -----
         46

```

It\_cron can support four task modes, include one-time tasks, asap takes, next interval tasks and fixed interval tasks. You can pass in the task mode in the fourth parameter and there are four parameters to choose from (If you want to configure the task mode, the first parameter task name must be passed in):

- 'single' represents a one-time task, this means that when the task is executed for the first time, the task will not be executed again.

```

-- Change to Vacuum only once immediately
SELECT cron.schedule('dayly-vacuum', '* * * * *',
'VACUUM', 'single');
  schedule
  -----
         46

```

```

-- Change to Vacuum every 30 seconds
SELECT cron.schedule('daily-vacuum', '* / 30 * * * * *',
'VACUUM', 'next');
    schedule
    -----
        46

```

```

-- Change to Vacuum only once at the next 10:00:30am
(East eight time zone)
SELECT cron.schedule('daily-vacuum', '30 0 10 * * *',
'VACUUM', 'single');
    schedule
    -----
        46

```

```

-- Change to Vacuum every day at 10:00:30am (East eight
time zone)
SELECT cron.schedule('daily-vacuum', '30 0 10 * * *',
'VACUUM', 'next');
    schedule
    -----
        46

```

- 'asap' represents a asap scheduled task, for the same task it runs at most one instance of a job at a time. If a second run is supposed to start before the first one finishes, then the second run is queued and started as soon as the first run completes.

```

-- Change to Vacuum every 30 seconds
SELECT cron.schedule('daily-vacuum', '* / 30 * * * * *',
'VACUUM', 'asap');
    schedule
    -----
        46

```

```

-- Change to Vacuum every day at 10:00:30am (East eight
time zone)
SELECT cron.schedule('daily-vacuum', '30 0 10 * * *',
'VACUUM', 'asap');
    schedule
    -----
        46

```

- 'next' represents a next interval scheduled task, for the same task it runs at most one instance of a job at a time. If a second run is supposed to start before the first one finishes, then the second run is queued and started at the time point of the next timing cycle.

Compatible with the previous version, the mode parameter input 'timing' is the same as 'next'.

```

-- Change to Vacuum every 30 seconds
SELECT cron.schedule('daily-vacuum', '* / 30 * * * * *',
'VACUUM', 'next');
    schedule
    -----

```

46

```

-- Change to Vacuum every day at 10:00:30am (East eight
time zone)
SELECT cron.schedule('daily-vacuum', '30 0 10 * * *',
'VACUUM', 'next');

```

```

schedule
-----

```

46

- 'fixed' represents a fixed interval scheduled task, for the same task it runs at most four instances of a job at a time by default. If a second run is supposed to start before the first one finishes, then the second run will not wait, and will start at the time point of the timing cycle, then will be executed in parallel with the first unfinished task.

You can modify the maximum number of concurrent executions for the same task when it expires by configuring the 'cron.max\_connections\_per\_task' GUC parameters in the lightdb.conf and restarting the database to take effect. The maximum upper limit is 16.

```

-- Change to Vacuum every 30 seconds
SELECT cron.schedule('daily-vacuum', '*/30 * * * * *',
'VACUUM', 'fixed');

```

```

schedule
-----

```

46

```

-- Change to Vacuum every day at 10:00:30am (East eight
time zone)
SELECT cron.schedule('daily-vacuum', '30 0 10 * * *',
'VACUUM', 'fixed');

```

```

schedule
-----

```

46

It\_cron can support time zone configuration. You can pass the timezone value in the fifth parameter. If you want to configure the time zone, the first parameter task name and the fourth parameter task mode must be passed in. If no time zone is configured, the default is East eight time zone:

```

-- Change to Vacuum every day at 10:00am (GMT)
SELECT cron.schedule('daily-vacuum', '0 10 * * *',
'VACUUM', 'next', '0');

```

```

schedule
-----

```

46

```

-- Change to vacuum every day at 10:00am (West ten time
zone)

```

```

SELECT cron.schedule('daily-vacuum', '0 10 * * *',
'VACUUM', 'next', '-10');

```

```

schedule
-----

```

46

```

-- Change to vacuum only once at the next 10:00am (East
six time zone)

```

```

SELECT cron.schedule('daily-vacuum', '0 10 * * *',
'VACUUM', 'single', '6');
schedule
-----
46

```

It\_cron can support the execution of linux os commands. You can pass the command type value in the sixth parameter. pass parameter 'sql' represents that the second parameter is the sql command, and pass parameter 'linux' represents that the second parameter is the sql command. If you want to configure the command type, the first parameter task name, the fourth parameter task mode and the fifth parameter time zone must be passed in. If no command type is configured, the default is sql command. Note that you must be a super user to execute linux commands:

```

-- Change to Vacuum every day at 10:00am (East eight
time zone)
SELECT cron.schedule('daily-vacuum', '0 10 * * *',
'VACUUM', 'next', '8', 'sql');
schedule
-----
46

-- delete log file every day at 23:59 (East eight time
zone)
SELECT cron.schedule('daily-touch', '59 23 * * *', 'rm
-rf $LTDATA/log/*', 'next', '8', 'linux');
schedule
-----
46

```

It\_cron can run multiple jobs in parallel, and by default it uses next interval mode, i.e. it runs at most one instance of a job at a time. If a second run is supposed to start before the first one finishes, then the second run is queued and started at the time point of the next timing cycle.

It\_cron supports a default timeout of 3 minutes for scheduled tasks for SQL commands, which is valid for all types of tasks. If the task execution times out, it will log the error in cron.job\_run\_details and return, waiting for the next execution. You can modify the timing task timeout time by setting the guc parameter cron.task\_running\_timeout in lightdb.conf and restarting the database to take effect. The maximum value is 60 minutes; if it is set to 0, it means there is no timeout limit.

Note that there is no timeout mechanism for linux command timing tasks.

The schedule uses the standard cron syntax, in which \* means "run every time period", and a specific number means "but only at this time":

```

##### min (0 - 59)
# ##### hour (0 - 23)
# # ##### day of month (1 - 31)
# # # ##### month (1 - 12)
# # # # ##### day of week (0 - 6) (0 to 6
are Sunday to
# # # # # Saturday, or use names; 7
is also Sunday)
# # # # #
# # # # #
* * * * *

```



An easy way to create a cron schedule is: [crontab.guru](https://crontab.guru/)<sup>2</sup>.

It has been enhanced on the basis of standard cron syntax to supports second-level tasks:

```
#####second (0 - 59)
# ##### minute (0 - 59)
# # ##### hour (0 - 23)
# # # ##### day of month (1 - 31)
# # # # ##### month (1 - 12)
# # # # # ##### day of week (0 - 6) (0 to
6 are Sunday to
# # # # # # Saturday, or use names; 7
is also Sunday)
# # # # # #
# # # # # #
* * * * *
```

For security, jobs are executed in the database in which the `cron.schedule` function is called with the same permissions as the current user. In addition, users are only able to see their own jobs in the `cron.job` table and `cron.lt_job` view.

## F.26. It\_freespacemap

The `lt_freespacemap` module provides a means for examining the free space map (FSM). It provides a function called `pg_freespace`, or two overloaded functions, to be precise. The functions show the value recorded in the free space map for a given page, or for all pages in the relation.

By default use is restricted to superusers and members of the `pg_stat_scan_tables` role. Access may be granted to others using `GRANT`.

### F.26.1. Functions

`pg_freespace(rel regclass IN, blkno bigint IN) returns int2`

Returns the amount of free space on the page of the relation, specified by `blkno`, according to the FSM.

`pg_freespace(rel regclass IN, blkno OUT bigint, avail OUT int2)`

Displays the amount of free space on each page of the relation, according to the FSM. A set of (`blkno bigint`, `avail int2`) tuples is returned, one tuple for each page in the relation.

The values stored in the free space map are not exact. They're rounded to precision of 1/256th of `BLCKSZ` (32 bytes with default `BLCKSZ`), and they're not kept fully up-to-date as tuples are inserted and updated.

For indexes, what is tracked is entirely-unused pages, rather than free space within pages. Therefore, the values are not meaningful, just whether a page is full or empty.

#### Note

The interface was changed in version 8.4, to reflect the new FSM implementation introduced in the same version.

<sup>2</sup> <https://crontab.guru/>

## F.26.2. Sample Output

```
lightdb@postgres=# SELECT * FROM pg_freespace('foo');
```

blkno	avail
0	0
1	0
2	0
3	32
4	704
5	704
6	704
7	1216
8	704
9	704
10	704
11	704
12	704
13	704
14	704
15	704
16	704
17	704
18	704
19	3648

```
(20 rows)
```

```
lightdb@postgres=# SELECT * FROM pg_freespace('foo', 7);  
pg_freespace
```

1216
------

```
(1 row)
```

## F.26.3. Author

Original version by Mark Kirkwood <markir@paradise.net.nz>. Rewritten in version 8.4 to suit new FSM implementation by Heikki Linnakangas <heikki@enterprisedb.com>

## F.27. It\_hint\_plan

### F.27.1. Name

`It_hint_plan` -- controls execution plan with hinting phrases in comment of special form.

### F.27.2. Synopsis

LightDB uses cost based optimizer, which utilizes data statistics, not static rules. The planner (optimizer) estimates costs of each possible execution plans for a SQL statement then the execution plan with the lowest cost finally be executed. The planner does its best to select the best best execution plan, but not perfect, since it doesn't count some properties of the data, for example, correlation between columns.

`It_hint_plan` makes it possible to tweak execution plans using so-called "hints", which are simple descriptions in the SQL comment of special form.

## F.27.3. Description

### F.27.3.1. Basic Usage

lt\_hint\_plan reads hinting phrases in a comment of special form given with the target SQL statement. The special form is beginning by the character sequence "/\*+" and ends with "\*/". Hint phrases are consists of hint name and following parameters enclosed by parentheses and delimited by spaces or a comma. Each hinting phrases can be delimited by new lines for readability. the hint at the beginning of sql is called the global level hint, and the hint in the statement is called the stmt level hint(only affect current query block without using qb\_name hint).

In the example below , hash join is selected as the joining method and scanning ltbench\_accounts by sequential scan method.

```
lightdb@postgres=# /*+
lightdb@postgres*#      HashJoin(a b)
lightdb@postgres*#      SeqScan(a)
lightdb@postgres*#      */
lightdb@postgres-# EXPLAIN SELECT *
lightdb@postgres-#      FROM ltbench_branches b
lightdb@postgres-#      JOIN ltbench_accounts a ON b.bid = a.bid
lightdb@postgres-#      ORDER BY a.aid;
                                                                    QUERY PLAN
-----
          Sort  (cost=31465.84..31715.84 rows=100000 width=197)
          Sort Key: a.aid
          -> Hash Join  (cost=1.02..4016.02 rows=100000 width=197)
              Hash Cond: (a.bid = b.bid)
              -> Seq Scan on ltbench_accounts a  (cost=0.00..2640.00
              rows=100000 width=97)
              -> Hash  (cost=1.01..1.01 rows=1 width=100)
                  -> Seq Scan on ltbench_branches b
                  (cost=0.00..1.01 rows=1 width=100)
          (7 rows)

lightdb@postgres=#
```

## F.27.4. The hint table

Hints are described in a comment in a special form in the above section. This is inconvenient in the case where queries cannot be edited. In the case hints can be placed in a special table named "hint\_plan.hints". The table consists of the following columns.

**Table F.12. hint table**

column	description
id	Unique number to identify a row for a hint. This column is filled automatically by sequence.
norm_query_string	A pattern matches to the query to be hinted. Constants in the query have to be replace with '?' as in the following example. White space is significant in the pattern.
application_name	The value of application_name of sessions to apply the hint. The hint in the example below applies to sessions connected from Itsql. An empty string means sessions of any application_name.

column	description
hints	Hint phrase. This must be a series of hints excluding surrounding comment marks.

The following example shows how to operate with the hint table.

```
lightdb@postgres=# INSERT INTO hint_plan.hints(norm_query_string,
application_name, hints)
lightdb@postgres-#     VALUES (
lightdb@postgres(#     'EXPLAIN (COSTS false) SELECT * FROM t1
WHERE t1.id = ?;',
lightdb@postgres(#     '',
lightdb@postgres(#     'SeqScan(t1)'
lightdb@postgres(#     );
INSERT 0 1
lightdb@postgres=# UPDATE hint_plan.hints
lightdb@postgres-#     SET hints = 'IndexScan(t1)'
lightdb@postgres-#     WHERE id = 1;
UPDATE 1
lightdb@postgres=# DELETE FROM hint_plan.hints
lightdb@postgres-#     WHERE id = 1;
DELETE 1
lightdb@postgres=#
```

The hint table is owned by the creator user and having the default privileges at the time of creation, during CREATE EXTENSION. Table hints are prioritized than comment hints.

## F.27.4.1. The types of hints

Hinting phrases are classified into eight types based on what kind of object and how they can affect planning. Scanning methods, join methods, joining order, row number correction, parallel query, GUC setting, query block name, and other hints. You will see the lists of hint phrases of each type in Hint list.

### F.27.4.1.1. Hints for scan methods

Scan method hints enforce specific scanning method on the target table. It `hint_plan` recognizes the target table by alias names if any. They are 'SeqScan', 'IndexScan' and so on in this kind of hint.

Scan hints are effective on ordinary tables, inheritance tables, UNLOGGED tables, temporary tables and system catalogs. External(foreign) tables, table functions, VALUES clause, CTEs, views and subqueries are not affected.

```
lightdb@postgres=# /*+
lightdb@postgres*#     SeqScan(t1)
lightdb@postgres*#     IndexScan(t2 t2_pkey)
lightdb@postgres*# */
lightdb@postgres-# SELECT * FROM table1 t1 JOIN table table2 t2 ON
(t1.key = t2.key);
```

For oracle compatibility, keywords of 'full' and 'index' are also supported. They are just aliases for 'seqscan', 'indexscan'.

```
lightdb@postgres=# EXPLAIN SELECT* FROM t2, t1 WHERE t1.id =
t2.id;

QUERY PLAN
```

```
Hash Join (cost=60.85..99.39 rows=2260 width=16)
Hash Cond: (t2.id = t1.id)
-> Seq Scan on t2 (cost=0.00..32.60 rows=2260 width=8)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
    -> Seq Scan on t1 (cost=0.00..32.60 rows=2260 width=8)
(5 rows)
```

```
lightdb@postgres=# EXPLAIN SELECT /*+index(t1)*/ FROM t2, t1
WHERE t1.id = t2.id;
LOG:  lt_hint_plan:
used hint:
INDEX(t1@lt#0)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join (cost=61.01..111.85 rows=2260 width=16)
Hash Cond: (t1.id = t2.id)
-> Index Scan using t1_pkey on t1 @"lt#0" (cost=0.15..45.06
rows=2260 width=8)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
    -> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
(5 rows)
```

```
lightdb@postgres=# EXPLAIN SELECT /*+full(t1)*/ FROM t2, t1 WHERE
t1.id = t2.id;
LOG:  lt_hint_plan:
used hint:
FULL(t1@lt#0)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join (cost=60.85..99.39 rows=2260 width=16)
Hash Cond: (t1.id = t2.id)
-> Seq Scan on t1 @"lt#0" (cost=0.00..32.60 rows=2260 width=8)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
    -> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
(5 rows)
```

```
lightdb@postgres=#
```

### F.27.4.1.2. Hints for join methods

This can affect on joins only on ordinary tables, inheritance tables, UNLOGGED tables, temporary tables, external (foreign) tables, system catalogs, table functions, VALUES command results and CTEs are allowed to be in the parameter list. But joins on views and sub query are not affected.

For oracle compatibility, keywords of 'use\_hash', 'use\_nl', 'use\_merge', 'no\_use\_hash', 'no\_use\_nl' and 'no\_use\_merge' are also supported.

When `lightdb_dblevel_syntax_compatible_type` is 'off', join method hints can specify two or more tables, and will enforce the join methods of the joins involving specified tables.

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3)*/ FROM t1, t2 ,t3 WHERE t1.id = t2.id and t2.id=t3.id;
LOG:  lt_hint_plan:
used hint:
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (t1.id = t3.id)
-> Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Seq Scan on t1 @"lt#0"
      -> Hash
            -> Seq Scan on t2 @"lt#0"
-> Hash
      -> Seq Scan on t3 @"lt#0"
(9 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3) use_nl(t1 t2) use_merge(t1 t2 t3)*/ FROM t1, t2 ,t3 WHERE
t1.id = t2.id and t2.id=t3.id;
LOG:  lt_hint_plan:
used hint:
USE_NL(t1@lt#0 t2@lt#0)
USE_MERGE(t1@lt#0 t2@lt#0 t3@lt#0)
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Merge Join
Merge Cond: (t1.id = t3.id)
-> Nested Loop
      -> Index Scan using t1_pkey on t1 @"lt#0"
      -> Index Scan using t2_pkey on t2 @"lt#0"
            Index Cond: (id = t1.id)
-> Index Scan using t3_pkey on t3 @"lt#0"
(7 rows)
```

```
lightdb@postgres=#
```

When `lightdb_dblevel_syntax_compatible_type` is not 'off', join method hints can specify one or more tables, and will instructs the optimizer to join each specified table with another row source using specified join method. The optimizer uses those hints when the referenced table is forced to be the inner table of a join. The hints are ignored if the referenced table is the outer table. It is recommended to be used with the join order hints('leading', 'ordered').

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3)*/ FROM t1, t2 ,t3 WHERE t1.id = t2.id and t2.id=t3.id;
LOG:  lt_hint_plan:
used hint:
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (t1.id = t3.id)
-> Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Seq Scan on t1 @"lt#0"
      -> Hash
            -> Seq Scan on t2 @"lt#0"
-> Hash
      -> Seq Scan on t3 @"lt#0"
(9 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3) use_nl(t2) use_merge(t3)*/ FROM t1, t2 ,t3 WHERE t1.id =
t2.id and t2.id=t3.id;
LOG:  lt_hint_plan:
used hint:
USE_NL(t2@lt#0)
USE_MERGE(t3@lt#0)
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Merge Join
Merge Cond: (t1.id = t3.id)
-> Nested Loop
      -> Index Scan using t1_pkey on t1 @"lt#0"
      -> Index Scan using t2_pkey on t2 @"lt#0"
            Index Cond: (id = t1.id)
-> Index Scan using t3_pkey on t3 @"lt#0"
(7 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3) use_nl(t1) use_merge(t2)*/ FROM t1, t2 ,t3 WHERE t1.id =
t2.id and t2.id=t3.id;
LOG:  lt_hint_plan:
used hint:
USE_MERGE(t2@lt#0)
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
USE_NL(t1@lt#0)
duplication hint:
error hint:
```

QUERY PLAN

```

-----
Hash Join
Hash Cond: (t1.id = t3.id)
-> Merge Join
      Merge Cond: (t1.id = t2.id)
      -> Index Scan using t1_pkey on t1 @"lt#0"
      -> Index Scan using t2_pkey on t2 @"lt#0"
-> Hash
      -> Seq Scan on t3 @"lt#0"
(8 rows)

```

lightdb@postgres=#

When `lightdb_dblevel_syntax_compatible_type` is not 'off', join method hints that specify more than one table can be seen as a group of join method hints that specify one table, so when there is a conflict, it only affects the tables involved. e.g: 'use\_hash(a b)' and 'use\_nl(a)' is conflicted, but for table b, use\_hash is also used.

```

lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+leading(t1 t2
t3) use_nl(t2 t3) use_merge(t2)*/ FROM t1, t2 ,t3 WHERE t1.id =
t2.id and t2.id=t3.id;
INFO:  lt_hint_plan: hint syntax error at or near "use_nl(t2 t3)
use_merge(t2)"
DETAIL:  Conflict join method hint.
LOG:  lt_hint_plan:
used hint:
USE_NL(t3@lt#0) --> USE_NL(t2@lt#0 t3@lt#0)
Leading(((t1@lt#0 t2@lt#0) t3@lt#0))
not used hint:
duplication hint:
USE_NL(t2@lt#0) --> USE_NL(t2@lt#0 t3@lt#0)
USE_MERGE(t2@lt#0)
error hint:

```

#### QUERY PLAN

```

-----
Nested Loop
-> Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Seq Scan on t1 @"lt#0"
      -> Hash
          -> Seq Scan on t2 @"lt#0"
-> Index Scan using t3_pkey on t3 @"lt#0"
      Index Cond: (id = t1.id)
(8 rows)

```

lightdb@postgres=#

When `lightdb_dblevel_syntax_compatible_type` is not 'off', join method hints may conflict with 'swap\_join\_inputs' hint without using 'leading' hint.

```

lightdb@postgres=# EXPLAIN (COSTS false) SELECT/*+leading(t1 t2)
use_hash(t2) swap_join_inputs(t2)*/ * FROM t1, t2 WHERE t1.id =
t2.id;
LOG:  lt_hint_plan:
used hint:
USE_HASH(t2@lt#0)

```



```

Leading((t1@lt#0 t2@lt#0))
swap_join_inputs(t2@lt#0)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Hash Join
Hash Cond: (t2.id = t1.id)
-> Seq Scan on t2 @"lt#0"
-> Hash
      -> Seq Scan on t1 @"lt#0"
(5 rows)

```

```

lightdb@postgres=# EXPLAIN (COSTS false) SELECT /*+use_hash(t2)
swap_join_inputs(t2)*/ * FROM t1, t2 WHERE t1.id = t2.id;
INFO:  lt_hint_plan: join hint conflict with swap_join_inputs hint,
ignore swap_join_inputs
DETAIL:  use USE_HASH
LOG:  lt_hint_plan:
used hint:
USE_HASH(t2@lt#0)
not used hint:
duplication hint:
swap_join_inputs(t2@lt#0)
error hint:

```

QUERY PLAN

```

-----
Hash Join
Hash Cond: (t1.id = t2.id)
-> Seq Scan on t1 @"lt#0"
-> Hash
      -> Seq Scan on t2 @"lt#0"
(5 rows)

```

```
lightdb@postgres=#
```

### F.27.4.1.3. Hint for joining order

Normally this hint "Leading" enforces the order of join on two or more tables. There are two ways of enforcing. One is enforcing specific order of joining but not restricting direction at each join level. Another enforces join direction additionally. Details are seen in the hint list table.

```

lightdb@postgres=# /*+
lightdb@postgres*#      NestLoop(t1 t2)
lightdb@postgres*#      MergeJoin(t1 t2 t3)
lightdb@postgres*#      Leading(t1 t2 t3)
lightdb@postgres*#      */
lightdb@postgres=# SELECT * FROM table1 t1
lightdb@postgres=#      JOIN table table2 t2 ON (t1.key = t2.key)
lightdb@postgres=#      JOIN table table3 t3 ON (t2.key = t3.key);

```

For oracle compatibility, 'ordered' hint is also supported. The ORDERED hint instructs LightDB to join tables in the order in which they appear in the FROM clause. LightDB's 'ordered' hint is just an alias for 'leading' hint, so it will not override 'leading' hints like oracle does.

```
lightdb@postgres=# EXPLAIN SELECT * FROM t3, t2, t1 WHERE t1.id =
t2.id;
```

QUERY PLAN

```
-----
Nested Loop (cost=60.85..63982.64 rows=5107600 width=24)
-> Hash Join (cost=60.85..99.39 rows=2260 width=16)
    Hash Cond: (t2.id = t1.id)
        -> Seq Scan on t2 (cost=0.00..32.60 rows=2260 width=8)
        -> Hash (cost=32.60..32.60 rows=2260 width=8)
            -> Seq Scan on t1 (cost=0.00..32.60 rows=2260
width=8)
-> Materialize (cost=0.00..43.90 rows=2260 width=8)
    -> Seq Scan on t3 (cost=0.00..32.60 rows=2260 width=8)
(8 rows)
```

```
lightdb@postgres=# EXPLAIN SELECT /*+ordered*/ * FROM t3, t2, t1
WHERE t1.id = t2.id;
```

LOG: lt\_hint\_plan:

used hint:

Leading(@lt#0 ((t3@lt#0 t2@lt#0) t1@lt#0))

not used hint:

duplication hint:

error hint:

QUERY PLAN

```
-----
Hash Join (cost=60.85..77409.29 rows=5107600 width=24)
Hash Cond: (t2.id = t1.id)
-> Nested Loop (cost=0.00..63915.85 rows=5107600 width=16)
    -> Seq Scan on t3 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
    -> Materialize (cost=0.00..43.90 rows=2260 width=8)
        -> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
    -> Seq Scan on t1 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
(8 rows)
```

```
lightdb@postgres=#
```

For oracle compatibility, 'leading' hint is also supported to specify only one table, The table specified is used to start the join.

```
lightdb@postgres=# EXPLAIN SELECT * FROM t3, t2, t1 WHERE t1.id =
t2.id;
```

QUERY PLAN

```
-----
Nested Loop (cost=60.85..63982.64 rows=5107600 width=24)
-> Hash Join (cost=60.85..99.39 rows=2260 width=16)
    Hash Cond: (t2.id = t1.id)
        -> Seq Scan on t2 (cost=0.00..32.60 rows=2260 width=8)
        -> Hash (cost=32.60..32.60 rows=2260 width=8)
```

```

-> Seq Scan on t1 (cost=0.00..32.60 rows=2260
width=8)
-> Materialize (cost=0.00..43.90 rows=2260 width=8)
    -> Seq Scan on t3 (cost=0.00..32.60 rows=2260 width=8)
(8 rows)

```

```

lightdb@postgres=# EXPLAIN SELECT/*+leading(t1)*/ * FROM t3, t2,
t1 WHERE t1.id = t2.id;
LOG:  lt_hint_plan:
used hint:
Leading(t1@lt#0)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Nested Loop (cost=10000000060.85..10000063982.64 rows=5107600
width=24)
-> Hash Join (cost=60.85..99.39 rows=2260 width=16)
    Hash Cond: (t1.id = t2.id)
    -> Seq Scan on t1 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
    -> Hash (cost=32.60..32.60 rows=2260 width=8)
        -> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
-> Materialize (cost=0.00..43.90 rows=2260 width=8)
    -> Seq Scan on t3 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
(8 rows)

```

```

lightdb@postgres=# EXPLAIN SELECT/*+leading(t3)*/ * FROM t3, t2,
t1 WHERE t1.id = t2.id;
LOG:  lt_hint_plan:
used hint:
Leading(t3@lt#0)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Nested Loop (cost=10000000000.16..10000064316.68 rows=5107600
width=24)
-> Seq Scan on t3 @"lt#0" (cost=0.00..32.60 rows=2260 width=8)
-> Materialize (cost=10000000000.16..10000000444.73 rows=2260
width=16)
    -> Nested Loop (cost=10000000000.16..10000000433.43
rows=2260 width=16)
        -> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
        -> Index Scan using t1_pkey on t1 @"lt#0"
(cost=0.15..0.18 rows=1 width=8)
            Index Cond: (id = t2.id)

```

(7 rows)

```
lightdb@postgres=#
```

#### F.27.4.1.4. Hint for row number correction

This hint "Rows" corrects row number misestimation of joins that comes from restrictions of the planner.

This hint "Rows" also corrects row number misestimation of table or subquery.

```
lightdb@postgres=# /*+ Rows(a #10) */ SELECT... ; Sets rows of
table result to 10
lightdb@postgres=# /*+ Rows(a 10) */ SELECT... ; Sets rows of table
result to 10
lightdb@postgres=# /*+ Rows(a +10) */ SELECT... ; Increments row
number of table by 10
lightdb@postgres=# /*+ Rows(a -10) */ SELECT... ; Subtracts 10 from
the row number of table.
lightdb@postgres=# /*+ Rows(a *10) */ SELECT... ; Makes the row
number of table 10 times larger.
lightdb@postgres=# /*+ Rows(a b #10) */ SELECT... ; Sets rows of
join result to 10
lightdb@postgres=# /*+ Rows(a b 10) */ SELECT... ; Sets rows of
join result to 10
lightdb@postgres=# /*+ Rows(a b +10) */ SELECT... ; Increments row
number of join by 10
lightdb@postgres=# /*+ Rows(a b -10) */ SELECT... ; Subtracts 10
from the row number of join.
lightdb@postgres=# /*+ Rows(a b *10) */ SELECT... ; Makes the row
number of join 10 times larger.

lightdb@postgres=# /*+ cardinality(a #10) */ SELECT... ; Sets rows
of table result to 10
lightdb@postgres=# /*+ cardinality(a 10) */ SELECT... ; Sets rows
of table result to 10
lightdb@postgres=# /*+ cardinality(a +10) */ SELECT... ; Increments
row number of table by 10
lightdb@postgres=# /*+ cardinality(a -10) */ SELECT... ; Subtracts
10 from the row number of table.
lightdb@postgres=# /*+ cardinality(a *10) */ SELECT... ; Makes the
row number of table 10 times larger.
lightdb@postgres=# /*+ cardinality(a b #10) */ SELECT... ; Sets
rows of join result to 10
lightdb@postgres=# /*+ cardinality(a b 10) */ SELECT... ; Sets rows
of join result to 10
lightdb@postgres=# /*+ cardinality(a b +10) */ SELECT... ;
Increments row number of join by 10
lightdb@postgres=# /*+ cardinality(a b -10) */ SELECT... ;
Subtracts 10 from the row number of join.
lightdb@postgres=# /*+ cardinality(a b *10) */ SELECT... ; Makes
the row number of join 10 times larger.
```

For parameterized path, it is invalid, but it will affect the join cost based on parameterized path. It is different from Oracle, Oracle will not affect the join cost.

```
lightdb@postgres=# explain select /*+ use_nl(a b) leading(a b)*/
from t1 a , t2 b where a.key1=b.key1;
```

QUERY PLAN

```
-----
Nested Loop (cost=0.15..433.43 rows=2260 width=16)
-> Seq Scan on t1 a @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
-> Index Scan using t2_pkey on t2 b @"lt#0" (cost=0.15..0.18
rows=1 width=8)
Index Cond: (key1 = a.key1)
(4 rows)
```

```
lightdb@postgres=# explain select /*+ cardinality(b 1000)use_nl(a
b) leading(a b)*/ from t1 a , t2 b where a.key1=b.key1;
```

QUERY PLAN

```
-----
Nested Loop (cost=0.15..433.43 rows=1000 width=16)
-> Seq Scan on t1 a @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
-> Index Scan using t2_pkey on t2 b @"lt#0" (cost=0.15..0.18
rows=1 width=8)
Index Cond: (key1 = a.key1)
(4 rows)
```

```
chuhx@postgres=#
```

For subquery that cannot pull up, it will act on subquery; For a pulled up subquery, if there is only one table in the subquery, this will be applied to the tables in the subquery.

```
chuhx@postgres=# explain with cte as (select distinct * from t1)
select /*+hashjoin(t2, cte) cardinality(cte 1000) */ from t2,cte
where cte.key1=t2.key1;
```

QUERY PLAN

```
-----
Hash Join (cost=104.75..152.57 rows=1000 width=16)
Hash Cond: (t1.key1 = t2.key1)
-> HashAggregate (cost=43.90..66.50 rows=2260 width=8)
Group Key: t1.key1, t1.key2
-> Seq Scan on t1 @"lt#1" (cost=0.00..32.60 rows=2260
width=8)
-> Hash (cost=32.60..32.60 rows=2260 width=8)
-> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260
width=8)
(7 rows)
```

```
chuhx@postgres=# explain with cte as (select * from t1) select /
*+hashjoin(t2, cte) cardinality(cte 1000) */ from t2,cte where
cte.key1=t2.key1;
```

QUERY PLAN

```
-----
Hash Join (cost=45.10..83.64 rows=1000 width=16)
Hash Cond: (t2.key1 = t1.key1)
-> Seq Scan on t2 @"lt#0" (cost=0.00..32.60 rows=2260 width=8)
```

```

-> Hash (cost=32.60..32.60 rows=1000 width=8)
    -> Seq Scan on t1 @"lt#1" (cost=0.00..32.60 rows=1000
width=8)
(5 rows)

```

chuhx@postgres=#

### F.27.4.1.5. Hint for parallel plan

This hint "Parallel" enforces parallel execution configuration on scans. The third parameter specifies the strength of enforcement. "soft" means that `lt_hint_plan` only changes `max_parallel_worker_per_gather` and leave all others to planner. "hard" changes other planner parameters so as to forcibly apply the number. This can affect on ordinary tables, inheritance parents, unlogged tables and system catalogues. External tables, table functions, values clause, CTEs, views and subqueries are not affected. Internal tables of a view can be specified by its real name/alias as the target object. The following example shows that the query is enforced differently on each table.

```

lightdb@postgres=# explain /*+ Parallel(c1 3 hard) Parallel(c2 5
hard) */

```

```

        SELECT c2.a FROM c1 JOIN c2 ON (c1.a = c2.a);
        QUERY PLAN

```

```

-----
Hash Join (cost=2.86..11406.38 rows=101 width=4)
Hash Cond: (c1.a = c2.a)
-> Gather (cost=0.00..7652.13 rows=1000101 width=4)
    Workers Planned: 3
    -> Parallel Seq Scan on c1 (cost=0.00..7652.13
rows=322613 width=4)
-> Hash (cost=1.59..1.59 rows=101 width=4)
    -> Gather (cost=0.00..1.59 rows=101 width=4)
        Workers Planned: 5
        -> Parallel Seq Scan on c2 (cost=0.00..1.59
rows=59 width=4)

```

```

lightdb@postgres=# EXPLAIN /*+ Parallel(t1 5 hard) */ SELECT sum(a)
FROM t1;

```

QUERY PLAN

```

-----
Finalize Aggregate (cost=693.02..693.03 rows=1 width=8)
-> Gather (cost=693.00..693.01 rows=5 width=8)
    Workers Planned: 5
    -> Partial Aggregate (cost=693.00..693.01 rows=1
width=8)
        -> Parallel Seq Scan on t1 (cost=0.00..643.00
rows=20000 width=4)

```

This hint "Parallel" can also be used by specifying just an integer, indicating that it works for all tables in the current query block.

```

lightdb@postgres=# explain select /*+parallel(3)*/ from t1, t2
where t1.id=t2.id;

```

QUERY PLAN

-----  
-----

```

Hash Join (cost=28.25..34.19 rows=2260 width=16)
Hash Cond: (t1.id = t2.id)
-> Gather (cost=0.00..0.00 rows=2260 width=8)
      Workers Planned: 3
      -> Parallel Seq Scan on t1 @"lt#0" (cost=0.00..0.00
rows=729 width=8)
-> Hash (cost=0.00..0.00 rows=2260 width=8)
      -> Gather (cost=0.00..0.00 rows=2260 width=8)
            Workers Planned: 3
            -> Parallel Seq Scan on t2 @"lt#0" (cost=0.00..0.00
rows=729 width
=8)
(9 rows)

lightdb@postgres=#

```

### F.27.4.1.6. GUC parameters temporarily setting

'Set' hint changes GUC parameters just while planning. GUC parameter shown in Query Planning can have the expected effects on planning unless any other hint conflicts with the planner method configuration parameters. GUC parameters for `lt_hint_plan` are also settable by this hint but it won't work as your expectation.

```

lightdb@postgres=# /*+ Set(random_page_cost 2.0) */
lightdb@postgres=# SELECT * FROM table1 t1 WHERE key = 'value';
...

```

'Opt\_param' hint changes GUC parameters just while planning like 'Set' hint. But there are some differences from 'Set' hint (but same with oracle):

- Parameter name should be enclosed in single quotation marks.
- Parameter values that are strings should be enclosed in single quotation marks. Numeric parameter values are specified without quotation marks.

```

EXPLAIN (COSTS false) select * from test_opt_param1 a join
test_opt_param2 b on a.key1=b.key1;
          QUERY PLAN

```

```

-----
Hash Join
  Hash Cond: (a.key1 = b.key1)
    -> Seq Scan on test_opt_param1 a
    -> Hash
          -> Seq Scan on test_opt_param2 b
(5 rows)

```

```

EXPLAIN (COSTS false) select/*+opt_param('enable_hashjoin',
'off')*/ * from test_opt_param1 a join test_opt_param2 b on
a.key1=b.key1;

```

```

LOG:  lt_hint_plan:
used hint:
opt_param('enable_hashjoin' 'off')
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Merge Join
  Merge Cond: (a.key1 = b.key1)
  -> Index Scan using test_opt_param1_pkey on test_opt_param1 a
  @"lt#0"
  -> Index Scan using test_opt_param2_pkey on test_opt_param2 b
  @"lt#0"
(4 rows)
EXPLAIN (COSTS false) select /*+opt_param(enable_hashjoin, 'off')*/
 * from test_opt_param1 a join test_opt_param2 b on a.key1=b.key1;
INFO:  lt_hint_plan: hint syntax error at or near
"opt_param(enable_hashjoin, 'off')"
DETAIL:  opt_param hint requires parameter name to be enclosed in
single quotation marks.
LOG:  lt_hint_plan:
used hint:
not used hint:
duplication hint:
error hint:
opt_param(enable_hashjoin 'off')

```

QUERY PLAN

```

-----
Hash Join
  Hash Cond: (a.key1 = b.key1)
  -> Seq Scan on test_opt_param1 a @"lt#0"
  -> Hash
      -> Seq Scan on test_opt_param2 b @"lt#0"
(5 rows)

```

```

lightdb@postgres=# explain select * from test_opt_param1 where
key1=1;

```

QUERY PLAN

```

-----
Index Scan using test_opt_param1_pkey on test_opt_param1
(cost=0.15..2.17 r
ows=1 width=8)
  Index Cond: (key1 = 1)
(2 rows)

```

```

lightdb@postgres=# explain select /*+ Set(random_page_cost 1000) */
 * from test_opt_param1 where key1=1;

```

QUERY PLAN

```

-----
Seq Scan on test_opt_param1 @"lt#0" (cost=0.00..38.25 rows=1
width=8)
  Filter: (key1 = 1)
(2 rows)

```

### F.27.4.1.7. Query block name

Use the `qb_name` hint to define a name for a query block. This name can then be used in another query block to hint tables appearing in the named query block. If two or more query blocks have the



same name, or if the same query block is hinted twice with different names, all the names and the hints referencing them are ignored. Query blocks that are not named using this hint have unique system-generated names.

```
lightdb@postgres=# explain select /*+indexscan(t2@qb)*/ * from t1 ,
(select /*+qb_name(qb)*/ * from t2 where id >10) as tt;
LOG:  lt_hint_plan:
used hint:
IndexScan(t2@qb)
not used hint:
duplication hint:
error hint:
```

#### QUERY PLAN

```
-----
Nested Loop (cost=0.13..3.21 rows=3 width=532)
-> Index Scan using idx_t2_id on t2 (cost=0.13..2.15 rows=1
width=8)
      Index Cond: (id > 10)
-> Seq Scan on t1 (cost=0.00..1.03 rows=3 width=524)
(4 rows)
```

```
lightdb@postgres=#
lightdb@postgres=# explain select /*+indexscan(t2@qb)
indexscan(t3@qb1)*/ * from t1 ,(select /*+qb_name(qb)*/ * from t2
where id >10) as tt where exists (select /*+qb_name(qb1)*/ * from
t3 where id>1);
```

#### QUERY PLAN

```
-----
-
Result (cost=2.28..5.35 rows=3 width=532)
One-Time Filter: $0
InitPlan 1 (returns $0)
-> Index Scan using idx_t3_id on t3 @qb1 (cost=0.13..2.15
rows=1 width=0)
      Index Cond: (id > 1)
-> Nested Loop (cost=2.28..5.35 rows=3 width=532)
      -> Index Scan using idx_t2_id on t2 @qb (cost=0.13..2.15
rows=1 width=8)
            Index Cond: (id > 10)
      -> Seq Scan on t1 @"lt#0" (cost=0.00..1.03 rows=3
width=524)
(9 rows)
```

```
lightdb@postgres=#
```

### F.27.4.1.8. Other hints

Hints that cannot be classified into the above hints .

#### F.27.4.1.8.1. Hint for no merge

This hint "NO\_MERGE" instructs the optimizer not to combine the outer query and any inline view queries into a single query.

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from t1,
  (select /*+no_merge*/t2.id from t2,t3) tt where t1.id=tt.id;
LOG:  lt_hint_plan:
used hint:
no_merge
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (t2.id = t1.id)
->  Nested Loop
      ->  Seq Scan on t2 @"lt#0"
      ->  Materialize
            ->  Seq Scan on t3 @"lt#0"
->  Hash
      ->  Seq Scan on t1 @"lt#1"
(8 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select/*+ no_merge(tt)*/ *
  from t1, (select t2.id from t2,t3) tt where t1.id=tt.id;
LOG:  lt_hint_plan:
used hint:
no_merge(tt@lt#0)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (t2.id = t1.id)
->  Nested Loop
      ->  Seq Scan on t2
      ->  Materialize
            ->  Seq Scan on t3
->  Hash
      ->  Seq Scan on t1 @"lt#0"
(8 rows)
```

```
lightdb@postgres=#
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select/*+ no_merge(@qb)*/
  * from t1, (select/*+qb_name(qb)*/ t2.id from t2,t3) tt where
  t1.id=tt.id;
LOG:  lt_hint_plan:
used hint:
no_merge(@qb)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```

-----
Hash Join
Hash Cond: (t2.id = t1.id)
->  Nested Loop
      ->  Seq Scan on t2 @qb
      ->  Materialize
            ->  Seq Scan on t3 @qb
->  Hash
      ->  Seq Scan on t1 @"lt#0"
(8 rows)

lightdb@postgres=#

```

#### F.27.4.1.8.2. Hints for group by method(hash/sort)

The hint "use\_hash\_aggregation" instructs the optimizer to use hash aggregation when group by. The hint "no\_use\_hash\_aggregation" instructs the optimizer not to use hash aggregation when group by, then use sort.

There are two ways to use these hints. The first one has no parameters, specifying whether the current statement uses the hash algorithm, and the second one is combined with the query block name.

The following example shows the effect of the use\_hash\_aggregation hint.

```

lightdb@postgres=# EXPLAIN (COSTS false)  select max(id) from t1
where id>1 group by id order by id;
          QUERY PLAN
-----
GroupAggregate
Group Key: id
->  Index Only Scan using t1_pkey on t1
      Index Cond: (id > 1)
(4 rows)

lightdb@postgres=# EXPLAIN (COSTS false)  select /*+
use_hash_aggregation*/ max(id) from t1 where id>1 group by id
order by id;
          QUERY PLAN
-----
Sort
Sort Key: id
->  HashAggregate
      Group Key: id
      ->  Seq Scan on t1 @"lt#0"
            Filter: (id > 1)
(6 rows)

lightdb@postgres=#

```

The following example shows the effect of the no\_use\_hash\_aggregation hint.

```

lightdb@postgres=# EXPLAIN (COSTS false)  select max(id) from t1
where id>1 group by id;
          QUERY PLAN
-----
HashAggregate
Group Key: id
->  Seq Scan on t1

```

```

        Filter: (id > 1)
(4 rows)

lightdb@postgres=# EXPLAIN (COSTS false) select /*+
no_use_hash_aggregation*/ max(id) from t1 where id>1 group by id;
        QUERY PLAN
-----
GroupAggregate
Group Key: id
->  Index Only Scan using t1_pkey on t1 @"lt#0"
        Index Cond: (id > 1)
(4 rows)

lightdb@postgres=#

```

### F.27.4.1.8.3. Hints for special join(semijoin/antijoin)

Hints for semi-join are "semijoin", "hash\_sj", "nl\_sj", "merge\_sj" and "no\_semijoin", which are used to control whether to use semi-join or specify the algorithm for semi-join. Hints for anti-join are "hash\_aj", "nl\_aj", "merge\_aj", which are used to specify the algorithm for anti-join.

There are two ways to use these hints. The first one has no parameter and must be placed in sublink, and the second one is combined with the query block name.

The following example shows the effect of the hints with semi-join.

```

lightdb@postgres=# create table test1 (key1 int primary key, key2
int);
CREATE TABLE
lightdb@postgres=# create table test2 (key1 int primary key, key2
int);
CREATE TABLE
lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1 where
exists (select * from test2 where test1.key1=test2.key1);
        QUERY PLAN
-----
Hash Join
Hash Cond: (test1.key1 = test2.key1)
->  Seq Scan on test1
->  Hash
        ->  Seq Scan on test2
(5 rows)

lightdb@postgres=# EXPLAIN (COSTS false) select * from
test1 where exists (select /*+semijoin*/ * from test2 where
test1.key1=test2.key1);
        QUERY PLAN
-----
Merge Semi Join
Merge Cond: (test1.key1 = test2.key1)
->  Index Scan using test1_pkey on test1 @"lt#1"
->  Index Only Scan using test2_pkey on test2 @"lt#0"
(4 rows)

lightdb@postgres=# EXPLAIN (COSTS false) select * from
test1 where exists (select /*+hash_sj*/ * from test2 where
test1.key1=test2.key1);

```

QUERY PLAN

```
-----
Hash Semi Join
Hash Cond: (test1.key1 = test2.key1)
-> Seq Scan on test1 @"lt#1"
-> Hash
    -> Seq Scan on test2 @"lt#0"
(5 rows)
```

lightdb@postgres=#

The following example shows the effect of the hints without semi-join.

```
lightdb@postgres=# create table tt1 (id int, t int, name
varchar(255));
CREATE TABLE
lightdb@postgres=# create table tt2 (id int , salary int);
CREATE TABLE
lightdb@postgres=# create index idx_t1_id on tt1(id);
CREATE INDEX
lightdb@postgres=# create index idx_t2_id on tt2(id);
CREATE INDEX
lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false) select * from tt1 where
exists (select * from tt2 where tt1.id=tt2.id);
QUERY PLAN
```

```
-----
Nested Loop Semi Join
-> Seq Scan on tt1
-> Index Only Scan using idx_t2_id on tt2
    Index Cond: (id = tt1.id)
(4 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from tt1 where
exists (select /*+no_semijoin*/ from tt2 where tt1.id=tt2.id);
QUERY PLAN
```

```
-----
Hash Join
Hash Cond: (tt1.id = tt2.id)
-> Seq Scan on tt1 @"lt#1"
-> Hash
    -> HashAggregate
        Group Key: tt2.id
    -> Seq Scan on tt2 @"lt#0"
(7 rows)
```

lightdb@postgres=#

The following example shows the effect of the hints with anti-join.

```
lightdb@postgres=# create table tt1 (id int, t int, name
varchar(255));
CREATE TABLE
lightdb@postgres=# create table tt2 (id int , salary int);
CREATE TABLE
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1 where
not exists (select 1 from test2 where test1.key1=test2.key1);
```

QUERY PLAN

```
-----
Hash Anti Join
Hash Cond: (test1.key1 = test2.key1)
-> Seq Scan on test1
-> Hash
    -> Seq Scan on test2
(5 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1
where not exists (select /*+hash_aj*/ 1 from test2 where
test1.key1=test2.key1);
```

QUERY PLAN

```
-----
Hash Anti Join
Hash Cond: (test1.key1 = test2.key1)
-> Seq Scan on test1 @"lt#1"
-> Hash
    -> Seq Scan on test2 @"lt#0"
(5 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from
test1 where not exists (select /*+nl_aj*/ 1 from test2 where
test1.key1=test2.key1);
```

QUERY PLAN

```
-----
Nested Loop Anti Join
-> Seq Scan on test1 @"lt#1"
-> Index Only Scan using test2_pkey on test2 @"lt#0"
    Index Cond: (key1 = test1.key1)
(4 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1
where not exists (select /*+merge_aj*/ 1 from test2 where
test1.key1=test2.key1);
```

QUERY PLAN

```
-----
Merge Anti Join
Merge Cond: (test1.key1 = test2.key1)
-> Index Scan using test1_pkey on test1 @"lt#1"
-> Index Only Scan using test2_pkey on test2 @"lt#0"
(4 rows)
```

```
lightdb@postgres=#
```

"no\_semijoin" doesn't prevent pulling up sublink, instead it dose not chooses semijoin paths when other paths can be chosen.

```
no_semijoin invalid#
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1
where exists (select /*+no_semijoin*/ * from test2 where
test1.key1>test2.key2);
```

```
LOG:  lt_hint_plan:
```

```
used hint:
```

```
no_semijoin
```

```
not used hint:
```

```
duplication hint:
```

error hint:

QUERY PLAN

```
-----
Nested Loop Semi Join
Join Filter: (test1.key1 > test2.key2)
-> Seq Scan on test1 @"lt#1"
-> Materialize
    -> Seq Scan on test2 @"lt#0"
(5 rows)
```

lightdb@postgres=#

When used with join method hint, join method hint will be ignored. The following example shows it.

```
lightdb@postgres=# explain select /*+nestloop(test1 test2@qb)*/ *
  from test1 where exists (select /*+semijoin qb_name(qb)*/ *
    from test2 where test1.key1=test2.key1);
INFO:  lt_hint_plan: join type hint is conflicted with special join
  hint, ignore join type hint
DETAIL:  join type hint: NestLoop, special join hint:
  semijoin(@qb)
LOG:  lt_hint_plan:
used hint:
semijoin
not used hint:
duplication hint:
NestLoop(test1@lt#0 test2@qb)
error hint:
```

QUERY PLAN

```
-----
Merge Semi Join (cost=0.31..124.01 rows=2260 width=8)
Merge Cond: (test1.key1 = test2.key1)
-> Index Scan using test1_pkey on test1 @"lt#0" (cost=0.15..45.06
  rows=2260 width=8)
-> Index Only Scan using test2_pkey on test2 @qb
  (cost=0.15..45.06 rows=2260 width=4)
(4 rows)
```

lightdb@postgres=#

When used with the leading hint, parts of the leading hint that conflict with these hints will be ignored, but this may still render these hints ineffective. When there are conflicts, the result may not be as you expected, so the best way is resolve the conflict. The following example shows the conflict.

```
lightdb@postgres=# explain select /*+leading(test2@qb test1 )*/ *
  from test1 where exists (select /*+semijoin qb_name(qb)*/ *
    from test2 where test1.key1=test2.key1);
INFO:  lt_hint_plan: special join hint conflict with sub of leading
  hint, ignore sub of leading hint
```

```

DETAIL: use special join hint: semijoin(@qb), the sub of leading
       has 2 relation
LOG:   lt_hint_plan:
used hint:
Leading((test2@qb test1@lt#0))
semijoin
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Merge Semi Join (cost=0.31..124.01 rows=2260 width=8)
Merge Cond: (test1.key1 = test2.key1)
-> Index Scan using test1_pkey on test1 @"lt#0" (cost=0.15..45.06
   rows=2260 width=8)
-> Index Only Scan using test2_pkey on test2 @qb
   (cost=0.15..45.06 rows=2260 width=4)
   (4 rows)

lightdb@postgres=#

```

#### F.27.4.1.8.4. Hint for specify outer table of hashjoin

This hint "swap\_join\_inputs" specifies the outer table of hashjoin.

The following example shows the effect of "swap\_join\_inputs".

```

lightdb@postgres=# create table test1 (key1 int primary key, key2
int);
CREATE TABLE
lightdb@postgres=# create table test2 (key1 int primary key, key2
int);
CREATE TABLE
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1, test2
where test1.key1 = test2.key1;
          QUERY PLAN

```

```

-----
Hash Join
Hash Cond: (test1.key1 = test2.key1)
-> Seq Scan on test1
-> Hash
       -> Seq Scan on test2
(5 rows)

```

```

lightdb@postgres=# EXPLAIN (COSTS false) select /*
+swap_join_inputs(test2)*/ from test1, test2 where test1.key1 =
test2.key1;
LOG:   lt_hint_plan:
used hint:
swap_join_inputs(test2@lt#0)
not used hint:
duplication hint:

```



error hint:

QUERY PLAN

```
-----
Hash Join
Hash Cond: (test2.key1 = test1.key1)
-> Seq Scan on test2 @"lt#0"
-> Hash
    -> Seq Scan on test1 @"lt#0"
(5 rows)
```

lightdb@postgres=#

Using this hint will enforce SQL to use hashjoin if possible. The following example shows it.

```
lightdb@postgres=# create table t_1(key1 int not null);
CREATE TABLE
lightdb@postgres=# create table t_2(key1 int not null);
CREATE TABLE
lightdb@postgres=# explain select /*swap_join_inputs(t_2)*/ from
t_1,t_2 where t_1.key1=t_2.key1;
QUERY PLAN
```

```
-----
Merge Join (cost=359.57..860.00 rows=32512 width=8)
Merge Cond: (t_1.key1 = t_2.key1)
-> Sort (cost=179.78..186.16 rows=2550 width=4)
    Sort Key: t_1.key1
    -> Seq Scan on t_1 (cost=0.00..35.50 rows=2550 width=4)
-> Sort (cost=179.78..186.16 rows=2550 width=4)
    Sort Key: t_2.key1
    -> Seq Scan on t_2 (cost=0.00..35.50 rows=2550 width=4)
(8 rows)
```

```
lightdb@postgres=# explain select /*+swap_join_inputs(t_2)*/ from
t_1,t_2 where t_1.key1=t_2.key1;
LOG:  lt_hint_plan:
used hint:
swap_join_inputs(t_2@lt#0)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join (cost=67.38..1247.18 rows=32512 width=8)
Hash Cond: (t_2.key1 = t_1.key1)
-> Seq Scan on t_2 @"lt#0" (cost=0.00..35.50 rows=2550 width=4)
-> Hash (cost=35.50..35.50 rows=2550 width=4)
    -> Seq Scan on t_1 @"lt#0" (cost=0.00..35.50 rows=2550
width=4)
(5 rows)
```

lightdb@postgres=#

When used with the leading hint, parts of the leading hint that conflict with these hints will be ignored. The following example shows it.

```
lightdb@postgres=# EXPLAIN (COSTS false) select /*+ leading(test1
test2) swap_join_inputs(test2)*/ from test1, test2 where
test1.key1 = test2.key1;
INFO:  lt_hint_plan: leading hint conflict with swap_join_inputs
hint, ignore leading hint
DETAIL: use swap_join_hint(test2@lt#0)
LOG:  lt_hint_plan:
used hint:
Leading((test1@lt#0 test2@lt#0))
swap_join_inputs(test2@lt#0)
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (test2.key1 = test1.key1)
-> Seq Scan on test2 @"lt#0"
-> Hash
      -> Seq Scan on test1 @"lt#0"
(5 rows)
```

```
lightdb@postgres=#
```

When used with the join method hint, this hint can't be used if the join method hint specifies a non-hashjoin method. The following example shows it.

```
lightdb@postgres=# EXPLAIN (COSTS false) select /*+ nestloop(test1
test2) swap_join_inputs(test2)*/ from test1, test2 where
test1.key1 = test2.key1;
LOG:  lt_hint_plan:
used hint:
NestLoop(test1@lt#0 test2@lt#0)
not used hint:
swap_join_inputs(test2@lt#0)
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Nested Loop
-> Seq Scan on test1 @"lt#0"
-> Index Scan using test2_pkey on test2 @"lt#0"
      Index Cond: (key1 = test1.key1)
(4 rows)
```

```
lightdb@postgres=#
```

This hint shouldn't be used for semij-join and anti-join, because semi-join and anti-join can't change outer table. When used with semi-join and anti-join hint, this hint will be ignored. The following example shows it.

```
lightdb@postgres=# EXPLAIN (COSTS false) select/*
+swap_join_inputs(test2@qb)*/ * from test1 where exists ( select/
```

```
*+semijoin qb_name(qb)*/ * from test2 where test1.key1 =
test2.key1);
INFO:  lt_hint_plan: special join hint conflict with
swap_join_inputs hint, ignore swap_join_inputs hint
DETAIL: ignore swap_join_hint(test2@qb), use semijoin(@qb)
LOG:  lt_hint_plan:
used hint:
semijoin
not used hint:
duplication hint:
swap_join_inputs(test2@qb)
error hint:
```

QUERY PLAN

```
-----
Merge Semi Join
Merge Cond: (test1.key1 = test2.key1)
->  Index Scan using test1_pkey on test1 @"lt#0"
->  Index Only Scan using test2_pkey on test2 @qb
(4 rows)
```

lightdb@postgres=#

#### F.27.4.1.8.5. Hint to preserve the order of predicate evaluation

This hint "ordered\_predicates" forces the optimizer to preserve the order of predicate evaluation, except for predicates used as index keys. Use this hint for the WHERE clause of SELECT statements.

You can override these default evaluation rules using the ordered\_predicates hint, and your WHERE clause items will then be evaluated in the order that they appear in the query. The ordered\_predicates hint is commonly used in cases where a function is used in the WHERE clause of a query. It is also very useful in cases where you know the most restrictive predicates and you want Lightdb to evaluate these first.

The following example shows the effect of "ordered\_predicates".

```
lightdb@postgres=# create table test1 (key1 int, key2 int);
CREATE TABLE
lightdb@postgres=# create table test2 (key1 int, key2 int);
CREATE TABLE
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1 where
mod(key1,10)=2 and key2=2;
```

QUERY PLAN

```
-----
Seq Scan on test1
  Filter: ((key2 = 2) AND (mod(key1, 10) = 2))
(2 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select /*
+ordered_predicates*/ * from test1 where mod(key1,10)=2 and key2=2;
```

QUERY PLAN

```
-----
Seq Scan on test1 @"lt#0"
  Filter: ((mod(key1, 10) = 2) AND (key2 = 2))
(2 rows)
```

lightdb@postgres=#

This hint will not affect predicates that transitively generated by the optimizer.

In the following example, "b.key2 = 1" is regenerated by the optimizer, so its order can't be reserved.

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1 a left
join test2 b on a.key1=b.key1 and a.key2=b.key2 where mod(b.key2,
10) = 2 and b.key2 = 1;
```

QUERY PLAN

```
-----
Nested Loop
  Join Filter: (a.key1 = b.key1)
  -> Seq Scan on test2 b
      Filter: ((key2 = 1) AND (mod(key2, 10) = 2))
  -> Seq Scan on test1 a
      Filter: (key2 = 1)
(6 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select/*
+ordered_predicates*/ * from test1 a left join test2 b on
a.key1=b.key1 and a.key2=b.key2 where mod(b.key2, 10) = 2 and
b.key2 = 1;
```

QUERY PLAN

```
-----
Nested Loop
  Join Filter: (a.key1 = b.key1)
  -> Seq Scan on test2 b @"lt#0"
      Filter: ((key2 = 1) AND (mod(key2, 10) = 2))
  -> Seq Scan on test1 a @"lt#0"
      Filter: (key2 = 1)
(6 rows)
```

```
lightdb@postgres=#
```

#### F.27.4.1.8.6. Hint to control optimization about pull up sublink

The optimization about pull up sublink is an RBO. it will pull up sublink if it is possible. So there is no need to implement "unnest" hint, we only support syntax here.

The "no\_unnest" hint can be used to force to not pull up sublink.

The following example shows the effect of "no\_unnest".

```
lightdb@postgres=# create table test1 (key1 int, key2 int);
CREATE TABLE
lightdb@postgres=# create table test2 (key1 int, key2 int);
CREATE TABLE
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1 where
exists(select * from test2 where test1.key1=test2.key1);
```

QUERY PLAN

```
-----
Hash Join
  Hash Cond: (test1.key1 = test2.key1)
  -> Seq Scan on test1
  -> Hash
      -> HashAggregate
          Group Key: test2.key1
          -> Seq Scan on test2
(7 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select * from
test1 where exists(select/*+no_unnest*/ * from test2 where
test1.key1=test2.key1);
```

```
QUERY PLAN
```

```
-----
Seq Scan on test1 @"lt#1"
  Filter: (alternatives: SubPlan 1 or hashed SubPlan 2)
  SubPlan 1
    -> Seq Scan on test2 @"lt#0"
        Filter: (test1.key1 = key1)
  SubPlan 2
    -> Seq Scan on test2 test2_1 @"lt#0"
(7 rows)
```

```
lightdb@postgres=#
```

#### F.27.4.1.8.7. Hint to control parallel join mode

Now 'pq\_distribute' hint is only use for parallel hash join, and only this usage ('pq\_distribute(inner\_table none broadcast)') works.

The usage ('pq\_distribute(inner\_table hash hash)') is supported, but not work.

When used with 'leading' hint, it will be used only if the specified table is the inner table after using 'leading' hint.

The following example shows the effect of "pq\_distribute".

```
lightdb@postgres=# create table t1 (id int, val text);
CREATE TABLE
lightdb@postgres=# create table t2 (id int, val text);
CREATE TABLE
lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
lightdb@lt_test=# EXPLAIN (COSTS false) SELECT /*+ leading(t1 t2)
hashjoin(t1 t2)*/ * FROM t1 join t2 on t1.id=t2.id;
QUERY PLAN
```

```
-----
Gather
  Workers Planned: 3
  -> Parallel Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Parallel Seq Scan on t1 @"lt#0"
      -> Parallel Hash
          -> Parallel Seq Scan on t2 @"lt#0"
(7 rows)
```

```
lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
lightdb@lt_test=# EXPLAIN (COSTS false) select/*+leading(t1 t2)
hashjoin(t1 t2) pq_distribute(t2 none broadcast)*/ * from t1 join
t2 on t1.id=t2.id;
QUERY PLAN
```

```
-----
Gather
```

```

Workers Planned: 3
-> Hash Join
    Hash Cond: (t1.id = t2.id)
    -> Parallel Seq Scan on t1 @"lt#0"
    -> Hash
        -> Seq Scan on t2 @"lt#0"
(7 rows)

```

lightdb@lt\_test=#

When used with 'swap\_join\_inputs' hint, it will always be used if 'swap\_join\_inputs' hint is used. It is different from oracle, in oracle, 'pq\_distribute' will not work if the specified table is the inner table after using 'swap\_join\_inputs'.

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
EXPLAIN (COSTS false) select/*+leading(t1 t2) hashjoin(t1
t2) pq_distribute(t1 none broadcast)*/ * from t1 join t2 on
t1.id=t2.id;

```

QUERY PLAN

```

-----
Gather
  Workers Planned: 3
  -> Parallel Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Parallel Seq Scan on t1 @"lt#0"
      -> Parallel Hash
          -> Parallel Seq Scan on t2 @"lt#0"
(7 rows)

```

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
EXPLAIN (COSTS false) select/*+leading(t1 t2) hashjoin(t1 t2)
pq_distribute(t1 none broadcast) swap_join_inputs(t2)*/ * from t1
join t2 on t1.id=t2.id;

```

QUERY PLAN

```

-----
Gather
  Workers Planned: 3
  -> Hash Join
      Hash Cond: (t2.id = t1.id)
      -> Parallel Seq Scan on t2 @"lt#0"
      -> Hash
          -> Seq Scan on t1 @"lt#0"
(7 rows)

```

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
EXPLAIN (COSTS false) select/*+leading(t1 t2) hashjoin(t1 t2)
pq_distribute(t2 none broadcast) swap_join_inputs(t2)*/ * from t1
join t2 on t1.id=t2.id;

```

QUERY PLAN

```

-----
Gather
  Workers Planned: 3
  -> Hash Join
      Hash Cond: (t2.id = t1.id)
      -> Parallel Seq Scan on t2 @"lt#0"
      -> Hash
          -> Seq Scan on t1 @"lt#0"
(7 rows)

```

lightdb@lt\_test=#

Without specifying the order of join, 'pq\_distribute' hint might be used but doesn't work, because it can only work when the specified table is the inner table and the join is a parallel hash join. If the cost of another path which the specified table is the outer table is lower, the optimizer will choose another path.

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
EXPLAIN (COSTS false) select/*+hashjoin(t1 t2)pq_distribute(t2 none
broadcast)*/ * from t1 join t2 on t1.id=t2.id;
          QUERY PLAN

```

```

-----
Gather
  Workers Planned: 3
  -> Parallel Hash Join
      Hash Cond: (t2.id = t1.id)
      -> Parallel Seq Scan on t2 @"lt#0"
      -> Parallel Hash
          -> Parallel Seq Scan on t1 @"lt#0"
(7 rows)

```

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/
EXPLAIN (COSTS false) select/*+hashjoin(t1 t2)pq_distribute(t1 none
broadcast)*/ * from t1 join t2 on t1.id=t2.id;
          QUERY PLAN

```

```

-----
Gather
  Workers Planned: 3
  -> Parallel Hash Join
      Hash Cond: (t1.id = t2.id)
      -> Parallel Seq Scan on t1 @"lt#0"
      -> Parallel Hash
          -> Parallel Seq Scan on t2 @"lt#0"
(7 rows)

```

```

lightdb@lt_test=# /*+set(parallel_tuple_cost 0)
set(parallel_setup_cost 0) set(min_parallel_table_scan_size
0) set(min_parallel_index_scan_size 0)
set(max_parallel_workers_per_gather 8)*/

```

```
EXPLAIN (COSTS false) select /*+hashjoin(t1 t2)pg_distribute(t1 none
broadcast) pg_distribute(t2 none broadcast)*/ * from t1 join t2 on
t1.id=t2.id;
```

QUERY PLAN

```
-----
Gather
  Workers Planned: 3
  -> Hash Join
        Hash Cond: (t1.id = t2.id)
        -> Parallel Seq Scan on t1 @"lt#0"
        -> Hash
              -> Seq Scan on t2 @"lt#0"

(7 rows)

lightdb@lt_test=#
```

#### F.27.4.1.8.8. Hint about pushing down clauses with sublink

In LightDB, the optimization about pushing down clauses with sublink is an RBO. it will push down clauses with sublink if it is possible.

The "no\_push\_subq" hint can be used to force to not push down clauses with sublink.

The "push\_subq" hint can be used to force to push down clauses with sublink. But because LightDB will push down clauses with sublink if it is possible, there is no need to use it. if you use it, it will be marked used when it can be used.

The following example shows the effect of "no\_push\_subq". The "push\_subq" hint's usage is similar to "no\_push\_subq".

```
create table test_no_push_subq1 as select * from pg_class order by
oid limit 100;
create table test_no_push_subq2 as select * from pg_class order by
oid limit 100;
create table test_no_push_subq3 as select * from pg_class order by
oid limit 100;
create table test_no_push_subq4 as select * from pg_class order by
oid limit 100;
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.relytype =b.relytype and a.oid = b.oid
lightdb@postgres=# where a.oid = (select max(oid) from
test_no_push_subq2);
```

QUERY PLAN

```
-----
Nested Loop
  Join Filter: (a.relytype = b.relytype)
  InitPlan 1 (returns $0)
    -> Aggregate
          -> Seq Scan on test_no_push_subq2
  -> Seq Scan on test_no_push_subq1 a
        Filter: (oid = $0)
  -> Materialize
        -> Seq Scan on test_no_push_subq3 b
              Filter: (oid = $0)

(10 rows)

lightdb@postgres=# EXPLAIN (COSTS false)
```



```
lightdb@postgres-# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres-# where a.oid = (select/*+no_push_subq*/ max(oid)
from test_no_push_subq2);
```

QUERY PLAN

-----  
Hash Join

```
Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
Join Filter: (a.oid = $0)
InitPlan 1 (returns $0)
-> Aggregate
    -> Seq Scan on test_no_push_subq2 @"lt#0"
-> Seq Scan on test_no_push_subq1 a @"lt#1"
-> Hash
    -> Seq Scan on test_no_push_subq3 b @"lt#1"
```

(9 rows)

```
lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres-# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres-# where a.oid = (select max(oid) from
test_no_push_subq2 c where a.oid = c.oid);
```

QUERY PLAN

-----  
Nested Loop

```
Join Filter: ((a.reltype = b.reltype) AND (a.oid = b.oid))
-> Seq Scan on test_no_push_subq3 b
-> Materialize
    -> Seq Scan on test_no_push_subq1 a
        Filter: (oid = (SubPlan 2))
        SubPlan 2
            -> Result
                InitPlan 1 (returns $1)
                    -> Limit
                        -> Seq Scan on test_no_push_subq2 c
                            Filter: ((oid IS NOT NULL) AND
```

(a.oid = oid))  
(12 rows)

```
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres-# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres-# where a.oid = (select/*+no_push_subq*/ max(oid)
from test_no_push_subq2 c where a.oid = c.oid);
```

QUERY PLAN

-----  
Hash Join

```
Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
Join Filter: (a.oid = (SubPlan 2))
-> Seq Scan on test_no_push_subq1 a @"lt#1"
-> Hash
    -> Seq Scan on test_no_push_subq3 b @"lt#1"
SubPlan 2
-> Result
    InitPlan 1 (returns $1)
```

```

-> Limit
-> Seq Scan on test_no_push_subq2 c @"lt#0"
    Filter: ((oid IS NOT NULL) AND (a.oid =
oid))
(12 rows)

```

```

lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select * from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype
lightdb@postgres=# where (select oid from test_no_push_subq2 c
where c.oid=a.oid) = (select oid from test_no_push_subq3 d where
d.oid=a.oid);

```

QUERY PLAN

-----

Nested Loop

```

Join Filter: (a.reltype = b.reltype)
-> Seq Scan on test_no_push_subq3 b
-> Materialize
    -> Seq Scan on test_no_push_subq1 a
        Filter: ((SubPlan 1) = (SubPlan 2))
        SubPlan 1
            -> Seq Scan on test_no_push_subq2 c
                Filter: (oid = a.oid)
        SubPlan 2
            -> Seq Scan on test_no_push_subq3 d
                Filter: (oid = a.oid)

```

(12 rows)

```

lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select * from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype
lightdb@postgres=# where (select/*+no_push_subq*/ oid from
test_no_push_subq2 c where c.oid=a.oid) = (select oid from
test_no_push_subq3 d where d.oid=a.oid);

```

QUERY PLAN

-----

Hash Join

```

Hash Cond: (a.reltype = b.reltype)
Join Filter: ((SubPlan 1) = (SubPlan 2))
-> Seq Scan on test_no_push_subq1 a @"lt#2"
-> Hash
    -> Seq Scan on test_no_push_subq3 b @"lt#2"
    SubPlan 1
        -> Seq Scan on test_no_push_subq2 c @"lt#0"
            Filter: (oid = a.oid)
    SubPlan 2
        -> Seq Scan on test_no_push_subq3 d @"lt#1"
            Filter: (oid = a.oid)

```

(12 rows)

```

lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres=# where a.oid > all (select oid from
test_no_push_subq2 c where c.oid =a.oid);

```

QUERY PLAN

```

-----
Hash Join
  Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
  -> Seq Scan on test_no_push_subq1 a
        Filter: (SubPlan 1)
        SubPlan 1
          -> Seq Scan on test_no_push_subq2 c
                Filter: (oid = a.oid)
  -> Hash
        -> Seq Scan on test_no_push_subq3 b
(9 rows)

lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres=# where a.oid > all (select/*+ no_push_subq*/ oid
from test_no_push_subq2 c where c.oid =a.oid);
QUERY PLAN

```

```

-----
Hash Join
  Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
  Join Filter: (SubPlan 1)
  -> Seq Scan on test_no_push_subq1 a @"lt#1"
  -> Hash
        -> Seq Scan on test_no_push_subq3 b @"lt#1"
  SubPlan 1
    -> Seq Scan on test_no_push_subq2 c @"lt#0"
          Filter: (oid = a.oid)
(9 rows)

```

```

lightdb@postgres=#
lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid
lightdb@postgres=# where exists(select/*+no_unnest*/ * from
test_no_push_subq2 c where a.oid = c.oid and c.oid=2691);
QUERY PLAN

```

```

-----
Hash Join
  Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
  -> Seq Scan on test_no_push_subq1 a @"lt#1"
        Filter: (alternatives: SubPlan 1 or hashed SubPlan 2)
        SubPlan 1
          -> Result
                One-Time Filter: (a.oid = '2691'::oid)
                -> Seq Scan on test_no_push_subq2 c @"lt#0"
                      Filter: (oid = '2691'::oid)
        SubPlan 2
          -> Seq Scan on test_no_push_subq2 c_1 @"lt#0"
                Filter: (oid = '2691'::oid)
  -> Hash
        -> Seq Scan on test_no_push_subq3 b @"lt#1"
(14 rows)

```

```

lightdb@postgres=# EXPLAIN (COSTS false)
lightdb@postgres=# select a.oid from test_no_push_subq1 a join
test_no_push_subq3 b on a.reltype =b.reltype and a.oid = b.oid

```

```
lightdb@postgres-# where exists(select/*+no_unnest no_push_subq*/ *
from test_no_push_subq2 c where a.oid = c.oid and c.oid=2691);
QUERY PLAN
```

```
-----
Hash Join
Hash Cond: ((a.reltype = b.reltype) AND (a.oid = b.oid))
Join Filter: (alternatives: SubPlan 1 or hashed SubPlan 2)
-> Seq Scan on test_no_push_subq1 a @"lt#1"
-> Hash
    -> Seq Scan on test_no_push_subq3 b @"lt#1"
SubPlan 1
-> Result
    One-Time Filter: (a.oid = '2691'::oid)
    -> Seq Scan on test_no_push_subq2 c @"lt#0"
        Filter: (oid = '2691'::oid)
SubPlan 2
-> Seq Scan on test_no_push_subq2 c_1 @"lt#0"
    Filter: (oid = '2691'::oid)
(14 rows)
```

```
lightdb@postgres=#
```

Note that "no\_push\_subq" is not used when "push\_subq" and "no\_push\_subq" are not applied to the same sublink, but to the same filter (same with oracle). for example("no\_push\_subq" on subplan2 is not used):

```
EXPLAIN (COSTS false)
select * from test_push_subq1 a join test_push_subq3 b on a.reltype
=b.reltype
where ((select/*+no_push_subq*/ relname from test_push_subq2
c where c.oid=a.oid), (select/*+push_subq*/ reltype from
test_push_subq2 c where c.oid=a.oid)) = (select/*+no_push_subq*/
relname, reltype from test_push_subq2);
LOG:  lt_hint_plan:
used hint:
no_push_subq
push_subq
not used hint:
no_push_subq
duplication hint:
error hint:
```

QUERY PLAN

```
-----
Hash Join
Hash Cond: (a.reltype = b.reltype)
Join Filter: ((SubPlan 1) = $2)
InitPlan 3 (returns $2,$3)
-> Seq Scan on test_push_subq2 @"lt#0"
-> Seq Scan on test_push_subq1 a @"lt#3"
    Filter: ((SubPlan 2) = $3)
    SubPlan 2
        -> Seq Scan on test_push_subq2 c_1 @"lt#2"
            Filter: (oid = a.oid)
-> Hash
    -> Seq Scan on test_push_subq3 b @"lt#3"
SubPlan 1
```

```

-> Seq Scan on test_push_subq2 c @"lt#1"
    Filter: (oid = a.oid)
(15 rows)

```

#### F.27.4.1.8.9. Hint to ignore a unique key violation

The "ignore\_row\_on\_dupkey\_index" hint can be used to ignore a unique key violation for a specified set of columns or for a specified index. Currently using this hint is the same as using 'on conflict do nothing' clause. If you specify this hint when inserting data with DML error logging enabled, then the unique key violation is not logged and does not cause statement termination.

The semantic effect of this hint results in error messages if specific rules are violated:

- You must specify exactly one index. If you specify no index, then the statement causes LT008(oracle is ORA-38912). If you specify more than one index, then the statement causes LT010(oracle is ORA-38915).
- If you specify index, then the index must exist and be unique. Otherwise, the statement causes LT009(oracle is ORA-38913).
- The IGNORE\_ROW\_ON\_DUPKEY\_INDEX hint applies only to single-table INSERT operations. It is not supported for UPDATE, DELETE, MERGE(do not support hint yet, will ignore), or multitable insert operations, and will report LT011(oracle is ORA-38917).
- If the specified columns have more than one index, then the statement causes LT010(oracle does not have this because you cannot have more than one index on the same field).
- Cannot be used with an on conflict clause and will result in an LT011 error (oracle does not have an on conflict clause).

The following example shows the effect of the "ignore\_row\_on\_dupkey\_index" hint:

```

create table test_ignore_dupkey(key1 int, key2 int, key3 int, key4
int);
create unique index test_ignore_dupkey_ui1 on
test_ignore_dupkey(key1, key2);
create unique index test_ignore_dupkey_ui2 on
test_ignore_dupkey(key3, key4);
create index test_ignore_dupkey_i on test_ignore_dupkey(key3);

lightdb@postgres=# insert into test_ignore_dupkey values(1, 1, 1,
1);
INSERT 0 1
lightdb@postgres=# insert into test_ignore_dupkey values(1, 1, 1,
1);
ERROR:  duplicate key value violates unique constraint
"test_ignore_dupkey_ui1"
DETAIL:  Key (key1, key2)=(1, 1) already exists.
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
test_ignore_dupkey_ui1) */ into test_ignore_dupkey values(1, 1, 1,
2);
INSERT 0 0
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey(key1, key2)) */ into
test_ignore_dupkey values(1, 1, 1, 2);
INSERT 0 0
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey) */ into
test_ignore_dupkey values(1, 1, 1, 2);

```

```

ERROR:  An index must be specified in the index hint
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
  test_ignore_dupkey_ui3) */ into test_ignore_dupkey values(1, 1, 1,
  2);
ERROR:  Index specified in the index hint is invalid
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
  test_ignore_dupkey_i) */ into test_ignore_dupkey values(1, 1, 1,
  2);
ERROR:  Index specified in the index hint is invalid
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
  test_ignore_dupkey_ui1 test_ignore_dupkey_ui2) */ into
  test_ignore_dupkey values(1, 1, 1, 2);
ERROR:  Multiple indexes in ignore duplicate key hint
lightdb@postgres=# update/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
  test_ignore_dupkey_ui1) */ test_ignore_dupkey set key2 = 2 where
  key1 = 1;
ERROR:  IGNORE_ROW_ON_DUPKEY_INDEX hint disallowed for this
  operation
lightdb@postgres=# create unique index test_ignore_dupkey_ui3 on
  test_ignore_dupkey(key3, key4);
CREATE INDEX
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey(key3, key4)) */ into
  test_ignore_dupkey values(1, 2, 1, 1);
ERROR:  Multiple indexes in ignore duplicate key hint
DETAIL:  find multiple indexes by fields
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
  test_ignore_dupkey_ui1) */ into test_ignore_dupkey values(1, 1, 1,
  2)
lightdb@postgres=# on conflict (key1, key2) do nothing;
ERROR:  IGNORE_ROW_ON_DUPKEY_INDEX hint disallowed for this
  operation
DETAIL:  insert operation with on conflict clause is not supported
lightdb@postgres=#

```

The "ignore\_row\_on\_dupkey\_index" hint can work in canopy, but only for insert select statement, it is not supported for insert values statement.

```

create table test_ignore_dupkey(key1 int, key2 int, key3 int, key4
  int);
SELECT create_distributed_table('test_ignore_dupkey', 'key1');
create unique index test_ignore_dupkey_ui1 on
  test_ignore_dupkey(key1, key2);
create unique index test_ignore_dupkey_ui2 on
  test_ignore_dupkey(key1, key3);
create index test_ignore_dupkey_i on test_ignore_dupkey(key3);

lightdb@postgres=# insert into test_ignore_dupkey values(1, 1, 1,
  1);
INSERT 0 1
lightdb@postgres=# insert into test_ignore_dupkey values(1, 1, 1,
  1);

```

```

ERROR: duplicate key value violates unique constraint
       "test_ignore_dupkey_uil_102045"
DETAIL: Key (key1, key2)=(1, 1) already exists.
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey
       test_ignore_dupkey_uil) */ into test_ignore_dupkey values(1, 1, 2,
       1);
ERROR: duplicate key value violates unique constraint
       "test_ignore_dupkey_uil_102045"
DETAIL: Key (key1, key2)=(1, 1) already exists.

create table test_ignore_dupkey1(key1 int, key2 int, key3 int, key4
       int);
insert into test_ignore_dupkey1 values(1, 1, 1, 1);
insert into test_ignore_dupkey1 values(1, 1, 1, 1);
insert into test_ignore_dupkey1 values(1, 2, 1, 1);
insert into test_ignore_dupkey1 values(1, 2, 1, 1);
insert into test_ignore_dupkey1 values(1, 1, 1, 2);
insert into test_ignore_dupkey1 values(1, 1, 1, 2);
insert into test_ignore_dupkey1 values(1, 3, 1, 3);

lightdb@postgres=# insert into test_ignore_dupkey select * from
       test_ignore_dupkey1;
ERROR: duplicate key value violates unique constraint
       "test_ignore_dupkey_uil_102045"
DETAIL: Key (key1, key2)=(1, 1) already exists.
CONTEXT: COPY test_ignore_dupkey_102045, line 2
lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey(key1, key3)) */ into
       test_ignore_dupkey select * from test_ignore_dupkey1;
ERROR: duplicate key value violates unique constraint
       "test_ignore_dupkey_uil_102045"
DETAIL: Key (key1, key2)=(1, 1) already exists.
CONTEXT: COPY test_ignore_dupkey_102045, line 2
lightdb@postgres=# SELECT
       create_distributed_table('test_ignore_dupkey1', 'key1');
NOTICE: Copying data from local table...
NOTICE: copying the data has completed
DETAIL: The local data in the table is no longer visible, but is
       still on disk.
HINT: To remove the local data, run: SELECT
       truncate_local_data_after_distributing_table($
       $public.test_ignore_dupkey1$$)
       create_distributed_table
-----

(1 row)

lightdb@postgres=# insert/*
+IGNORE_ROW_ON_DUPKEY_INDEX(test_ignore_dupkey(key1, key3)) */ into
       test_ignore_dupkey select * from test_ignore_dupkey1;
INSERT 0 1
lightdb@postgres=# select * from test_ignore_dupkey;
       key1 | key2 | key3 | key4
-----+-----+-----+-----
           1 |     1 |     1 |     1
(1 row)

```

**F.27.4.1.8.10. Hint about pushing pred to subquery**

If you have a non-mergeable view or subquery (possible because of a `no_merge` hint) in your query, how should you operate the join from other tables? should you create one large view result and join it once (`no_push_pred`) or should you push the join predicate down into the view definition and recreate the view result set for every driving row from another table (`push_pred` and must be `nestloop`).

The "`no_push_pred`" hint instructs the optimizer not to push a join predicate into the view.

LightDB does not support to push a join predicate into the view yet. Now this is only supported for Oracle compatibility. So if you use "`no_push_pred`" hint, it will always work.

The following example shows the usage of the "`no_push_pred`" hint:

```
create table test_no_push_pred1 (key1 int primary key, key2 int);
create table test_no_push_pred2 (key1 int primary key, key2 int);
create table test_no_push_pred3 (key1 int primary key, key2 int);
```

```
set enable_hashjoin to off;
set enable_mergejoin to off;
```

```
lightdb@test_o=# EXPLAIN (COSTS false)
lightdb@test_o=# select /*+leading(a)*/ from test_no_push_pred1 a
  join (select * from test_no_push_pred2 order by key1 limit 1) b on
  a.key1 =b.key2;
```

QUERY PLAN

```
-----
-----
Nested Loop
  Join Filter: (a.key1 = test_no_push_pred2.key2)
  -> Seq Scan on test_no_push_pred1 a @"lt#1"
  -> Materialize
      -> Limit
          -> Index Scan using test_no_push_pred2_pkey on
test_no_push_pred2
(6 rows)
```

```
lightdb@test_o=# EXPLAIN (COSTS false)
lightdb@test_o=# select /*+leading(a) no_push_pred(b)*/ from
test_no_push_pred1 a join (select * from test_no_push_pred2 order
by key1 limit 1) b on a.key1 =b.key2;
```

QUERY PLAN

```
-----
-----
Nested Loop
  Join Filter: (a.key1 = test_no_push_pred2.key2)
  -> Seq Scan on test_no_push_pred1 a @"lt#1"
  -> Materialize
      -> Limit
          -> Index Scan using test_no_push_pred2_pkey on
test_no_push_pred2
(6 rows)
```

```
lightdb@test_o=# EXPLAIN (COSTS false)
```



```
lightdb@test_o=# select /*+leading(a) no_push_pred(@qb)*/
from test_no_push_pred1 a join (select/*+ qb_name(qb)*/ * from
test_no_push_pred2 order by key1 limit 1) b on a.key1 =b.key2;
QUERY PLAN
```

```
-----
Nested Loop
  Join Filter: (a.key1 = test_no_push_pred2.key2)
  -> Seq Scan on test_no_push_pred1 a @"lt#0"
  -> Materialize
      -> Limit
          -> Index Scan using test_no_push_pred2_pkey on
test_no_push_pred2 @qb
(6 rows)
```

```
lightdb@test_o=# EXPLAIN (COSTS false)
lightdb@test_o=# select /*+leading(a) */* from test_no_push_pred1 a
join (select/*+ no_push_pred*/ * from test_no_push_pred2 order by
key1 limit 1) b on a.key1 =b.key2;
QUERY PLAN
```

```
-----
Nested Loop
  Join Filter: (a.key1 = test_no_push_pred2.key2)
  -> Seq Scan on test_no_push_pred1 a @"lt#1"
  -> Materialize
      -> Limit
          -> Index Scan using test_no_push_pred2_pkey on
test_no_push_pred2 @"lt#0"
(6 rows)
```

#### F.27.4.1.8.11. Hint about star transformation

Star transformation is an optimizer transformation that avoids full table scans of fact tables in a star schema (star schema divides data into facts and dimensions). In joins of fact and dimension tables, a star transformation can avoid a full scan of a fact table. The star transformation improves performance by fetching only relevant fact rows that join to the constraint dimension rows. In some cases, queries have restrictive filters on other columns of the dimension tables. The combination of filters can dramatically reduce the data set that the database processes from the fact table.

The "no\_star\_transformation" hint instructs the optimizer not to perform star query transformation.

LightDB does not support star transformation yet. Now "no\_star\_transformation" hint is only supported for Oracle compatibility. So if you use "no\_star\_transformation" hint, it will always work.

The following example shows the usage of the "no\_star\_transformation" hint:

```
CREATE TABLE times (
    time_id NUMBER PRIMARY KEY,
    calendar_quarter_desc VARCHAR2(20)
);
```

```
CREATE TABLE customers (
    cust_id NUMBER PRIMARY KEY,
    cust_city VARCHAR2(20),
    cust_state_province VARCHAR2(20)
);
```

```
CREATE TABLE channels (
    channel_id NUMBER PRIMARY KEY,
    channel_class VARCHAR2(20),
    channel_desc VARCHAR2(20)
);
```

```
CREATE TABLE sales (
    time_id NUMBER REFERENCES times(time_id),
    cust_id NUMBER REFERENCES customers(cust_id),
    channel_id NUMBER REFERENCES channels(channel_id),
    amount_sold NUMBER
);
```

```
lightdb@postgres=# EXPLAIN (COSTS false) SELECT/*
+no_star_transformation*/ ch.channel_class, c.cust_city,
t.calendar_quarter_desc,
    SUM(s.amount_sold) sales_amount
FROM sales s, times t, customers c, channels ch
WHERE s.time_id = t.time_id
AND s.cust_id = c.cust_id
AND s.channel_id = ch.channel_id
AND c.cust_state_province = 'CA'
AND ch.channel_desc in ('Internet','Catalog')
AND t.calendar_quarter_desc IN ('1999-Q1','1999-Q2')
GROUP BY ch.channel_class, c.cust_city,
t.calendar_quarter_desc;
LOG:  lt_hint_plan:
used hint:
no_star_transformation
not used hint:
duplication hint:
error hint:
```

QUERY PLAN

```

-----
GroupAggregate
  Group Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Sort
      Sort Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Nested Loop
      -> Nested Loop
          -> Hash Join
              Hash Cond: (s.cust_id = c.cust_id)
              -> Seq Scan on sales s @"lt#0"
              -> Hash
                  -> Seq Scan on customers c

@"lt#0"
                                Filter:
((cust_state_province)::text
= 'CA'::text)
                                -> Index Scan using times_pkey on times t

@"lt#0"
                                Index Cond: (time_id = s.time_id)
                                Filter: ((calendar_quarter_desc)::text =
ANY ('{1
999-Q1,1999-Q2}'::text[]))
                                -> Index Scan using channels_pkey on channels ch

@"lt#0"
                                Index Cond: (channel_id = s.channel_id)
                                Filter: ((channel_desc)::text = ANY
('{Internet,Catalog
}'::text[]))
(18 rows)

lightdb@postgres=# EXPLAIN (COSTS false)
select/*+no_star_transformation(@qb)*/ * from (SELECT/
*+qb_name(qb)*/ ch.channel_class, c.cust_city,
t.calendar_quarter_desc,
SUM(s.amount_sold) sales_amount
FROM sales s, times t, customers c, channels ch
WHERE s.time_id = t.time_id
AND s.cust_id = c.cust_id
AND s.channel_id = ch.channel_id
AND c.cust_state_province = 'CA'
AND ch.channel_desc in ('Internet','Catalog')
AND t.calendar_quarter_desc IN ('1999-Q1','1999-Q2')
GROUP BY ch.channel_class, c.cust_city,
t.calendar_quarter_desc);
LOG:  lt_hint_plan:
used hint:
no_star_transformation(@qb)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
GroupAggregate
  Group Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Sort
      Sort Key: ch.channel_class, c.cust_city,
t.calendar_quarter_desc
  -> Nested Loop
      -> Nested Loop
          -> Hash Join
              Hash Cond: (s.cust_id = c.cust_id)
              -> Seq Scan on sales s @qb
              -> Hash
                  -> Seq Scan on customers c @qb
                  Filter:
((cust_state_province)::text
= 'CA'::text)
              -> Index Scan using times_pkey on times t @qb
                  Index Cond: (time_id = s.time_id)
                  Filter: ((calendar_quarter_desc)::text =
ANY ('{1
999-Q1,1999-Q2}'::text[]))
              -> Index Scan using channels_pkey on channels ch
                  @qb
                  Index Cond: (channel_id = s.channel_id)
                  Filter: ((channel_desc)::text = ANY
('{Internet,Catalog
}'::text[]))
(18 rows)

```

#### F.27.4.1.8.12. Hint about direct-path insert

During direct-path INSERT operations, the database appends the inserted data after existing data in the table. Data is written directly into data files, bypassing the buffer cache. Free space in the table is not reused, and referential integrity constraints are ignored. Direct-path INSERT can perform significantly better than conventional insert.

The "append" hint instructs the optimizer to use direct-path INSERT with the subquery syntax of the INSERT statement.

LightDB does not support direct-path INSERT yet. Now "append" hint is only supported for Oracle compatibility. So if you use "append" hint, it will always be unused.

The following example shows the usage of the "append" hint:

```

create table test_append(key1 int, key2 int, key3 int, key4 int);
create table test_append1(key1 int, key2 int, key3 int, key4 int);

insert into test_append1 values(1,2,3,4);
insert into test_append1 values(11,21,31,41);
insert into test_append1 values(111,211,311,411);

lightdb@test_oracle_lt_hint_plan=# EXPLAIN (COSTS FALSE) insert/*
+append */ into test_append select 1, 1, 1, 2 from dual;
LOG:  lt_hint_plan:
used hint:

```

```

not used hint:
append
duplication hint:
error hint:

          QUERY PLAN
-----
Insert on test_append @"lt#1"
  -> Result
(2 rows)

lightdb@test_oracle_lt_hint_plan=# EXPLAIN (COSTS FALSE) insert/*
+append */ into test_append select * from test_append1;
LOG:  lt_hint_plan:
used hint:
not used hint:
append
duplication hint:
error hint:

          QUERY PLAN
-----
Insert on test_append @"lt#1"
  -> Seq Scan on test_append1
(2 rows)

```

### F.27.4.2. GUC parameters for lt\_hint\_plan

GUC parameters below affect the behavior of lt\_hint\_plan.

**Table F.13. GUC parameters for lt\_hint\_plan**

Parameter name	description	Default
lt_hint_plan.enable_hint	Enables lt_hint_plan.	on
lt_hint_plan.enable_hinting_by_table	Enables hinting by table. true or false.	off
lt_hint_plan.parse_messages	Specifies the log level of hint parse error. Valid values are error, warning, notice, info, log, debug.	INFO
lt_hint_plan.debug_controls	Controls debug print and verbosity. Valid vaiues are off, on, detailed and verbose.	off
lt_hint_plan.messages	Specifies message level of debug print. Valid values are error, warning, notice, info, log, debug.	INFO
lt_hint_plan.show_verbose_info	Show verbose info in debug print.	on

## F.27.5. Details in hinting

### F.27.5.1. Syntax and placement

For global level hint, `lt_hint_plan` reads only the first block comment at sql head(before first character of sql)

```
lightdb@postgres=# /*+ indexscan(b)*/ explain select * from
ltbench_accounts b where b.aid>10;
                                QUERY PLAN
```

```
-----
Index Scan using ltbench_accounts_pkey on ltbench_accounts b
 (cost=0.29..3666.12
 rows=99990 width=97)
Index Cond: (aid > 10)
(2 rows)
```

```
lightdb@postgres=#
```

For stmt level hint, `lt_hint_plan` reads hints from only the first block comment after select, update, delete, insert keyword. hint only works on current query block without using `qb_name`. In the following example HashJoin(a b) and SeqScan(a) are parsed as hints but IndexScan(a) and IndexScan(b) are not.

```
lightdb@postgres=# /*+
lightdb@postgres*#   HashJoin(a b)
lightdb@postgres*#   */
lightdb@postgres-# /*+ IndexScan(a) */
lightdb@postgres-# EXPLAIN SELECT /*+ SeqScan(a) */ *
lightdb@postgres-#   FROM /*+ IndexScan(b) */ltbench_branches b
lightdb@postgres-#   JOIN ltbench_accounts a ON b.bid = a.bid
lightdb@postgres-#   ORDER BY a.aid;
                                QUERY PLAN
```

```
-----
----
Sort  (cost=24236.84..24486.84 rows=100000 width=461)
Sort Key: a.aid
-> Hash Join  (cost=1.02..4016.02 rows=100000 width=461)
      Hash Cond: (a.bid = b.bid)
        -> Seq Scan on ltbench_accounts a  (cost=0.00..2640.00
      rows=100000 width=
97)
          -> Hash  (cost=1.01..1.01 rows=1 width=364)
                -> Seq Scan on ltbench_branches b  (cost=0.00..1.01
      rows=1 width=36
4)
(7 rows)
```

```
lightdb@postgres=#
```

### F.27.5.2. Using with PL/pgSQL

`lt_hint_plan` works for queries in PL/pgSQL scripts with some restrictions.

- Hints affect only on the following kind of queries.
  - Queries that returns one row. (SELECT, INSERT, UPDATE and DELETE)
  - Queries that returns multiple rows. (RETURN QUERY)
  - Dynamic SQL statements. (EXECUTE)
  - Cursor open. (OPEN)
  - Loop over result of a query (FOR)
- A hint comment have to be placed after the first word in a query as the following since preceding comments are not sent as a part of the query.

```
lightdb@postgres=# CREATE FUNCTION hints_func(integer) RETURNS
integer AS $$
lightdb@postgres$# DECLARE
lightdb@postgres$#     id integer;
lightdb@postgres$#     cnt integer;
lightdb@postgres$# BEGIN
lightdb@postgres$#     SELECT /*+ NoIndexScan(a) */ aid
lightdb@postgres$#         INTO id FROM ltbench_accounts a WHERE
lightdb@postgres$#     aid = $1;
lightdb@postgres$#     SELECT /*+ SeqScan(a) */ count(*)
lightdb@postgres$#         INTO cnt FROM ltbench_accounts a;
lightdb@postgres$#     RETURN id + cnt;
lightdb@postgres$# END;
lightdb@postgres$# $$ LANGUAGE plpgsql;
```

### F.27.5.3. Letter case in the object names

Like the way LightDB handles object names, `lt_hint_plan` will convert object names to lowercase. Therefore an object name TBL in a hint matches TBL, tbl or Tbl in database. With quotes, `lt_hint_plan` will not convert object names to lowercase. Therefore an object name "TBL" in a hint matches only "TBL" in database and does not match any unquoted names like TBL, tbl or Tbl.

### F.27.5.4. Escaping special characters in object names

The objects as the hint parameter should be enclosed by double quotes if they includes parentheses, double quotes and white spaces. The escaping rule is the same as LightDB.

### F.27.5.5. Distinction between multiple occurrences of a table

`lt_hint_plan` identifies the target object by using aliases if exists. This behavior is usable to point a specific occurrence among multiple occurrences of one table.

```
lightdb@postgres=# /*+ HashJoin(t1 t1) */
lightdb@postgres-# EXPLAIN SELECT * FROM s1.t1
lightdb@postgres-# JOIN public.t1 ON (s1.t1.id=public.t1.id);
INFO:  hint syntax error at or near "HashJoin(t1 t1)"
DETAIL:  Relation name "t1" is ambiguous.
...
lightdb@postgres=# /*+ HashJoin(pt st) */
lightdb@postgres-# EXPLAIN SELECT * FROM s1.t1 st
lightdb@postgres-# JOIN public.t1 pt ON (st.id=pt.id);
QUERY PLAN
-----
```

```

Hash Join (cost=64.00..1112.00 rows=28800 width=8)
Hash Cond: (st.id = pt.id)
-> Seq Scan on t1 st (cost=0.00..34.00 rows=2400 width=4)
-> Hash (cost=34.00..34.00 rows=2400 width=4)
    -> Seq Scan on t1 pt (cost=0.00..34.00 rows=2400
width=4)

```

### F.27.5.6. Underlying tables of views or rules

Hints are applicable on views itself, and they can affect the queries within if the object names match the object names in the expanded query on the view when used as global level hint. but for stmt level hint, it need use qb\_name hint to manipulate talbes in view.

```

create view test_v as select /*+qb_name(qb)*/ * from t1 where id
>10;
EXPLAIN (COSTS false) select /*+indexscan(t1)*/ * from test_v;
LOG:  lt_hint_plan:
used hint:
not used hint:
IndexScan(t1@lt#0)
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Seq Scan on t1 @qb
Filter: (id > 10)
(2 rows)

```

```

EXPLAIN (COSTS false) select /*+indexscan(t1@qb)*/ * from test_v;
LOG:  lt_hint_plan:
used hint:
IndexScan(t1@qb)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Index Scan using t1_pkey on t1 @qb
Index Cond: (id > 10)
(2 rows)

```

```

/*+indexscan(t1)*/
EXPLAIN (COSTS false) select * from test_v;
LOG:  lt_hint_plan:
used hint:
IndexScan(t1@lt#-1)
not used hint:
duplication hint:
error hint:

```

QUERY PLAN

```

-----
Index Scan using t1_pkey on t1 @qb
Index Cond: (id > 10)
(2 rows)

```



### F.27.5.7. Inheritance tables

Hints can point only the parent of an inheritance tables and the hint affect all the inheritance. Hints simultaneously point directly to children are not in effect.

### F.27.5.8. Hinting on multistatements

For global level hint, one multistatement can have exactly one hint comment and the hints affects all of the individual statement in the multistatement. Notice that the seemingly multistatement on the interactive interface of ltsql is internally a sequence of single statements so hints affects only on the statement just following. For stmt level hint, it is same with single statement.

### F.27.5.9. VALUES expressions

VALUES expressions in FROM clause are named as \*VALUES\* internally so it is hintable if it is the only VALUES in a query. Two or more VALUES expressions in a query seems distinguishable looking its explain result. But in reality it is mere a cosmetic and they are not distinguishable.

```
lightdb@postgres=# /*+ MergeJoin(*VALUES*_1 *VALUES*) */
      EXPLAIN SELECT * FROM (VALUES (1, 1), (2, 2)) v (a, b)
      JOIN (VALUES (1, 5), (2, 8), (3, 4)) w (a, c) ON v.a = w.a;
INFO:  lt_hint_plan: hint syntax error at or near
      "MergeJoin(*VALUES*_1 *VALUES*) "
DETAIL:  Relation name "*VALUES*" is ambiguous.
      QUERY PLAN
-----
      Hash Join  (cost=0.05..0.12 rows=2 width=16)
      Hash Cond: ("*VALUES*_1".column1 = "*VALUES*".column1)
      -> Values Scan on "*VALUES*_1"  (cost=0.00..0.04 rows=3
width=8)
      -> Hash  (cost=0.03..0.03 rows=2 width=8)
      -> Values Scan on "*VALUES*"  (cost=0.00..0.03 rows=2
width=8)
```

### F.27.5.10. Cost value in explain may wrong

lt\_hint\_plan makes the execution plan choose the desired path by increasing the cost of the undesired path (cost += disable\_cost, disable\_cost=1.0e10).

Sometimes even if hint is used, sql will not execute as hinted because the desired path is not available, such as using indexscan hint on a table without index. In this case the cost in explain is not accurate.

The actual cost can be obtained by subtracting the disable\_cost.

```
lightdb@postgres=# create table test(id int);
CREATE TABLE
lightdb@postgres=# explain select * from test where id=1;
      QUERY PLAN
-----
      Seq Scan on test  (cost=0.00..41.88 rows=13 width=4)
      Filter: (id = 1)
      (2 rows)

lightdb@postgres=# explain select /*+indexscan(test)*/ from test
      where id=1;
      QUERY PLAN
-----
```

```
Seq Scan on test @"lt#0" (cost=10000000000.00..10000000041.88
 rows=13 width=4)
Filter: (id = 1)
(2 rows)
```

```
lightdb@postgres=#
```

## F.27.6. Subqueries

Subqueries in the following context occasionally can be hinted using the name "ANY\_subquery".

```
IN (SELECT ... {LIMIT | OFFSET ...} ...)
= ANY (SELECT ... {LIMIT | OFFSET ...} ...)
= SOME (SELECT ... {LIMIT | OFFSET ...} ...)
```

For these syntaxes, planner internally assigns the name to the subquery when planning joins on tables including it, so join hints are applicable on such joins using the implicit name as the following.

```
lightdb@postgres=# /*+HashJoin(a1 ANY_subquery)*/
lightdb@postgres=# EXPLAIN SELECT *
lightdb@postgres=# FROM ltbench_accounts a1
lightdb@postgres=# WHERE aid IN (SELECT bid FROM ltbench_accounts
a2 LIMIT 10);
```

QUERY PLAN

```
-----
Hash Semi Join (cost=0.49..2903.00 rows=1 width=97)
Hash Cond: (a1.aid = a2.bid)
-> Seq Scan on ltbench_accounts a1 (cost=0.00..2640.00
rows=100000 width=97)
-> Hash (cost=0.36..0.36 rows=10 width=4)
-> Limit (cost=0.00..0.26 rows=10 width=4)
-> Seq Scan on ltbench_accounts a2
(cost=0.00..2640.00 rows=100000 width=4)
```

### F.27.6.1. Using IndexOnlyScan hint

Index scan may unexpectedly performed on another index when the index specified in IndexOnlyScan hint cannot perform index only scan.

### F.27.6.2. Behavior of NoIndexScan

NoIndexScan hint involves NoIndexOnlyScan.

### F.27.6.3. Parallel hint and UNION

A UNION can run in parallel only when all underlying subqueries are parallel-safe. Conversely enforcing parallel on any of the subqueries let a parallel-executable UNION run in parallel. Meanwhile, a parallel hint with zero workers hinhbits a scan from executed in parallel.

### F.27.6.4. Setting It\_hint\_plan parameters by Set hints

It\_hint\_plan paramters change the behavior of itself so some parameters doesn't work as expected.

- Hints to change enable\_hint, enable\_hint\_tables are ignored even though they are reported as "used hints" in debug logs.
- Setting debug\_print and message\_level works from midst of the processing of the target query.

## F.27.6.5. Scan and Join Hints on Subqueries

Scan hints, join hints(include join method and join order hints) and rows hint on referenced subquery(Mergeable) are ignored unless the subquery contains a single table. If the subquery contains a single table, the scan path hint or join hint on it applies to the table inside the subquery.

```
lightdb@postgres=# create table test1(id int primary key, value
int);
CREATE TABLE
lightdb@postgres=# create table test2(id int primary key, value
int);
CREATE TABLE
lightdb@postgres=# EXPLAIN (COSTS false) select * from test1,
(select * from (select * from test2) x) y where test1.id=y.id;
QUERY PLAN
```

```
-----
Hash Join
Hash Cond: (test1.id = test2.id)
-> Seq Scan on test1
-> Hash
    -> Seq Scan on test2
(5 rows)
```

```
lightdb@postgres=# EXPLAIN (COSTS false) select /*+indexscan(y)*/
* from test1,(select * from (select * from test2) x) y where
test1.id=y.id;
QUERY PLAN
```

```
-----
Hash Join
Hash Cond: (test2.id = test1.id)
-> Index Scan using test2_pkey on test2 @"lt#2"
-> Hash
    -> Seq Scan on test1 @"lt#0"
(5 rows)
```

```
lightdb@postgres=#
```

## F.27.7. Compatible with canopy

Now `lt_hint_plan` is compatible with canopy, it can be used to control execution plan involving Distributed Tables and Reference Tables.

### F.27.7.1. Hint state

To view the usage state of hints on data nodes, first you need to turn on `debug_print` on datanode, then set `canopy.log_remote_commands` to on, and finally set `canopy.worker_min_messages` to 'log' and `client_min_messages` to 'log' or set `lt_hint_plan.message_level` to 'notice'. The following example shows it.

```
lightdb@postgres=# CREATE TABLE t1 (id int PRIMARY KEY, val int);
CREATE TABLE
lightdb@postgres=# SELECT create_distributed_table('t1', 'id');
create_distributed_table
```

```
-----
(1 row)
```

```

lightdb@postgres=# set lt_hint_plan.message_level = 'notice';
SET
lightdb@postgres=# set canopy.log_remote_commands=on;
SET
lightdb@postgres=# explain select /*+indexscan(t1)*/ from t1 where
id=10;
NOTICE:  lt_hint_plan:
used hint:
not used hint:
IndexScan(t1@lt#0)
duplication hint:
error hint:

NOTICE:  issuing BEGIN TRANSACTION ISOLATION LEVEL READ
COMMITTED;SELECT assign_distributed_transaction_id(0, 24,
'2022-03-14 15:49:45.634614+08');
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 2
NOTICE:  issuing SAVEPOINT canopy_explain_savepoint
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 2
NOTICE:  issuing /*+ IndexScan(t1) */EXPLAIN (ANALYZE FALSE,
VERBOSE FALSE, COSTS TRUE, BUFFERS FALSE, WAL FALSE, TIMING FALSE,
SUMMARY FALSE, FORMAT TEXT) SELECT id, val FROM public.t1_102044
t1 WHERE (id OPERATOR(pg_catalog.=) 10)
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 2
NOTICE:  lt_hint_plan:
used hint:
IndexScan(t1@lt#-1)
not used hint:
duplication hint:
error hint:
DETAIL:  from 192.168.247.128:6432
NOTICE:  issuing ROLLBACK TO SAVEPOINT canopy_explain_savepoint
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 2
NOTICE:  issuing COMMIT
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 2
QUERY PLAN

-----
-----
Custom Scan (Canopy Adaptive) (cost=0.00..0.00 rows=0 width=0)
Task Count: 1
Tasks Shown: All
-> Task
      Node: host=192.168.247.128 port=6432 dbname=postgres
      -> Index Scan using t1_pkey_102044 on t1_102044 t1
      (cost=0.15..2.17 rows
=1 width=8)
      Index Cond: (id = 10)
(7 rows)

lightdb@postgres=#

```

## F.27.7.2. Limitations

CTEs and subqueries that cannot be pushed down and do not contain references to the outer query are planned by recursively calling the planner function with the subquery as the parse tree. The resulting

plan are executed independently, and SQL statement has been splited. Therefore hints that act on both out query and subquery, and no\_merge, semijoin/antijoin hints that act on subqueries will have no effect. The following example shows it.

```
lightdb@postgres=# CREATE TABLE t1 (id int PRIMARY KEY, val int);
CREATE TABLE
lightdb@postgres=# CREATE TABLE t2 (id int PRIMARY KEY, val int);
CREATE TABLE
lightdb@postgres=# SELECT create_distributed_table('t1', 'id');
create_distributed_table
-----
```

(1 row)

```
lightdb@postgres=# SELECT create_distributed_table('t2', 'id');
create_distributed_table
-----
```

(1 row)

```
lightdb@postgres=#
lightdb@postgres=# explain select /*+indexscan(t2@qb) hashjoin(t1
t2@qb)*/ * from t1, (select /*+qb_name(qb)*/ * from t2 where t2.id
>11) x where t1.id=10;
```

```
INFO:  lt_hint_plan: disable hint after spliting sql , hint:
"HashJoin"
```

```
DETAIL:  it is invalid because of split SQL, defined at
"hashjoin(t1 t2@qb)"
```

```
NOTICE:  lt_hint_plan:
used hint:
```

```
IndexScan(t2@qb)
```

```
not used hint:
```

```
duplication hint:
```

```
error hint:
```

```
NOTICE:  lt_hint_plan:
```

```
used hint:
```

```
IndexScan(t2@qb)
```

```
HashJoin(t1@lt#0 t2@qb)
```

```
not used hint:
```

```
duplication hint:
```

```
error hint:
```

```
NOTICE:  issuing BEGIN TRANSACTION ISOLATION LEVEL READ
COMMITTED;SELECT assign_distributed_transaction_id(0, 36,
'2022-03-14 16:06:20.313852+08');
```

```
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
```

```
NOTICE:  issuing SAVEPOINT canopy_explain_savepoint
```

```
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
```

```
NOTICE:  issuing /*+ IndexScan(t2) */EXPLAIN (ANALYZE FALSE,
VERBOSE FALSE, COSTS TRUE, BUFFERS FALSE, WAL FALSE, TIMING FALSE,
SUMMARY FALSE, FORMAT TEXT) SELECT id, val FROM public.t2_102136
t2 WHERE (id OPERATOR(pg_catalog.>) 11)
```

```
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
```

```
NOTICE:  lt_hint_plan:
```

```
used hint:
```

```
IndexScan(t2@lt#-1)
```

```

not used hint:
duplication hint:
error hint:
DETAIL:  from 192.168.247.128:6432
NOTICE:  issuing ROLLBACK TO SAVEPOINT canopy_explain_savepoint
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
NOTICE:  issuing SAVEPOINT canopy_explain_savepoint
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
NOTICE:  issuing EXPLAIN (ANALYZE FALSE, VERBOSE FALSE, COSTS TRUE,
    BUFFERS FALSE, WAL FALSE, TIMING FALSE, SUMMARY FALSE, FORMAT
    TEXT) SELECT t1.id, t1.val, x.id, x.val FROM public.t1_102108
    t1, (SELECT intermediate_result.id, intermediate_result.val
    FROM read_intermediate_result('11_1'::text,
    'binary'::canopy_copy_format) intermediate_result(id integer, val
    integer)) x WHERE (t1.id OPERATOR(pg_catalog.=) 10)
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
NOTICE:  issuing ROLLBACK TO SAVEPOINT canopy_explain_savepoint
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
NOTICE:  issuing COMMIT
DETAIL:  on server lightdb@192.168.247.128:6432 connectionId: 3
                                                    QUERY PLAN

```

```

-----
Custom Scan (Canopy Adaptive) (cost=0.00..0.00 rows=0 width=0)
-> Distributed Subplan 11_1
    -> Custom Scan (Canopy Adaptive) (cost=0.00..0.00
    rows=100000 width=8)
        Task Count: 32
        Tasks Shown: One of 32
        -> Task
            Node: host=192.168.247.128 port=6432
            dbname=postgres
            -> Index Scan using t2_pkey_102136 on
            t2_102136 t2 (cost=0.1
            5..24.33 rows=753 width=8)
                Index Cond: (id > 11)
            Task Count: 1
            Tasks Shown: All
            -> Task
                Node: host=192.168.247.128 port=6432 dbname=postgres
                -> Nested Loop (cost=0.16..22.17 rows=1000 width=16)
                    -> Index Scan using t1_pkey_102108 on t1_102108 t1
                    (cost=0.15..2.1
                    7 rows=1 width=8)
                        Index Cond: (id = 10)
                    -> Function Scan on read_intermediate_result
                    intermediate_result (
                    cost=0.00..10.00 rows=1000 width=8)
                    (17 rows)

lightdb@postgres=#

```

## F.27.8. Errors

`It_hint_plan` ignores invalid hint and continues to find next valid hint. When it finds an invalid hint, the error will be reported but only when it is an explain SQL. Followings are the typical errors.

### F.27.8.1. Syntax errors

Any syntactical errors or wrong hint names are reported as an syntax error. These errors are reported in the server log with the message level which specified by `lt_hint_plan.message_level` if `lt_hint_plan.debug_print` is on and above. Keyword that started with digit will not be a hint name, it will not be reported as an syntax error, but will be ignored.

### F.27.8.2. Object misspecifications

Object misspecifications results silent ingorance of the hints. This kind of error is reported as "not used hints" in the server log by the same condition to syntax errors.

### F.27.8.3. Redundant or conflicting hints

For same query block, one hint will be active when redundant hints, no hint will be active when hints conflicting with each other. For diffent query block, when redundant hints or hints conflicting with each other, only sub query's hint will be active. No matter when redundant hints or hints conflicting with each other, This kind of error is reported as "duplication hints" in the server log by the same condition to syntax errors. if `qb_name` hint conflict , both will be ignored.

### F.27.8.4. Nested comments

For global level hint, hint comment cannot include another block comment within. If `lt_hint_plan` finds it, differently from other erros, it stops parsing and abandans all hints already parsed. This kind of error is reported in the same manner as other errors. For stmt level hint, hint comment cannot include another block comment within. it will ignore `'/*'` in hint comment. if report error, it only affect current query block's hint.

```
lightdb@postgres=# explain select * from t1 ,(select * from t2
  where id >10) as tt where exists (select /*+ /*+seqscan(t1)*/ */
  from t3 where id>1);;
INFO:  lt_hint_plan: hint syntax error at or near "+seqscan(t1)"
DETAIL:  Unrecognized hint keyword "+seqscan".
          QUERY PLAN
```

```
-----
Result  (cost=1.04..3.13 rows=3 width=532)
One-Time Filter: $0
InitPlan 1 (returns $0)
  ->  Seq Scan on t3 @"lt#0"  (cost=0.00..1.04 rows=1 width=0)
      Filter: (id > 1)
->  Nested Loop  (cost=1.04..3.13 rows=3 width=532)
      ->  Seq Scan on t2  (cost=0.00..1.04 rows=1 width=8)
          Filter: (id > 10)
      ->  Seq Scan on t1 @"lt#1"  (cost=0.00..1.03 rows=3
width=524)
(9 rows)
```

```
lightdb@postgres=# explain select * from t1 ,(select * from t2
  where id >10) as tt where exists (select /*+ /*seqscan(t1)*/ */
  from t3 where id>1);;
LOG:  lt_hint_plan:
used hint:
not used hint:
SeqScan(t1@lt#0)
duplication hint:
error hint:
```

## QUERY PLAN

```

-----
Result (cost=1.04..3.13 rows=3 width=532)
One-Time Filter: $0
InitPlan 1 (returns $0)
  -> Seq Scan on t3 @"lt#0" (cost=0.00..1.04 rows=1 width=0)
      Filter: (id > 1)
-> Nested Loop (cost=1.04..3.13 rows=3 width=532)
    -> Seq Scan on t2 (cost=0.00..1.04 rows=1 width=8)
        Filter: (id > 10)
    -> Seq Scan on t1 @"lt#1" (cost=0.00..1.03 rows=3
width=524)
(9 rows)

```

```
lightdb@postgres=#
```

## F.27.9. Functional limitations

### F.27.9.1. Influences of some of planner GUC parameters

The planner does not try to consider joining order for FROM clause entries more than from\_collapse\_limit. It\_hint\_plan cannot affect joining order as expected for the case.

### F.27.9.2. Hints trying to enforce unexecutable plans

Planner chooses any executable plans when the enforced plan cannot be executed.

- FULL OUTER JOIN to use nested loop
- To use indexes that does not have columns used in quals
- To do TID scans for queries without ctid conditions

### F.27.9.3. Queries in ECPG

ECPG removes comments in queries written as embedded SQLs so hints cannot be passed form those queries. The only exception is that EXECUTE command passes given string unmodified. Please consider hint tables in the case.

### F.27.9.4. Work with It\_stat\_statements

It\_stat\_statements generates a query id ignoring comments. As the result the identical queires with different hints are summerized as the same query.

## F.27.10. Hint list

The available hints are listed below.

**Table F.14. Hints list**

Group	Format	Description
Scan method	SeqScan(table) full(table)	Forces sequential scan on the table
	TidScan(table)	Forces TID scan on the table.
	IndexScan(table[ index...]) index(table[ index...])	Forces index scan on the table. Restricts to specified indexes if any.



Group	Format	Description
	IndexOnlyScan(table[ index...])	Forces index only scan on the table. Restricts to specified indexes if any. Index scan may be used if index only scan is not available.
	BitmapScan(table[ index...])	Forces bitmap scan on the table. Restricts to specified indexes if any.
	IndexScanRegexp(table[ POSIX Regexp...]) IndexOnlyScanRegexp(table[ POSIX Regexp...]) BitmapScanRegexp(table[ POSIX Regexp...])	Forces index scan or index only scan or bitmap scan on the table. Restricts to indexes that matches the specified POSIX regular expression pattern
	NoSeqScan(table)	Forces not to do sequential scan on the table.
	NoTidScan(table)	Forces not to do TID scan on the table.
	NoIndexScan(table)	Forces not to do index scan and index only scan on the table.
	NoIndexOnlyScan(table)	Forces not to do index only scan on the table.
	NoBitmapScan(table)	Forces not to do bitmap scan on the table.
<b>Join method</b>	NestLoop(table table[ table...]) use_nl(table table[ table...])	Forces nested loop for the joins consist of the specified tables.
	HashJoin(table table[ table...]) use_hash(table table[ table...])	Forces hash join for the joins consist of the specified tables.
	MergeJoin(table table[ table...]) use_merge(table table[ table...])	Forces merge join for the joins consist of the specified tables.
	NoNestLoop(table table[ table...]) no_use_nl(table table[ table...])	Forces not to do nested loop for the joins consist of the specified tables.
	NoHashJoin(table table[ table...]) no_use_hash(table table[ table...])	Forces not to do hash join for the joins consist of the specified tables.
	NoMergeJoin(table table[ table...]) no_use_merge(table table[ table...])	Forces not to do merge join for the joins consist of the specified tables.
<b>Join method(oracle mode)</b>	NestLoop(table [ table...]) use_nl(table[ table...])	Forces nested loop for the joins that the specified table is the inner table.
	HashJoin(table[ table...]) use_hash(table[ table...])	Forces hash join for the joins that the specified table is the inner table.
	MergeJoin(table[ table...]) use_merge(table[ table...])	Forces merge join for the joins that the specified table is the inner table.

Group	Format	Description
	NoNestLoop(table[ table...]) no_use_nl(table[ table...])	Forces not to do nested loop for the joins that the specified table is the inner table.
	NoHashJoin(table[ table...]) no_use_hash(table[ table...])	Forces not to do hash join for the joins that the specified table is the inner table.
	NoMergeJoin(table[ table...]) no_use_merge(table[ table...])	Forces not to do merge join for the joins that the specified table is the inner table.
<b>Join order</b>	Leading(table table[ table...]) Ordered(table table[ table...])	Forces join order and directions as specified.
	Leading([join pair]) Ordered([join pair])	Forces join order and directions as specified. A join pair is a pair of tables and/or other join pairs enclosed by parentheses, which can make a nested structure.
	Ordered Leading	Forces to join tables in the order in which they appear in the FROM clause.
	Leading(table) Ordered(table)	Forces to join tables using the specified table as the first table of the join execution plan.
<b>Row number correction</b>	Rows(table [ table...] correction) cardinality(table [ table... ] correction)	Corrects row number of a result of the joins consist of the specified tables or a table or a result of subquery. The available correction methods are absolute (#[n] or [n]), addition (+[n]), subtract (-[n]) and multiplication (*[n]). [n] should be a string that strtod() can read.
<b>Parallel query configuration</b>	Parallel(table [# of workers] [soft hard])	Enforce or inhibit parallel execution of specified table. [# of workers] is the desired number of parallel workers, where zero means inhibiting parallel execution. If the third parameter is soft , it just changes max_parallel_workers_per_gather and leave everything else to planner. Hard(default) means enforcing the specified number of workers.
	Parallel([# of workers] [soft hard])	Enforce or inhibit parallel execution of tables at current query block. [# of workers] is the desired number of parallel workers, where zero means inhibiting parallel execution. If the second parameter is soft , it just changes

Group	Format	Description
		max_parallel_workers_per_gather and leave everything else to planner. Hard(default) means enforcing the specified number of workers.
<b>GUC</b>	Set(GUC-param value)	Set the GUC parameter to the value while planner is running.
	Opt_param('GUC-param' value)	Set the GUC parameter to the value while planner is running.
<b>Query block name</b>	qb_name(name)	Set the query block name, then tables in this query block can be hint in outer query block. can't use for GUC.
<b>No merge</b>	no_merge[(sub query name)] no_merge(@queryblock_name)	Forces not to pull up subquery. Priority is higher than Join method and Join order
<b>Group by method</b>	use_hash_aggregation	Forces hash aggregation method for group by.
	no_use_hash_aggregation	Forces not to use hash method for group by, then use sort method.
<b>Semijoin(specail join)</b>	semijoin	Forces to transforms a correlated EXISTS subquery into a semi-join to access the specified table.
	hash_sj	Forces to transforms a correlated EXISTS subquery into a hash semi-join to access the specified table.
	nl_sj	Forces to transforms a correlated EXISTS subquery into a nestloop semi-join to access the specified table.
	merge_sj	Forces to transforms a correlated EXISTS subquery into a merge semi-join to access the specified table.
	no_semijoin	Forces not to use semi-join if possible, rather than not to pull up sublink
<b>Antijoin(specail join)</b>	hash_aj	Forces to transforms a correlated NOT EXISTS subquery into a hash anti-join to access the specified table.
	nl_aj	Forces to transforms a correlated NOT EXISTS subquery into a nestloop anti-join to access the specified table.
	merge_aj	Forces to transforms a correlated NOT EXISTS

Group	Format	Description
		subquery into a merge anti-join to access the specified table.
<b>Swap_join_inputs</b>	swap_join_input(table)	Forces to use the table as outer table when hashjoin
<b>Ordered predicates</b>	ordered_predicates	Forces the optimizer to preserve the order of predicate evaluation
<b>Unnest</b>	unnest	Pull up sublink is an RBO, so only syntax is supported
<b>No unnest</b>	no_unnest	Forces the optimizer to not pull up sublink
<b>Pq_distribute</b>	pq_distribute(inner_table outer_distribution inner_distribution)	The pq_distribute hint instructs the optimizer how to execute parallel join, inner_table is the inner table of the join, outer_distribution is the distribution for the outer table and inner_distribution is the distribution for the inner table. Now only 'none broadcast' and 'hash hash' is supported, and only 'none broadcast' can work.
<b>No_push_subq</b>	no_push_subq	instructs the optimizer to evaluate nested sublinks as the last step in the execution plan.
<b>Push_subq</b>	push_subq	instructs the optimizer to evaluate nested sublinks at the earliest possible step in the execution plan(it is default in LightDB).
<b>Ignore_row_on_dupkey_index</b>	ignore_row_on_dupkey_index(table indexname) ignore_row_on_dupkey_index(table (colname[, colname...]))	Force to ignore a unique key violation for a specified set of columns or for a specified index.
<b>No_push_pred</b>	no_push_pred[(sub query name)] no_push_pred(@queryblock_name)	Instructs the optimizer not to push a join predicate into the new or subquery.
<b>No_star_transformation</b>	no_star_transformation	Instructs the optimizer not to perform star query transformation.
<b>Append</b>	append	Instructs the optimizer to use direct-path INSERT with the subquery syntax of the INSERT statement.

## F.28. It\_log\_long\_xact

Pl/pgsql function to log long running transactions in LightDB, can optionally output details of any blocking statements and cancel/terminate problematic statements/transactions.

Schedule with cron or similar if required.

Use the cancel/terminate functionality with care, and see notes about better alternatives for some use cases built into lightdb.

## F.28.1. Usage

To simply log long running transactions just call the function passing the shortest duration to start logging at:

```
TEST=# SELECT pg_log_long_xact('1s');
NOTICE: long_xact pid: 4465 duration: 431.325747 ms user:
glyn application: ltsql client: [local] statement: <IDLE> in
transaction
NOTICE: long_xact pid: 16532 duration: 327.438302 ms user: glyn
application: ltsql client: [local] statement: UPDATE balls SET
description = 'TEST' WHERE id = 5;
pg_log_long_xact
-----
(0 rows)
```

To log extra information about locks the long running transactions might be waiting on, supply the second argument as true (although you could log similar information by just enabling `log_lock_waits`):

```
TEST=# SELECT pg_log_long_xact('1s', true);
NOTICE: long_xact pid: 4465 duration: 471.885373 ms user:
glyn application: ltsql client: [local] statement: <IDLE> in
transaction
NOTICE: long_xact pid: 16532 duration: 367.997928 ms user: glyn
application: ltsql client: [local] statement: UPDATE balls SET
description = 'TEST' WHERE id = 5;
NOTICE: long_xact waiter pid: 16532 blocker detail is; pid:
4465 duration: 471.885373 ms relation: any (public.balls
(RowExclusiveLock)) lock type: transaction id 311824482 user:
glyn application: ltsql client: [local] statement: <IDLE> in
transaction
pg_log_long_xact
-----
(0 rows)
```

To set the level of raise used pass a third argument which can be any of “debug”, “log”, “info”, “notice”, “warning” or “text” to output as a text resultset. (in hindsight the default should probably have been “log”)

```
TEST=# \t off
Showing only tuples.
TEST=# SELECT pg_log_long_xact('1s', true, 'text');
long_xact pid: 4465 duration: 574.477076 ms user: glyn
application: ltsql client: [local] statement: <IDLE> in
transaction
long_xact pid: 16532 duration: 470.589631 ms user: glyn
application: ltsql client: [local] statement: UPDATE balls SET
description = 'TEST' WHERE id = 5;
long_xact waiter pid: 16532 blocker detail is; pid: 4465 duration:
574.477076 ms relation: any (public.balls (RowExclusiveLock))
lock type: transaction id 311824482 user: glyn application: ltsql
client: [local] statement: <IDLE> in transaction
```

To make it start cancelling statements exceeding a specific duration we pass a duration as the fourth argument; the first transaction exceeding this will be cancelled on each run, with blocking statements prioritised.

(there's a `lock_timeout` parameter that will abort any statement waiting longer than the specified number of milliseconds, which is much better. Note that the difference here is that this function will attempt to abort the blocking transaction rather than the waiting statement, or if there is no locking just the longest transaction.)

```
TEST=# SELECT pg_log_long_xact('1s', true, 'text', '10 minutes');
 long_xact pid: 4465 duration: 895.57988 ms user: glyn application:
 ltsql client: [local] statement: <IDLE> in transaction
 long_xact unable to cancel backend with pid: 4465
 long_xact pid: 16532 duration: 791.692435 ms user: glyn
 application: ltsql client: [local] statement: UPDATE balls SET
 description = 'TEST' WHERE id = 5;
 long_xact waiter pid: 16532 blocker detail is; pid: 4465 duration:
 895.57988 ms relation: any (public.balls (RowExclusiveLock)) lock
 type: transaction id 31182
4482 user: glyn application: ltsql client: [local] statement:
 <IDLE> in transaction
```

We can also provide a duration as the fifth argument to terminate backends with transactions exceeding this, with prioritisation as per cancelling:

```
TEST=# SELECT pg_log_long_xact('1s', true, 'text', '10 minutes',
 '15 minutes');
 long_xact pid: 4465 duration: 1026.90736 ms user: glyn
 application: ltsql client: [local] statement: <IDLE> in
 transaction
 long_xact terminated backend with pid: 4465
 long_xact pid: 16532 duration: 923.019915 ms user: glyn
 application: ltsql client: [local] statement: UPDATE balls SET
 description = 'TEST' WHERE id = 5;
```

By default the function only cancels/terminates the longest running blocker, or longest running transaction, we can be more forceful than that by passing an extra parameter to tell it to cancel statements/terminate backends of all long running transactions it finds:

```
TEST=# \t off
TEST=# SELECT pg_log_long_xact('1s', true, 'text', '2 minutes', '3
 minutes', true);
 long_xact pid: 19065 duration: 187.279089 ms user: glyn
 application: ltsql client: [local] statement: <IDLE> in
 transaction
 long_xact terminated backend with pid: 19065
 long_xact pid: 16532 duration: 184.251569 ms user: glyn
 application: ltsql client: [local] statement: UPDATE balls SET
 description = 'TEST' WHERE id = 5;
 long_xact cancelled backend with pid: 16532
(4 rows)
```

## F.29. It\_ope

## F.29.1. What is It\_ope?

Order-Preserving Encryption is an encryption method for data preservation order, which allows comparison operations to be directly applied to encrypted data without decrypting operands.

It\_ope support order-preserving encryption for three data types: `bigint`, `double precision`, and `text`. The maximum supported plaintext length of the `text` type is 128 bytes, and the currently supported character types include a total of 128 characters from 0 to 127 in ASCII. The type of ciphertext encrypted by three types of plaintext is `ope_type`.

The ciphertext type `ope_type` supports the following operators: `>`, `>=`, `<`, `<=`, `=` and `!=`. At the same time, the `ope_type` type ciphertext encrypted by the `text` type plaintext supports the like `'xxx %'` operation.

The ciphertext type `ope_type` also supports order `by`, `between...and`, `IN`, `NOT IN` and `BTREE` index.

## F.29.2. function usage

### F.29.2.1. bigint type order-preserving encryption

The `bigint` type encryption interface: `ope_bigint_encrypt(plaintext bigint) return ope_type`.

```
SELECT ope_bigint_encrypt(12345678);
           ope_bigint_encrypt
-----
663667376838DD03DDFF2F57DE01DE028841DF02DF43DF63DF65DF68
```

### F.29.2.2. double precision type order-preserving encryption

The `double precision` type encryption interface: `ope_double_encrypt(plaintext double precision) return ope_type`.

```
SELECT ope_double_encrypt(1234.5678);
           ope_double_encrypt
-----
663667376838DC02DDFF5227DE01DE026961DF02DDF4DF43DF63DF65DF68DDFDDDFDDDFDDDFDDDD
```

### F.29.2.3. text type order-preserving encryption

The `text` type encryption interface: `ope_text_encrypt(plaintext text) return ope_type`.

```
SELECT ope_text_encrypt('123456789@qq.com');
           ope_text_encrypt
-----
6535643463336232DDFF52CBDE01DE02FD63DF02DF43DF63DF65DF68DF6CDFE2FF82FF82DDF4FD
```

### F.29.2.4. OPE decryption

The OPE decryption interface: `ope_decrypt(ciphertext ope_type) return text`.

## F.29.2.5. OPE example

The following is an example of order-preserving encryption of text type:

```
-- The info field in the test_ope table is plaintext of text type,
-- and the opedata field is order-preserving encrypted ciphertext of
-- type ope_type:
create table test_ope(id int, info text, opedata ope_type, crt_time
timestamp not null);
CREATE TABLE
```

```
create index opedata_index on test_ope USING BTREE (opedata);
CREATE INDEX
```

```
select * from test_ope ;
      id | info
```

```
| opedata
```

```
| crt_time
```

```
-----+-----
+-----+-----
+-----+-----
      1 | 27025cc9acd114a4f5192930ebc6fffb |
6535643463336232DE01067CDF65DDFD8BE9DE01DF43FDDFFDDDF6CFDDAFDDFFDE2DDFFDDFFDF
| 2022-06-16 11:10:37.170803
      2 | cc97ddaf161894af7d5fbbe4ae31d0a1 |
6535643463336232FDDFE67CFDDFD6C8BE9DF65FDE2FDE2FDDAFDEBDDFFDF63DDFFDF68DF6CDF
| 2022-06-16 12:10:37.170955
      3 | 433dc866e329799e7d134992b13960fa |
6535643463336232DF021A7DDE02DE028BE9FDE2FDDFD68DF63DF63FDE3DE02DE01DF6CDF65DF
| 2022-06-16 13:10:37.170999
      4 | dff20cb13ce5d0365a6eb7625167e158 |
6535643463336232FDE2557DFDEBDFEB8BE9DE01DDFDFFDDFDBDDFFDE02FDDFFDE3DF43FDE2DD
| 2022-06-16 14:10:37.171109
      5 | c07b52a7943c3ee93aea8b05c04edbf3 |
6535643463336232FDDDFC17DDDFDDF658BE9FDDDBDF43DE01FDDADF65DF6CDF02DE02FDDFFDE02FD
| 2022-06-16 15:10:37.171169
      6 | cf87a3591009b652ba01dd3eb6a50d42 |
6535643463336232FDDDF047EFDEBDF688BE9DF65FDDADE02DF43DF6CDDFFDDFDDDFDDF6CFDDBF
| 2022-06-16 16:10:37.171208
      7 | c2a1654f7e4887339e552d9d70666c1c |
6535643463336232FDDDF157EDE01FD8A8BE9DDFFDF63DF43DF02FDEBDF65FDE3DF02DF68DF68DF
| 2022-06-16 17:10:37.171225
      8 | 127306338277eef17554ce089d28eb9d |
6535643463336232DDFF257EDE01DF658BE9DE02DDFDDF63DE02DE02DF68DE01DF65DF65FDE3FD
| 2022-06-16 18:10:37.171241
      9 | 4b7c57af3114003805bc0dd861ac7996 |
6535643463336232DF02387EFDDDF658BE9FDDFD43DF65FDDAFDEBDE02DDFFDDFFDF02DDFDD
| 2022-06-16 19:10:37.171261
     10 | 8ed90bd708f01094507636b80d9ef465 |
6535643463336232DF686F7EFDE3FDE28BE9DF6CDDFDFFDDBFDE2DF65DDFDDF68FDEBDDFDDDFDD
| 2022-06-16 20:10:37.171317
```

```
select * from test_ope order by opedata;
      id | info
```

```
| opedata
```



```

|          crt_time
+-----+
+-----+
+-----+
      8 | 127306338277eef17554ce089d28eb9d |
6535643463336232DDFF257EDE01DF658BE9DE02DDFDDF63DE02DE02DF68DE01DF65DF65FDE3FD
| 2022-06-16 18:10:37.171241
      1 | 27025cc9acd114a4f5192930ebc6fffb |
6535643463336232DE01067CDF65DDFD8BE9DE01DF43FDDFFDDFDF6CFDDAFDDFFDE2DDFFDDFFDF
| 2022-06-16 11:10:37.170803
      3 | 433dc866e329799e7d134992b13960fa |
6535643463336232DF021A7DDE02DE028BE9FDE2FDDFDF68DF63DF63FDE3DE02DE01DF6CDF65DF
| 2022-06-16 13:10:37.170999
      9 | 4b7c57af3114003805bc0dd861ac7996 |
6535643463336232DF02387EFDDDBDF658BE9FDDFDF43DF65FDDAFDEBDE02DDFFDDFFDF02DDFDD
| 2022-06-16 19:10:37.171261
     10 | 8ed90bd708f01094507636b80d9ef465 |
6535643463336232DF686F7EFDE3FDE28BE9DF6CDDFDFDDBFDE2DF65DDFDDF68FDEBDDFDDDFDD
| 2022-06-16 20:10:37.171317
      5 | c07b52a7943c3ee93aea8b05c04edbf3 |
6535643463336232FDDFC17DDDFDDF658BE9FDDDBDF43DE01FDDADF65DF6CDF02DE02FDDFDE02FD
| 2022-06-16 15:10:37.171169
      7 | c2a1654f7e4887339e552d9d70666c1c |
6535643463336232FDDF157EDE01FDDA8BE9DDFFDF63DF43DF02FDEBDF65FDE3DF02DF68DF68DF
| 2022-06-16 17:10:37.171225
      2 | cc97ddaf161894af7d5fbbe4ae31d0a1 |
6535643463336232FDDFE67CFDDFDF6C8BE9DF65FDE2FDE2FDDAFDEBDDFFDF63DDFFDF68DF6CDF
| 2022-06-16 12:10:37.170955
      6 | cf87a3591009b652ba01dd3eb6a50d42 |
6535643463336232FDDF047EFDEBDF688BE9DF65FDDADE02DF43DF6CDDFFDDFDDDFDDF6CFDDDB
| 2022-06-16 16:10:37.171208
      4 | dff20cb13ce5d0365a6eb7625167e158 |
6535643463336232FDE2557DFDEBFDEB8BE9DE01DDFDFDDFFDDDBDDFFDE02FDDFFDE3DF43FDE2DD
| 2022-06-16 14:10:37.171109

```

```

select * from test_ope where opedata > ope_text_encrypt('c') and
opeidata <= ope_text_encrypt('d');

```

```

      id |          info          |          opedata
+-----+
+-----+
+-----+
      2 | cc97ddaf161894af7d5fbbe4ae31d0a1 |
6535643463336232FDDFE67CFDDFDF6C8BE9DF65FDE2FDE2FDDAFDEBDDFFDF63DDFFDF68DF6CDF
| 2022-06-16 12:10:37.170955
      5 | c07b52a7943c3ee93aea8b05c04edbf3 |
6535643463336232FDDFC17DDDFDDF658BE9FDDDBDF43DE01FDDADF65DF6CDF02DE02FDDFDE02FD
| 2022-06-16 15:10:37.171169
      6 | cf87a3591009b652ba01dd3eb6a50d42 |
6535643463336232FDDF047EFDEBDF688BE9DF65FDDADE02DF43DF6CDDFFDDFDDDFDDF6CFDDDB
| 2022-06-16 16:10:37.171208
      7 | c2a1654f7e4887339e552d9d70666c1c |
6535643463336232FDDF157EDE01FDDA8BE9DDFFDF63DF43DF02FDEBDF65FDE3DF02DF68DF68DF
| 2022-06-16 17:10:37.171225

```

Additional Supplied Modules

---

```
select * from test_ope where opedata like 'dff20%';
      id |          info          |
```

opedata

```
|          crt_time
-----+-----
```

```
+-----+-----
4 | dff20cb13ce5d0365a6eb7625167e158 |
6535643463336232FDE2557DFDEBFDEB8BE9DE01DDFDFDDFFDDBDDFFDE02FDDFFDE3DF43FDE2DD
| 2022-06-16 14:10:37.171109
```

```
select * from test_ope where opedata between ope_text_encrypt('c')
and ope_text_encrypt('d');
```

```
      id |          info          |
```

opedata

```
|          crt_time
-----+-----
```

```
+-----+-----
2 | cc97ddaf161894af7d5fbbe4ae31d0a1 |
6535643463336232FDDDFE67CFDDDFDF6C8BE9DF65FDE2FDE2FDDAFDEBDDFFDF63DDFFDF68DF6CDF
| 2022-06-16 12:10:37.170955
```

```
5 | c07b52a7943c3ee93aea8b05c04edbf3 |
```

```
6535643463336232FDDDFC17DDDFDDF658BE9FDDDBDF43DE01FDDADF65DF6CDF02DE02FDDFFDE02FD
| 2022-06-16 15:10:37.171169
```

```
6 | cf87a3591009b652ba01dd3eb6a50d42 |
```

```
6535643463336232FDDDF047EFDEBDF688BE9DF65FDDADE02DF43DF6CDDFFDDFFDDDFDDF6CFDDDBDF
| 2022-06-16 16:10:37.171208
```

```
7 | c2a1654f7e4887339e552d9d70666c1c |
```

```
6535643463336232FDDDF157EDE01FDDA8BE9DDFFDF63DF43DF02FDEBDF65FDE3DF02DF68DF68DF
| 2022-06-16 17:10:37.171225
```

```
select * from test_ope where opedata =
ope_text_encrypt('127306338277eef17554ce089d28eb9d');
```

```
      id |          info          |
```

opedata

```
|          crt_time
-----+-----
```

```
+-----+-----
8 | 127306338277eef17554ce089d28eb9d |
6535643463336232DDFF257EDE01DF658BE9DE02DDFDDF63DE02DE02DF68DE01DF65DF65FDE3FD
| 2022-06-16 18:10:37.171241
```

```
select ope_text_encrypt('cc97ddaf161894af7d5fbbe4ae31d0a1') IN
(select opedata from test_ope);
      ?column?
-----
```

t

```
select ope_text_encrypt('cc97ddaf161894af7d5fbbe4ae31d0a1') NOT IN
(select opedata from test_ope);
      ?column?
-----
```

f

```
select ope_decrypt(test_ope.opedata) from test_ope where id = 2;
           ope_decrypt
-----
cc97ddaf161894af7d5fbbe4ae31d0a1
```

## F.30. lt\_pathman

The `lt_pathman` module provides optimized partitioning mechanism and functions to manage partitions.

### F.30.1. Overview

**Partitioning** means splitting one large table into smaller pieces. Each row in such table is moved to a single partition according to the partitioning key.

LightDB provides native partitioning:

```
CREATE TABLE test(id int4, value text) PARTITION BY RANGE(id);
CREATE TABLE test_1 PARTITION OF test FOR VALUES FROM (1) TO (10);
CREATE TABLE test_2 PARTITION OF test FOR VALUES FROM (10) TO (20);
```

It's not so different from the classic approach; there are implicit check constraints, and most of its limitations are still relevant.

Despite the flexibility, this approach forces the planner to perform an exhaustive search and to check constraints on each partition to determine whether it should be present in the plan or not. Large amount of partitions may result in significant planning overhead.

The `lt_pathman` module features partition managing functions and optimized planning mechanism which utilizes knowledge of the partitions' structure. It stores partitioning configuration in the `pathman_config` table; each row contains a single entry for a partitioned table (relation name, partitioning column and its type). During the initialization stage the `lt_pathman` module caches some information about child partitions in the shared memory, which is used later for plan construction. Before a `SELECT` query is executed, `lt_pathman` traverses the condition tree in search of expressions like:

```
VARIABLE OP CONST
```

where `VARIABLE` is a partitioning key, `OP` is a comparison operator (supported operators are `=`, `<`, `<=`, `>`, `>=`), `CONST` is a scalar value. For example:

```
WHERE id = 150
```

Based on the partitioning type and condition's operator, `lt_pathman` searches for the corresponding partitions and builds the plan. Currently `lt_pathman` supports two partitioning schemes:

- **RANGE** - maps rows to partitions using partitioning key ranges assigned to each partition. Optimization is achieved by using the binary search algorithm;
- **HASH** - maps rows to partitions using a generic hash function.

More interesting features are yet to come. Stay tuned!

### F.30.2. Feature highlights

- HASH and RANGE partitioning schemes;

- Partitioning by expression and composite key;
- Both automatic and manual partition management;
- Support for integer, floating point, date and other types, including domains;
- Effective query planning for partitioned tables (JOINS, subselects etc);
- RuntimeAppend & RuntimeMergeAppend custom plan nodes to pick partitions at runtime;
- PartitionFilter: an efficient drop-in replacement for INSERT triggers;
- PartitionRouter and PartitionOverseer for cross-partition UPDATE queries (instead of triggers);
- Automatic partition creation for new INSERTed data (only for RANGE partitioning);
- Improved COPY FROM statement that is able to insert rows directly into partitions;
- User-defined callbacks for partition creation event handling;
- Non-blocking concurrent table partitioning;
- FDW support (foreign partitions);
- Various GUC toggles and configurable settings.
- Partial support of declarative partitioning.

## F.30.3. Available functions

### F.30.3.1. Module's version

```
pathman_version()
```

This function returns a complete version number of the loaded `lt_pathman` module in MAJOR.MINOR.PATCH format.

### F.30.3.2. Partition creation

```
create_hash_partitions(parent_relid    REGCLASS,  
                       expression     TEXT,  
                       partitions_count INTEGER,  
                       partition_data  BOOLEAN DEFAULT TRUE,  
                       partition_names TEXT[] DEFAULT NULL,  
                       tablespaces    TEXT[] DEFAULT NULL)
```

Performs HASH partitioning for relation by partitioning expression `expr`. The `partitions_count` parameter specifies the number of partitions to create; it cannot be changed afterwards. If `partition_data` is true then all the data will be automatically copied from the parent table to partitions. Note that data migration may took a while to finish and the table will be locked until transaction commits. See `partition_table_concurrently()` for a lock-free way to migrate data. Partition creation callback is invoked for each partition if set beforehand (see `set_init_callback()`).

```
create_range_partitions(parent_relid    REGCLASS,  
                       expression     TEXT,  
                       start_value     ANYELEMENT,  
                       p_interval     ANYELEMENT,  
                       p_count        INTEGER DEFAULT NULL,  
                       partition_data  BOOLEAN DEFAULT TRUE)
```

```
create_range_partitions(parent_relid    REGCLASS,  
                       expression     TEXT,  
                       start_value     ANYELEMENT,  
                       p_interval     INTERVAL,  
                       p_count        INTEGER DEFAULT NULL,
```

```

                                partition_data  BOOLEAN DEFAULT TRUE)

create_range_partitions(parent_relid  REGCLASS,
                       expression    TEXT,
                       bounds        ANYARRAY,
                       partition_names TEXT[] DEFAULT NULL,
                       tablespaces    TEXT[] DEFAULT NULL,
                       partition_data BOOLEAN DEFAULT TRUE)

```

Performs RANGE partitioning for relation by partitioning expression `expr`, `start_value` argument specifies initial value, `p_interval` sets the default range for auto created partitions or partitions created with `append_range_partition()` or `prepend_range_partition()` (if NULL then auto partition creation feature won't work), `p_count` is the number of pre-made partitions (if not set then `lt_pathman` tries to determine it based on expression's values). The bounds array can be built using `generate_range_bounds()`. Partition creation callback is invoked for each partition if set beforehand.

```

generate_range_bounds(p_start  ANYELEMENT,
                     p_interval INTERVAL,
                     p_count   INTEGER)

```

```

generate_range_bounds(p_start  ANYELEMENT,
                     p_interval ANYELEMENT,
                     p_count   INTEGER)

```

Builds bounds array for `create_range_partitions()`.

### F.30.3.3. Data migration

```

partition_table_concurrently(relation  REGCLASS,
                             batch_size INTEGER DEFAULT 1000,
                             sleep_time FLOAT8 DEFAULT 1.0)

```

Starts a background worker to move data from parent table to partitions. The worker utilizes short transactions to copy small batches of data (up to 10K rows per transaction) and thus doesn't significantly interfere with user's activity. If the worker is unable to lock rows of a batch, it sleeps for `sleep_time` seconds before the next attempt and tries again up to 60 times, and quits if it's still unable to lock the batch.

```

stop_concurrent_part_task(relation REGCLASS)

```

Stops a background worker performing a concurrent partitioning task. Note: worker will exit after it finishes relocating a current batch.

### F.30.3.4. Triggers

Triggers are no longer required nor for INSERTs, neither for cross-partition UPDATES. However, user-supplied triggers *are supported*:

- Each **inserted row** results in execution of BEFORE/AFTER INSERT trigger functions of a *corresponding partition*.
- Each **updated row** results in execution of BEFORE/AFTER UPDATE trigger functions of a *corresponding partition*.
- Each **moved row** (cross-partition update) results in execution of BEFORE UPDATE + BEFORE/AFTER DELETE + BEFORE/AFTER INSERT trigger functions of *corresponding partitions*.

### F.30.3.5. Post-creation partition management

```
replace_hash_partition(old_partition REGCLASS,  
                      new_partition REGCLASS,  
                      lock_parent   BOOLEAN DEFAULT TRUE)
```

Replaces specified partition of HASH-partitioned table with another table. The `lock_parent` parameter will prevent any INSERT/UPDATE/ALTER TABLE queries to parent table.

```
split_range_partition(partition_relid REGCLASS,  
                    split_value      ANYELEMENT,  
                    partition_name   TEXT DEFAULT NULL,  
                    tablespace      TEXT DEFAULT NULL)
```

Split RANGE partition in two by `split_value`. Partition creation callback is invoked for a new partition if available.

```
merge_range_partitions(variadic partitions REGCLASS[])
```

Merge several adjacent RANGE partitions. Partitions are automatically ordered by increasing bounds; all the data will be accumulated in the first partition.

```
append_range_partition(parent_relid   REGCLASS,  
                      partition_name TEXT DEFAULT NULL,  
                      tablespace     TEXT DEFAULT NULL)
```

Append new RANGE partition with `pathman_config.range_interval` as interval.

```
prepend_range_partition(parent_relid   REGCLASS,  
                      partition_name TEXT DEFAULT NULL,  
                      tablespace     TEXT DEFAULT NULL)
```

Prepend new RANGE partition with `pathman_config.range_interval` as interval.

```
add_range_partition(parent_relid   REGCLASS,  
                   start_value    ANYELEMENT,  
                   end_value      ANYELEMENT,  
                   partition_name TEXT DEFAULT NULL,  
                   tablespace     TEXT DEFAULT NULL)
```

Create new RANGE partition for relation with specified range bounds. If `start_value` or `end_value` are NULL then corresponding range bound will be infinite.

```
drop_range_partition(partition TEXT, delete_data BOOLEAN DEFAULT  
                    TRUE)
```

Drop RANGE partition and all of its data if `delete_data` is true.

```
attach_range_partition(parent_relid   REGCLASS,  
                      partition_relid REGCLASS,  
                      start_value    ANYELEMENT,  
                      end_value      ANYELEMENT)
```

Attach partition to the existing RANGE-partitioned relation. The attached table must have exactly the same structure as the parent table, including the dropped columns. Partition creation callback is invoked if set (see `pathman_config_params`).

```
detach_range_partition(partition_relid REGCLASS)
```

Detach partition from the existing RANGE-partitioned relation.

```
disable_pathman_for(parent_relid REGCLASS)
```

Permanently disable `lt_pathman` partitioning mechanism for the specified parent table and remove the insert trigger if it exists. All partitions and data remain unchanged.

```
drop_partitions(parent_relid REGCLASS,  
                delete_data BOOLEAN DEFAULT FALSE)
```

Drop partitions of the `parent` table (both foreign and local relations). If `delete_data` is `false`, the data is copied to the parent table first. Default is `false`.

To remove partitioned table along with all partitions fully, use conventional `DROP TABLE relation CASCADE`. However, care should be taken in somewhat rare case when you are running logical replication and `DROP` was executed by replication apply worker, e.g. via trigger on replicated table. `lt_pathman` uses `pathman_ddl_trigger` event trigger to remove the record about dropped table from `pathman_config`, and this trigger by default won't fire on replica, leading to inconsistent state when `lt_pathman` thinks that the table still exists, but in fact it doesn't. If this is the case, configure this trigger to fire on replica too:

```
ALTER EVENT TRIGGER pathman_ddl_trigger ENABLE ALWAYS;
```

Physical replication doesn't have this problem since DDL as well as `pathman_config` table is replicated too; master and slave LightDB instances are basically identical, and it is only harmful to keep this trigger in `ALWAYS` mode.

### F.30.3.6. Additional parameters

```
set_interval(relation REGCLASS, value ANYELEMENT)
```

Update RANGE partitioned table interval. Note that interval must not be negative and it must not be trivial, i.e. its value should be greater than zero for numeric types, at least 1 microsecond for `TIMESTAMP` and at least 1 day for `DATE`.

```
set_enable_parent(relation REGCLASS, value BOOLEAN)
```

Include/exclude parent table into/from query plan. In original LightDB planner parent table is always included into query plan even if it's empty which can lead to additional overhead. You can use `disable_parent()` if you are never going to use parent table as a storage. Default value depends on the `partition_data` parameter that was specified during initial partitioning in `create_range_partitions()` function. If the `partition_data` parameter was `true` then all data have already been migrated to partitions and parent table disabled. Otherwise it is enabled.

```
set_auto(relation REGCLASS, value BOOLEAN)
```

Enable/disable auto partition propagation (only for RANGE partitioning). It is enabled by default.

```
set_init_callback(relation REGCLASS, callback REGPROC DEFAULT 0)
```

Set partition creation callback to be invoked for each attached or created partition (both HASH and RANGE). If callback is marked with SECURITY INVOKER, it's executed with the privileges of the user that produced a statement which has led to creation of a new partition (e.g. INSERT INTO partitioned\_table VALUES (-5)). The callback must have the following signature: part\_init\_callback(args JSONB) RETURNS VOID. Parameter arg consists of several fields whose presence depends on partitioning type:

```
/* RANGE-partitioned table abc (child abc_4) */
{
  "parent":          "abc",
  "parent_schema":  "public",
  "parttype":        "2",
  "partition":       "abc_4",
  "partition_schema": "public",
  "range_max":       "401",
  "range_min":       "301"
}

/* HASH-partitioned table abc (child abc_0) */
{
  "parent":          "abc",
  "parent_schema":  "public",
  "parttype":        "1",
  "partition":       "abc_0",
  "partition_schema": "public"
}
```

```
set_set_spawn_using_bgw(relation REGCLASS, value BOOLEAN)
```

When INSERTing new data beyond the partitioning range, use SpawnPartitionsWorker to create new partitions in a separate transaction.

## F.30.4. Views and tables

### F.30.4.1. pathman\_config — main config storage

```
CREATE TABLE IF NOT EXISTS pathman_config (
  partrel          REGCLASS NOT NULL PRIMARY KEY,
  expr             TEXT NOT NULL,
  parttype         INTEGER NOT NULL,
  range_interval   TEXT,
  cooked_expr      TEXT);
```

This table stores a list of partitioned tables.

### F.30.4.2. pathman\_config\_params — optional parameters

```
CREATE TABLE IF NOT EXISTS pathman_config_params (
  partrel          REGCLASS NOT NULL PRIMARY KEY,
  enable_parent    BOOLEAN NOT NULL DEFAULT TRUE,
  auto             BOOLEAN NOT NULL DEFAULT TRUE,
```



```
init_callback    TEXT DEFAULT NULL,  
spawn_using_bgw BOOLEAN NOT NULL DEFAULT FALSE);
```

This table stores optional parameters which override standard behavior.

### F.30.4.3. `pathman_concurrent_part_tasks` — currently running partitioning workers

```
-- helper SRF function  
CREATE OR REPLACE FUNCTION show_concurrent_part_tasks()  
RETURNS TABLE (  
    userid      REGROLE,  
    pid         INT,  
    dbid        OID,  
    relid       REGCLASS,  
    processed   INT,  
    status      TEXT)  
AS 'lt_pathman', 'show_concurrent_part_tasks_internal'  
LANGUAGE C STRICT;  
  
CREATE OR REPLACE VIEW pathman_concurrent_part_tasks  
AS SELECT * FROM show_concurrent_part_tasks();
```

This view lists all currently running concurrent partitioning tasks.

### F.30.4.4. `pathman_partition_list` — list of all existing partitions

```
-- helper SRF function  
CREATE OR REPLACE FUNCTION show_partition_list()  
RETURNS TABLE (  
    parent      REGCLASS,  
    partition   REGCLASS,  
    parttype    INT4,  
    expr        TEXT,  
    range_min   TEXT,  
    range_max   TEXT)  
AS 'lt_pathman', 'show_partition_list_internal'  
LANGUAGE C STRICT;  
  
CREATE OR REPLACE VIEW pathman_partition_list  
AS SELECT * FROM show_partition_list();
```

This view lists all existing partitions, as well as their parents and range boundaries (NULL for HASH partitions).

### F.30.4.5. `pathman_cache_stats` — per-backend memory consumption

```
-- helper SRF function  
CREATE OR REPLACE FUNCTION @extschema@.show_cache_stats()  
RETURNS TABLE (  
    context     TEXT,  
    size        INT8,
```

```

        used          INT8,
        entries       INT8)
AS 'lt_pathman', 'show_cache_stats_internal'
LANGUAGE C STRICT;

CREATE OR REPLACE VIEW @extschema@.pathman_cache_stats
AS SELECT * FROM @extschema@.show_cache_stats();

```

Shows memory consumption of various caches.

## F.30.5. Declarative partitioning

ATTACH PARTITION, DETACH PARTITION and CREATE TABLE .. PARTITION OF commands could be used with tables partitioned by `lt_pathman`:

```

CREATE TABLE child1 (LIKE partitioned_table);

--- attach new partition
ALTER TABLE partitioned_table ATTACH PARTITION child1
    FOR VALUES FROM ('2015-05-01') TO ('2015-06-01');

--- detach the partition
ALTER TABLE partitioned_table DETACH PARTITION child1;

-- create a partition
CREATE TABLE child2 PARTITION OF partitioned_table
    FOR VALUES IN ('2015-05-01', '2015-06-01');

```

## F.30.6. Custom plan nodes

`lt_pathman` provides a couple of custom plan nodes<sup>3</sup> which aim to reduce execution time, namely:

- `RuntimeAppend` (overrides `Append` plan node)
- `RuntimeMergeAppend` (overrides `MergeAppend` plan node)
- `PartitionFilter` (drop-in replacement for `INSERT` triggers)
- `PartitionOverseer` (implements cross-partition `UPDATES`)
- `PartitionRouter` (implements cross-partition `UPDATES`)

`PartitionFilter` acts as a *proxy node* for `INSERT`'s child scan, which means it can redirect output tuples to the corresponding partition:

```

EXPLAIN (COSTS OFF)
INSERT INTO partitioned_table
SELECT generate_series(1, 10), random();
      QUERY PLAN
-----
Insert on partitioned_table
-> Custom Scan (PartitionFilter)
    -> Subquery Scan on "*SELECT*"
        -> Result

(4 rows)

```

`PartitionOverseer` and `PartitionRouter` are another *proxy nodes* used in conjunction with `PartitionFilter` to enable cross-partition `UPDATES` (i.e. when update of partitioning key

<sup>3</sup> <https://wiki.postgresql.org/wiki/CustomScanAPI>

requires that we move row to another partition). Since this node has a great deal of side effects (ordinary UPDATE becomes slower; cross-partition UPDATE is transformed into DELETE + INSERT), it is disabled by default. To enable it, refer to the list of GUCs below.

```
EXPLAIN (COSTS OFF)
UPDATE partitioned_table
SET value = value + 1 WHERE value = 2;
          QUERY PLAN
-----
Custom Scan (PartitionOverseer)
  -> Update on partitioned_table_2
      -> Custom Scan (PartitionFilter)
          -> Custom Scan (PartitionRouter)
              -> Seq Scan on partitioned_table_2
                  Filter: (value = 2)

(6 rows)
```

RuntimeAppend and RuntimeMergeAppend have much in common: they come in handy in a case when WHERE condition takes form of:

```
VARIABLE OP PARAM
```

This kind of expressions can no longer be optimized at planning time since the parameter's value is not known until the execution stage takes place. The problem can be solved by embedding the *WHERE condition analysis routine* into the original Append's code, thus making it pick only required scans out of a whole bunch of planned partition scans. This effectively boils down to creation of a custom node capable of performing such a check.

There are at least several cases that demonstrate usefulness of these nodes:

```
/* create table we're going to partition */
CREATE TABLE partitioned_table(id INT NOT NULL, payload REAL);

/* insert some data */
INSERT INTO partitioned_table
SELECT generate_series(1, 1000), random();

/* perform partitioning */
SELECT create_hash_partitions('partitioned_table', 'id', 100);

/* create ordinary table */
CREATE TABLE some_table AS SELECT generate_series(1, 100) AS VAL;

• id = (select ... limit 1)
```

```
EXPLAIN (COSTS OFF, ANALYZE) SELECT * FROM partitioned_table
WHERE id = (SELECT * FROM some_table LIMIT 1);
          QUERY PLAN
-----
Custom Scan (RuntimeAppend) (actual time=0.030..0.033 rows=1
loops=1)
  InitPlan 1 (returns $0)
    -> Limit (actual time=0.011..0.011 rows=1 loops=1)
        -> Seq Scan on some_table (actual time=0.010..0.010
rows=1 loops=1)
```

```

-> Seq Scan on partitioned_table_70 partitioned_table (actual
time=0.004..0.006 rows=1 loops=1)
    Filter: (id = $0)
    Rows Removed by Filter: 9
Planning time: 1.131 ms
Execution time: 0.075 ms
(9 rows)

```

```

/* disable RuntimeAppend node */
SET lt_pathman.enable_runtimeappend = f;

```

```

EXPLAIN (COSTS OFF, ANALYZE) SELECT * FROM partitioned_table
WHERE id = (SELECT * FROM some_table LIMIT 1);
                QUERY PLAN
-----

```

```

Append (actual time=0.196..0.274 rows=1 loops=1)
  InitPlan 1 (returns $0)
    -> Limit (actual time=0.005..0.005 rows=1 loops=1)
        -> Seq Scan on some_table (actual time=0.003..0.003
rows=1 loops=1)
    -> Seq Scan on partitioned_table_0 (actual time=0.014..0.014
rows=0 loops=1)
        Filter: (id = $0)
        Rows Removed by Filter: 6
    -> Seq Scan on partitioned_table_1 (actual time=0.003..0.003
rows=0 loops=1)
        Filter: (id = $0)
        Rows Removed by Filter: 5
    ... /* more plans follow */
Planning time: 1.140 ms
Execution time: 0.855 ms
(306 rows)

```

• **id = ANY (select ...)**

```

EXPLAIN (COSTS OFF, ANALYZE) SELECT * FROM partitioned_table
WHERE id = any (SELECT * FROM some_table limit 4);
                QUERY PLAN
-----

```

```

Nested Loop (actual time=0.025..0.060 rows=4 loops=1)
  -> Limit (actual time=0.009..0.011 rows=4 loops=1)
      -> Seq Scan on some_table (actual time=0.008..0.010
rows=4 loops=1)
  -> Custom Scan (RuntimeAppend) (actual time=0.002..0.004 rows=1
loops=4)
      -> Seq Scan on partitioned_table_70 partitioned_table
(actual time=0.001..0.001 rows=10 loops=1)
      -> Seq Scan on partitioned_table_26 partitioned_table
(actual time=0.002..0.003 rows=9 loops=1)
      -> Seq Scan on partitioned_table_27 partitioned_table
(actual time=0.001..0.002 rows=20 loops=1)
      -> Seq Scan on partitioned_table_63 partitioned_table
(actual time=0.001..0.002 rows=9 loops=1)
Planning time: 0.771 ms
Execution time: 0.101 ms
(10 rows)

```

```

/* disable RuntimeAppend node */
SET lt_pathman.enable_runtimeappend = f;

EXPLAIN (COSTS OFF, ANALYZE) SELECT * FROM partitioned_table
WHERE id = any (SELECT * FROM some_table limit 4);
                                QUERY PLAN
-----
Nested Loop Semi Join (actual time=0.531..1.526 rows=4 loops=1)
  Join Filter: (partitioned_table.id = some_table.val)
  Rows Removed by Join Filter: 3990
  -> Append (actual time=0.190..0.470 rows=1000 loops=1)
    -> Seq Scan on partitioned_table (actual
time=0.187..0.187 rows=0 loops=1)
    -> Seq Scan on partitioned_table_0 (actual
time=0.002..0.004 rows=6 loops=1)
    -> Seq Scan on partitioned_table_1 (actual
time=0.001..0.001 rows=5 loops=1)
    -> Seq Scan on partitioned_table_2 (actual
time=0.002..0.004 rows=14 loops=1)
... /* 96 scans follow */
  -> Materialize (actual time=0.000..0.000 rows=4 loops=1000)
    -> Limit (actual time=0.005..0.006 rows=4 loops=1)
      -> Seq Scan on some_table (actual time=0.003..0.004
rows=4 loops=1)
Planning time: 2.169 ms
Execution time: 2.059 ms
(110 rows)

```

- **NestLoop involving a partitioned table**, which is omitted since it's occasionally shown above.

## F.30.7. Examples

### F.30.7.1. Common tips

- You can easily add *partition* column containing the names of the underlying partitions using the system attribute called *tableoid*:

```
SELECT tableoid::regclass AS partition, * FROM partitioned_table;
```

- Though indices on a parent table aren't particularly useful (since it's supposed to be empty), they act as prototypes for indices on partitions. For each index on the parent table, *lt\_pathman* will create a similar index on every partition.
- All running concurrent partitioning tasks can be listed using the *pathman\_concurrent\_part\_tasks* view:

```

SELECT * FROM pathman_concurrent_part_tasks;
userid | pid  | dbid  | relid | processed | status
-----+-----+-----+-----+-----+-----
dmitry | 7367 | 16384 | test  | 472000    | working
(1 row)

```

- *pathman\_partition\_list* in conjunction with *drop\_range\_partition()* can be used to drop RANGE partitions in a more flexible way compared to good old DROP TABLE:

```

SELECT drop_range_partition(partition, false) /* move data to
parent */
FROM pathman_partition_list
WHERE parent = 'part_test'::regclass AND range_min::int < 500;
NOTICE:  1 rows copied from part_test_11
NOTICE:  100 rows copied from part_test_1
NOTICE:  100 rows copied from part_test_2
drop_range_partition
-----
dummy_test_11
dummy_test_1
dummy_test_2
(3 rows)

```

- You can turn foreign tables into partitions using the `attach_range_partition()` function. Rows that were meant to be inserted into parent will be redirected to foreign partitions (as usual, `PartitionFilter` will be involved), though by default it is prohibited to insert rows into partitions provided not by `postgres_fdw`. Only superuser is allowed to set `lt_pathman.insert_into_fdw` GUC variable.

## F.30.7.2. HASH partitioning

Consider an example of HASH partitioning. First create a table with some integer column:

```

CREATE TABLE items (
    id          SERIAL PRIMARY KEY,
    name       TEXT,
    code       BIGINT);

INSERT INTO items (id, name, code)
SELECT g, md5(g::text), random() * 100000
FROM generate_series(1, 100000) as g;

```

Now run the `create_hash_partitions()` function with appropriate arguments:

```
SELECT create_hash_partitions('items', 'id', 100);
```

This will create new partitions and move the data from parent to partitions.

Here's an example of the query performing filtering by partitioning key:

```

SELECT * FROM items WHERE id = 1234;
 id | name | code
-----+-----+-----
 1234 | 81dc9bdb52d04dc20036dbd8313ed055 | 1855
(1 row)

```

```

EXPLAIN SELECT * FROM items WHERE id = 1234;
                    QUERY PLAN
-----
Append  (cost=0.28..8.29 rows=0 width=0)
->  Index Scan using items_34_pkey on items_34  (cost=0.28..8.29
rows=0 width=0)
      Index Cond: (id = 1234)

```

Notice that the `Append` node contains only one child scan which corresponds to the `WHERE` clause.

**Important:** pay attention to the fact that `lt_pathman` excludes the parent table from the query plan.

To access parent table use `ONLY` modifier:

```
EXPLAIN SELECT * FROM ONLY items;
          QUERY PLAN
-----
Seq Scan on items (cost=0.00..0.00 rows=1 width=45)
```

### F.30.7.3. RANGE partitioning

Consider an example of RANGE partitioning. Let's create a table containing some dummy logs:

```
CREATE TABLE journal (
    id      SERIAL,
    dt      TIMESTAMP NOT NULL,
    level   INTEGER,
    msg     TEXT);

-- similar index will also be created for each partition
CREATE INDEX ON journal(dt);

-- generate some data
INSERT INTO journal (dt, level, msg)
SELECT g, random() * 6, md5(g::text)
FROM generate_series('2015-01-01'::date, '2015-12-31'::date, '1
minute') as g;
```

Run the `create_range_partitions()` function to create partitions so that each partition would contain the data for one day:

```
SELECT create_range_partitions('journal', 'dt', '2015-01-01'::date,
'1 day'::interval);
```

It will create 365 partitions and move the data from parent to partitions.

New partitions are appended automatically by insert trigger, but it can be done manually with the following functions:

```
-- add new partition with specified range
SELECT add_range_partition('journal', '2016-01-01'::date,
'2016-01-07'::date);

-- append new partition with default range
SELECT append_range_partition('journal');
```

The first one creates a partition with specified range. The second one creates a partition with default interval and appends it to the partition list. It is also possible to attach an existing table as partition. For example, we may want to attach an archive table (or even foreign table from another server) for some outdated data:

```
CREATE FOREIGN TABLE journal_archive (
    id      INTEGER NOT NULL,
    dt      TIMESTAMP NOT NULL,
    level   INTEGER,
```

```

msg      TEXT)
SERVER archive_server;

SELECT attach_range_partition('journal', 'journal_archive',
    '2014-01-01'::date, '2015-01-01'::date);

```

**Important:** the definition of the attached table must match the one of the existing partitioned table, including the dropped columns.

To merge to adjacent partitions, use the `merge_range_partitions()` function:

```
SELECT merge_range_partitions('journal_archive', 'journal_1');
```

To split partition by value, use the `split_range_partition()` function:

```
SELECT split_range_partition('journal_366', '2016-01-03'::date);
```

To detach partition, use the `detach_range_partition()` function:

```
SELECT detach_range_partition('journal_archive');
```

Here's an example of the query performing filtering by partitioning key:

```

SELECT * FROM journal WHERE dt >= '2015-06-01' AND dt <
    '2015-06-03';

```

id	dt	level	msg
217441	2015-06-01 00:00:00	2	15053892d993ce19f580a128f87e3dbf
217442	2015-06-01 00:01:00	1	3a7c46f18a952d62ce5418ac2056010c
217443	2015-06-01 00:02:00	0	92c8de8f82faf0b139a3d99f2792311d
...			

(2880 rows)

```

EXPLAIN SELECT * FROM journal WHERE dt >= '2015-06-01' AND dt <
    '2015-06-03';

```

QUERY PLAN

```

-----
Append (cost=0.00..58.80 rows=0 width=0)
-> Seq Scan on journal_152 (cost=0.00..29.40 rows=0 width=0)
-> Seq Scan on journal_153 (cost=0.00..29.40 rows=0 width=0)
(3 rows)

```

### F.30.7.4. Disabling `lt_pathman`

There are several user-accessible GUC variables designed to toggle the whole module or specific custom nodes on and off:

- `lt_pathman.enable` — disable (or enable) `lt_pathman` **completely**
- `lt_pathman.enable_runtimeappend` — toggle `RuntimeAppend` custom node on
- `lt_pathman.enable_runtimemergeappend` — toggle `RuntimeMergeAppend` custom node on
- `lt_pathman.enable_partitionfilter` — toggle `PartitionFilter` custom node on(for INSERTs)



- `lt_pathman.enable_partitionrouter` — toggle PartitionRouter custom node on(for cross-partition UPDATES)
- `lt_pathman.enable_auto_partition` — toggle automatic partition creation on(per session)
- `lt_pathman.enable_bounds_cache` — toggle bounds cache on(faster updates of partitioning scheme)
- `lt_pathman.insert_into_fdw` — allow INSERTs into various FDWs (`disabled | postgres | any_fdw`)
- `lt_pathman.override_copy` — toggle COPY statement hooking on

To **permanently** disable `lt_pathman` for some previously partitioned table, use the `disable_pathman_for()` function:

```
SELECT disable_pathman_for('range_rel');
```

All sections and data will remain unchanged and will be handled by the standard LightDB inheritance mechanism.

## F.31. lt\_patch

The `lt_patch` module provides a means for tracking the information of all patches executed by a server.

Before creating `lt_patch` you must first create `file_fdw` extension and set `LTHOME` environment variable.

When `lt_patch` is loaded, it tracks patches across all databases of the server. To access and manipulate these patch information, the module provides a table, `lt_patch`, and the utility functions `lt_patch`. These are not available globally but can be enabled for a specific database with `CREATE EXTENSION lt_patch`.

### F.31.1. The lt\_patch table

The information gathered by the module are made available via a table named `lt_patch`. This table contains one row for each distinct path. The columns of the table are shown in Table F.15.

**Table F.15. lt\_patch Columns**

Column	Type	Description
<code>name</code>	<code>varchar</code>	patch name
<code>dependency</code>	<code>varchar</code>	dependency patch
<code>component_type</code>	<code>varchar</code>	component type : PATCH BUGFIX
<code>apply_type</code>	<code>varchar</code>	apply type : INSTANCE APP BOTH
<code>apply_version</code>	<code>varchar</code>	apply version
<code>action</code>	<code>varchar</code>	action : REMOVED INSTALLED
<code>status</code>	<code>varchar</code>	status : "APP FAILED" "APP SUCCESS" "INSTANCE FAILED" "SUCCESS"

Column Type	Description
create_time timestamp	patch create time
update_time timestamp	patch update time

## F.31.2. Functions

`lt_patch(showtext boolean)` returns setof record

The `lt_patch` table is defined in terms of a function also named `lt_patch`.

## F.31.3. Sample Output

```
lightdb@postgres=# select * from lt_patch;
   name      | dependency | component_type | apply_type |
apply_version | action    | status  | create_time |
update_time
-----+-----+-----+-----+-----
patch-1.0-8717 |          | patch      | BOTH      |
| 13.8-22.4   | removed  |          | 2022-12-29 18:25:48 |
2022-12-29 19:24:33
1.0-8719      |          | patch      | BOTH      |
| 13.8-22.4   | removed  |          | 2022-12-29 19:58:39 |
2022-12-29 21:18:52
(2 rows)
```

```
lightdb@postgres=# select lt_patch();
                                lt_patch
-----+-----+-----+-----+-----
(patch-1.0-8717,,patch,BOTH,13.8-22.4,removed,, "2022-12-29
18:25:48", "2022-12-29 19:24:33")
(1.0-8719,,patch,BOTH,13.8-22.4,removed,, "2022-12-29
19:58:39", "2022-12-29 21:18:52")
(2 rows)
```

## F.32. lt\_prewarm

The `lt_prewarm` module provides a convenient way to load relation data into either the operating system buffer cache or the LightDB buffer cache. Prewarming can be performed manually using the `pg_prewarm` function, or can be performed automatically by including `lt_prewarm` in `shared_preload_libraries`. In the latter case, the system will run a background worker which periodically records the contents of shared buffers in a file called `autoprewarm.blocks` and will, using 2 background workers, reload those same blocks after a restart.

Lightdb adds the function of automatic prewarming during startup (restart), including automatically prewarming the database, tables and indexes. When prewarming the database, it will prewarms all non system tables under the database (including partition tables and indexes under the table). When prewarming the table alone, it will also prewarms the partition tables and indexes of the table. Of course, when configuring the prewarming database and the tables under the database at the same time, we will not repeat the prewarming.

## F.32.1. Functions

```
pg_prewarm(regclass, mode text default 'buffer', fork text default
'main',
           first_block int8 default null,
           last_block int8 default null) RETURNS int8
```

The first argument is the relation to be prewarmed. The second argument is the prewarming method to be used, as further discussed below; the third is the relation fork to be prewarmed, usually `main`. The fourth argument is the first block number to prewarm (`NULL` is accepted as a synonym for zero). The fifth argument is the last block number to prewarm (`NULL` means prewarm through the last block in the relation). The return value is the number of blocks prewarmed.

There are three available prewarming methods. `prefetch` issues asynchronous prefetch requests to the operating system, if this is supported, or throws an error otherwise. `read` reads the requested range of blocks; unlike `prefetch`, this is synchronous and supported on all platforms and builds, but may be slower. `buffer` reads the requested range of blocks into the database buffer cache.

Note that with any of these methods, attempting to prewarm more blocks than can be cached — by the OS when using `prefetch` or `read`, or by LightDB when using `buffer` — will likely result in lower-numbered blocks being evicted as higher numbered blocks are read in. Prewarmed data also enjoys no special protection from cache evictions, so it is possible that other system activity may evict the newly prewarmed blocks shortly after they are read; conversely, prewarming may also evict other data from cache. For these reasons, prewarming is typically most useful at startup, when caches are largely empty.

```
autoprewarm_start_worker() RETURNS void
```

Launch the main autoprewarm worker. This will normally happen automatically, but is useful if automatic prewarm was not configured at server startup time and you wish to start up the worker at a later time.

```
autoprewarm_dump_now() RETURNS int8
```

Update `autoprewarm.blocks` immediately. This may be useful if the autoprewarm worker is not running but you anticipate running it after the next restart. The return value is the number of records written to `autoprewarm.blocks`.

## F.32.2. Configuration Parameters

```
lt_prewarm.autoprewarm (boolean)
```

Controls whether the server should run the autoprewarm worker. This is on by default. This parameter can only be set at server start.

```
lt_prewarm.autoprewarm_interval (int)
```

This is the interval between updates to `autoprewarm.blocks`. The default is 300 seconds. If set to 0, the file will not be dumped at regular intervals, but only when the server is shut down.

These parameters must be set in `lightdb.conf`. Typical usage might be:

```
# lightdb.conf
shared_preload_libraries = 'pg_prewarm'

pg_prewarm.autoprewarm = true
```

```
pg_prewarm.autoprewarm_interval = 300s
```

```
lt_prewarm.lt_autoprewarm_dbs (text)
```

This parameter configures the list of databases to be prewarmed automatically. for example, `lt_prewarm.lt_autoprewarm_dbs = 'db1, db2, db3'`.

```
lt_prewarm.lt_autoprewarm_tables (text)
```

This parameter configures the list of tables to be prewarmed automatically. for example, `lt_prewarm.lt_autoprewarm_tables = 'db1.schema1.t1, db1.schema1.t2, db1.schema2.t1, db2.schema1.t1'`.

```
lt_prewarm.lt_autoprewarm_indexes (text)
```

This parameter configures the list of indexes to be prewarmed automatically. for example, `lt_prewarm.lt_autoprewarm_indexes = 'db1.schema1.i1, db1.schema1.i2, db1.schema2.i1, db2.schema1.i1'`.

### F.32.3. Author

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## F.33. It\_proctab

`lt_proctab` is a collection of stored functions that can access the operating systems process table so that system statistics can be queried through the database.

### F.33.1. functions

#### F.33.1.1. pg\_proctab

Gets information about all LightDB processes. The list of all processes is retrieved from `pg_stat_activity`, and process information is retrieved from the `/proc` system file.

```
lightdb@postgres=# select * from pg_proctab();
-[ RECORD 1 ]-----+-----
pid           | 64994
comm          | lightdb
fullcomm      | lightdb: autovacuum launcher
state         | S
ppid          | 64986
pgrp          | 64994
session       | 64994
tty_nr        | 0
tpgid         | -1
flags         | 4202560
minflt        | 529
cminflt       | 0
majflt        | 0
cmajflt       | 0
utime         | 1
stime         | 0
cutime        | 0
cstime        | 0
priority      | 20
nice          | 0
```

num_threads		1
itrealvalue		0
starttime		3258371
vsize		1902161920
rss		3588
exit_signal		17
processor		3
rt_priority		0
policy		0
delayacct_blkio_ticks		0
uid		1001
username		lightdb
rchar		66914
wchar		26
syscr		72
syscw		26
reads		0
writes		0
cwrites		0

### F.33.1.2. pg\_cputime

CPU information obtained from /proc/stat.

```
lightdb@postgres=# select * from pg_cputime();
 user | nice | system | idle | iowait
-----+-----+-----+-----+-----
 289580 | 61 | 29378 | 15540161 | 7253
(1 row)
```

### F.33.1.3. pg\_loadavg

Load information obtained from /proc/loadavg.

```
lightdb@postgres=# select * from pg_loadavg();
 load1 | load5 | load15 | last_pid
-----+-----+-----+-----
 0.08 | 0.05 | 0.05 | 74363
(1 row)
```

### F.33.1.4. pg\_loadavg

Memory usage information obtained from /proc/meminfo.

```
lightdb@postgres=# select * from pg_memusage();
 memused | memfree | memshared | membuffers | memcached | swapused
 | swapfree | swapcached
-----+-----+-----+-----+-----+-----
 4441516 | 3552556 | 0 | 2084 | 3770828 | 0
 | 4064252 | 0
(1 row)
```

### F.33.1.5. pg\_diskusage

Disk usage information obtained from /proc/diskstats

```
lightdb@postgres=# select * from pg_diskusage();
-[ RECORD 1 ]-----+-----
major          | 8
minor          | 0
devname        | sda
reads_completed | 36385
reads_merged   | 67
sectors_read    | 2060883
readtime       | 25260
writes_completed | 384347
writes_merged   | 3697
sectors_written | 16852473
writetime      | 351385
current_io     | 0
iotime         | 326759
totaliotime    | 372183
```

## F.34. It\_profile

This extension for LightDB helps you to find out most resource-consuming activities in your LightDB databases.

### F.34.1. Concepts

Extension is based on statistic views of LightDB and contrib extension *lt\_stat\_statements*, *lt\_stat\_activity* and *system\_stats*. It is written in pure pl/pgsql and doesn't need any external libraries or software, but LightDB database itself.

Historic repository will be created in your database by this extension. This repository will hold statistic "samples" for your lightdb clusters. Sample is taken by calling *take\_sample()* function. LightDB also provide another *lt\_cron* extension tool performing periodic take sample tasks.

Periodic samples can help you finding most resource intensive activities in the past. Suppose, you were reported performance degradation several hours ago. Resolving such issue, you can build a report between two samples bounding performance issue period to see load profile of your database.

You can take an explicit sample before running any batch processing, and after it will be done.

Any time you are taking a sample, *pg\_stat\_statements\_reset()* will be called, ensuring you wont loose statements due to reaching *lt\_stat\_statements.max*. Also, report will contain section, informing you if captured statements count in any sample reaches 90% of *lt\_stat\_statements.max*.

*lt\_profile*, installed in one cluster is able to collect statistics from other clusters, called *servers*. You just need to define some servers, providing names and connection strings and make sure connection can be established to all databases of all *servers*. Now you can track, for example, statistics on your standbys from master, or from any other server. Once extension is installed, a *local* server is automatically created - this is a server for cluster where *lt\_profile* resides.

### F.34.2. Extension architecture

Extension consists of four parts:

- **Historic repository** is a storage for sampling data. Repository is a set of extension tables.
- **Sample management engine** is a set of functions, used for taking *samples* and support repository by removing obsolete sample data from it.

- **Report engine** is a set of functions used for report generation based on data from historic repository.
- **Administrative functions** allows you to create and manage *servers* and *baselines*.

## F.34.2.1. Extension tables

### F.34.2.1.1. servers

Monitored servers (LightDB clusters) list.

**Table F.16. servers Columns**

Column Type	Description
server_id integer	Server id
server_name name	Server name
server_description text	Server description
server_created timestamp with time zone DEFAULT	Server created timestamp, default now()
db_exclude name[ ]	Databases that should be excluded
enabled boolean	Enabled or not, default true
connstr text	Connstr for dblink
max_sample_age integer	Global setting of max_sample_age would be overridden by this value if set
last_sample_id integer	Last sample id, default 0
size_smp_wnd_start time with time zone	Sample window start timestamp
size_smp_wnd_dur interval hour to second	Sample window duration
size_smp_interval interval day to minute	Sample window interval

### F.34.2.1.2. samples

Sample times list.

**Table F.17. samples Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
sample_time timestamp (0) with time zone	Timestamp of this sample

### F.34.2.1.3. sample\_server\_hardware

Server hardware information (collected by system\_stats). The information includes the number of CPUs, threads, cores, sockets, memory, etc.

**Table F.18. sample\_server\_hardware Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
architecture text	Cpu architecture of the system
byte_order text	Byte order of the architecture
cpus integer	Cpu count
threads_per_core integer	Thread count per core
cores_per_socket integer	Core count per socket
sockets integer	Sockets of the system
vendor_id text	Vendor id
cpu_family integer	Cpu family
model integer	Model of the system
model_name text	Model name of the system
cpu_mhz text	Cpu frequency in mhz
l1dcache text	Level 1 data cache
l1icache text	Level 1 instruction cache
l2cache text	Level 2 cache
l3cache t	Level 3 cache
memory_total integer	Memory in total
swap_total integer	Swap memory in total

### F.34.2.1.4. sample\_cluster\_instance

Cluster configuration information.



**Table F.19. sample\_cluster\_instance Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
hostname text	Hostname (reference servers.server_name)
cluster_name text	Cluster name (reference current_setting('cluster_name'))
role text	Role, Primary if pg_is_in_recovery() = false, otherwise standby
release text	Version of LightDB, for example: LightDB 13.8-23.1
startup_time timestamp	Startup time

**F.34.2.1.5. sample\_kernel\_settings**

Sample kernel settings.

**Table F.20. sample\_kernel\_settings Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
name text	Name
value text	Value
sourcefile text	Source file

**F.34.2.1.6. sample\_cpu\_usage**

Sample cpu usage, the data is produced by analyzing statistics from /proc/stat.

**Table F.21. sample\_cpu\_usage Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
user_cpu float4	User cpu
sys_cpu float4	

Column Type	Description
	Sys cpu
idle_cpu float4	Idle cpu
io_wait float4	Io wait

#### F.34.2.1.7. sample\_db\_memory\_usage

Sample memory usage.

**Table F.22. sample\_db\_memory\_usage Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
shared_memory bigint	Shared memory size in bytes
local_memory bigint	Local memory size in bytes

#### F.34.2.1.8. sample\_settings

Sample settings.

**Table F.23. sample\_settings Columns**

Column Type	Description
server_id integer	Server id
first_seen timestamp (0) with time zone	First seen timestamp
setting_scope smallint	Scope of setting. Currently may be 1 for pg_settings and 2 for other adm functions (like version)
name text	Name
setting text	Setting
reset_val text	Reset val
boot_val text	Boot val
unit text	Unit
sourcefile text	Source file
sourceline integer	

Column Type	Description
	Source line
pending_restart boolean	Pending restart flag

### F.34.2.1.9. sample\_timings

Sample timings for various function call of sample system.

**Table F.24. sample\_timings Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
event text	Sample event
time_spent interval MINUTE TO SECOND (2)	Spent time for the related event on this sample

### F.34.2.1.10. baselines

Baselines setting.

**Table F.25. baselines Columns**

Column Type	Description
server_id integer	Server id
bl_id integer	Baseline sample id
bl_name varchar (25)	Baseline sample name
keep_until timestamp (0) with time zone	Timestamp indicating the end of life for this baseline sample

### F.34.2.1.11. bl\_samples

Baseline Sample list.

**Table F.26. bl\_samples Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
bl_id integer	Baseline id

**F.34.2.1.12. stmt\_list**

Statement list.

**Table F.27. stmt\_list Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
queryid_md5 char(32)	Md5 of the query id
query text	Query is a sql statement in text format

**F.34.2.1.13. sample\_stat\_database**

Sample statistic for database.

**Table F.28. sample\_stat\_database Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
datid oid	Database id
datname name	Database name
xact_commit bigint	Transaction commit count
xact_rollback bigint	Transaction rollback count
blks_read bigint	Blocks read count
blks_hit bigint	Blocks hit count
tup_returned bigint	Tuple returned count
tup_fetched bigint	Tuple fetched count
tup_inserted bigint	Tuple inserted count
tup_updated bigint	Tuple updated count
tup_deleted bigint	Tuple deleted count
conflicts bigint	Conflicts in total, including tablespace, lock, snapshot, bufferpin, startup_deadlock
temp_files bigint	

Column Type	Description
	Temporary files
temp_bytes bigint	Temporary files size in bytes
deadlocks bigint	Deadlocks
blk_read_time double precision	Block read time
blk_write_time double precision	Block write time
stats_reset timestamp with time zone	Timestamp of reset for the statistics.
datsize bigint	Database size
datsize_delta bigint	Database delta size
datistemplate boolean	True for a template database

#### F.34.2.1.14. sample\_statements

Sample statistic for statements.

**Table F.29. sample\_statements Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
userid oid	OID of user who executed the statement
datid oid	OID of database in which the statement was executed
queryid bigint	Internal hash code, computed from the statement's parse tree
queryid_md5 char(32)	Md5 of query, query is the sql statement in text format
plans bigint	Number of times the statement was planned (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
total_plan_time double precision	Total time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
min_plan_time double precision	Minimum time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
max_plan_time double precision	

<b>Column Type</b>	<b>Description</b>
	Maximum time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>mean_plan_time</code> double precision	Mean time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>stddev_plan_time</code> double precision	Population standard deviation of time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>calls</code> bigint	Number of times the statement was executed
<code>total_exec_time</code> double precision	Total time spent executing the statement, in milliseconds
<code>min_exec_time</code> double precision	Minimum time spent executing the statement, in milliseconds
<code>max_exec_time</code> double precision	Maximum time spent executing the statement, in milliseconds
<code>mean_exec_time</code> double precision	Mean time spent executing the statement, in milliseconds
<code>stddev_exec_time</code> double precision	Population standard deviation of time spent executing the statement, in milliseconds
<code>rows</code> bigint	Total number of rows retrieved or affected by the statement
<code>shared_blks_hit</code> bigint	Total number of shared block cache hits by the statement
<code>shared_blks_read</code> bigint	Total number of shared blocks read by the statement
<code>shared_blks_dirtied</code> bigint	Total number of shared blocks dirtied by the statement
<code>shared_blks_written</code> bigint	Total number of shared blocks written by the statement
<code>local_blks_hit</code> bigint	Total number of local block cache hits by the statement
<code>local_blks_read</code> bigint	Total number of local blocks read by the statement
<code>local_blks_dirtied</code> bigint	Total number of local blocks dirtied by the statement
<code>local_blks_written</code> bigint	Total number of local blocks written by the statement
<code>temp_blks_read</code> bigint	Total number of temp blocks read by the statement
<code>temp_blks_written</code> bigint	Total number of temp blocks written by the statement
<code>blk_read_time</code> double precision	Total time the statement spent reading blocks, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)
<code>blk_write_time</code> double precision	

<b>Column Type</b>	<b>Description</b>
	Total time the statement spent writing blocks, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)
<code>wal_records</code> bigint	Total number of WAL records generated by the statement
<code>wal_fpi</code> bigint	Total number of WAL full page images generated by the statement
<code>wal_bytes</code> numeric	Total amount of WAL generated by the statement in bytes

### F.34.2.1.15. `sample_statements_total`

Sample statistic for statements in total, group by database.

**Table F.30. `sample_statements_total` Columns**

<b>Column Type</b>	<b>Description</b>
<code>server_id</code> integer	Server id
<code>datid</code> oid	OID of database in which the statement was executed
<code>plans</code> bigint	Number of times the statement was planned (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>total_plan_time</code> double precision	Total time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>calls</code> bigint	Number of times the statement was executed
<code>total_exec_time</code> double precision	Total time spent executing the statement, in milliseconds
<code>rows</code> bigint	Total number of rows retrieved or affected by the database
<code>shared_blks_hit</code> bigint	Total number of shared block cache hits by the database
<code>shared_blks_read</code> bigint	Total number of shared blocks read by the database
<code>shared_blks_dirtied</code> bigint	Total number of shared blocks dirtied by the database
<code>shared_blks_written</code> bigint	Total number of shared blocks written by the database
<code>local_blks_hit</code> bigint	Total number of local block cache hits by the database
<code>local_blks_read</code> bigint	Total number of local blocks read by the database
<code>local_blks_dirtied</code> bigint	Total number of local blocks dirtied by the database
<code>local_blks_written</code> bigint	Total number of local blocks written by the database

<b>Column Type</b>	<b>Description</b>
temp_blks_read bigint	Total number of temp blocks read by the database
temp_blks_written bigint	Total number of temp blocks written by the statement by the database
blk_read_time double precision	Total time the statement spent reading blocks, in milliseconds (if track_io_timing is enabled, otherwise zero) by the database
blk_write_time double precision	Total time the statement spent writing blocks, in milliseconds (if track_io_timing is enabled, otherwise zero) by the database
wal_records bigint	Total number of WAL records generated by the database
wal_fpi bigint	Total number of WAL full page images generated by the database
wal_bytes numeric	Total amount of WAL generated by all statements in bytes by the database
statements bigint	Total statements count by the database

#### F.34.2.1.16. sample\_wait\_event\_total

Sample statistic for wait events in total.

**Table F.31. sample\_wait\_event\_total Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
pid integer	Backend process id related to this wait event
queryid bigint	Queryid related to the wait event
wait_event_type text	Wait event type in text
wait_event text	Wait event in text
wait_time double precision	Total wait time of this kind of event since the last sample
state text	Backend state in text

#### F.34.2.1.17. tablespaces\_list

Tablespaces, captured in samples.



**Table F.32. tablespaces\_list Columns**

Column Type	Description
server_id integer	Server id
tablespaceid oid	OID of the tablespace
tablespacename name	Name of the tablespace
tablespacepath oid	Path of the tablespace

**F.34.2.1.18. sample\_stat\_tablespaces**

Sample statistic for tablespace. The data is from the call of function `pg_tablespace_size(oid)`.

**Table F.33. sample\_stat\_tablespaces Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
tablespaceid oid	OID of tablespace
size integer	Total disk space used in the tablespace, in bytes
size_delta integer	Delta disk space compared with the size that captured by last sample, in bytes

**F.34.2.1.19. tables\_list**

Table list related to the server and database.

**Table F.34. tables\_list Columns**

Column Type	Description
server_id integer	Server id
datid oid	OID of the database
relid oid	Relid of the table (reference <code>pg_class.oid</code> )
relkind char(1)	Relkind of the table
reltoastrelid oid	OID of the TOAST table associated with this table (reference <code>pg_class.reltoastrelid</code> )
schemaname name	Schemaname of the table
relname name	

Column Type	Description
	Name of the table (reference pg_class.relname)

### F.34.2.1.20. sample\_stat\_tables

Sample statistic for tables.

**Table F.35. sample\_stat\_tables Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of the database
relid oid	Relid of the table (reference pg_class.oid)
tablespaceid oid	OID of tablespace (reference sample_stat_tablespace.tablespaceid)
seq_scan bigint	Delta of sequence scan since last sample
seq_tup_read bigint	Delta of sequence tuple read since last sample
idx_scan bigint	Delta of index scan since last scan
idx_tup_fetch bigint	Delta of index tuple fetch since last sample
n_tup_ins bigint	Delta of inserted tuple count since last sample
n_tup_upd bigint	Delta of updated tuple count since last sample
n_tup_del bigint	Delta of deleted tuple count since last sample
n_tup_hot_upd bigint	Delta of hot updated tuple count since last sample
n_live_tup bigint	Number of live tuple
n_dead_tup bigint	Number of dead tuple
n_mod_since_analyze bigint	Number of modified since analyze
n_ins_since_vacuum bigint	Number of inserted since vacuum
sample_id timestamp with time zone	Timestamp of last vacuum
last_autovacuum timestamp with time zone	Timestamp of last autovacuum

<b>Column Type</b>	<b>Description</b>
last_analyze timestamp with time zone	Timestamp of last analyze
last_autoanalyze timestamp with time zone	Timestamp of last autoanalyze
vacuum_count bigint	Delta vacuum count since last sample
autovacuum_count bigint	Delta autovacuum count since last sample
analyze_count bigint	Delta analyze count since last sample
autoanalyze_count bigint	Delta auto analyze count since last sample
heap_blks_read bigint	Delta heap block read since last sample
heap_blks_hit bigint	Delta heap block hit since last sample
idx_blks_read bigint	Delta index blocks read since last sample
toast_blks_read integer	Delta toast blocks read since last sample
toast_blks_hit integer	Delta toast blocks hit since last sample
tidx_blks_read integer	Delta toast index blocks read since last sample
tidx_blks_hit integer	Delta toast index blocks hit since last sample
relsize integer	Toast table size
relsize_diff integer	Delta toast table size since last sample

### F.34.2.1.21. sample\_stat\_tables\_total

Sample statistic for tables, group by server,sample\_id,datid,relkind,tablespaceid.

**Table F.36. sample\_stat\_tables\_total Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of the database
sample_id oid	OID of tablespace
relkind char(1)	

<b>Column Type</b>	<b>Description</b>
	Relkind of the table
seq_scan bigint	Total seq_scan since last sample
seq_tup_read bigint	Total seq_tup_read since last sample
idx_scan bigint	Total index scan since last sample
idx_tup_fetch bigint	Total index tuple fetched since last sample
n_tup_ins bigint	Total number of tuple inserted since last sample
n_tup_upd bigint	Total number of tuple updated since last sample
n_tup_del bigint	Total number of tuple deleted
n_tup_hot_upd bigint	Total number of hot tuple updated since last sample
sample_id bigint	Sample id
vacuum_count bigint	Total vacuum count since last sample
autovacuum_count bigint	Total auto vacuum count since last sample
analyze_count bigint	Total analyze count since last sample
autoanalyze_count bigint	Total auto analyze count since last sample
heap_blks_read bigint	Total heap blocks read since last sample
heap_blks_hit bigint	Total heap blocks hit since last sample
idx_blks_read bigint	Total index blocks read since last sample
idx_blks_hit bigint	Total index blocks hit since last sample
toast_blks_read bigint	Total toast blocks read since last sample
toast_blks_hit bigint	Total toast blocks hit since last sample
tidx_blks_read bigint	Total toast index blocks read since last sample
tidx_blks_hit bigint	Total toast index blocks hit since last sample
relsize_diff bigint	Delta disk space for the table since last sample

**F.34.2.1.22. indexes\_list**

Sample index list, including index names and schemas, captured in samples.

**Table F.37. indexes\_list Columns**

Column	Type	Description
server_id	integer	Server id
datid	oid	OID of database
indexrelid	oid	The OID of the pg_class entry for this index
relid	oid	The OID of the pg_class entry for the table this index is for
schemaname	name	Schema of the table
indexrelname	name	Name of the table

**F.34.2.1.23. sample\_stat\_indexes**

Sample statistic for indexes.

**Table F.38. samples Columns**

Column	Type	Description
server_id	integer	Server id
datid	oid	OID of database
tablespaceid	oid	OID of tablespace
idx_scan	bigint	Delta Index scan since last sample
idx_tup_read	bigint	Delta index tuple read since last sample
idx_tup_fetch	bigint	Delta index tuple fetch since last sample
idx_blks_read	bigint	Delta index blocks read since last sample
idx_blks_hit	bigint	Delta Index blocks hit since last sample
relsize	bigint	Current disk space for the index
relsize_diff	bigint	Delta disk space of the index since last sample
indisunique	bigint	If true, this is a unique index

**F.34.2.1.24. sample\_stat\_indexes\_total**

Sample statistic index, group by server\_id,sample\_id,datid,tablespaceid.

**Table F.39. sample\_stat\_indexes\_total Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of the database
tablespaceid oid	OID of tablespace
idx_scan bigint	Total index scan since last sample
idx_tup_read bigint	Total index tuple read since last sample
idx_tup_fetch bigint	Total index tuple fetch since last sample
idx_blks_read bigint	Total index blocks read since last sample
idx_blks_hit bigint	Total index blocks hit since last sample
relsize_diff bigint	Total delta disk space for the index since last sample

**F.34.2.1.25. funcs\_list**

Sample function list.

**Table F.40. funcs\_list Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
datid integer	OID of database
funcid oid	OID of the function (reference pg_proc.oid)
schemaname name	Schemaname of the function (reference pg_namespace.schemaname)
funcname name	Function name (reference pg_proc.proname)
funcargs text	Function arguments

**F.34.2.1.26. sample\_stat\_user\_functions**

Sample statistic for user functions.

**Table F.41. sample\_stat\_user\_functions Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of the database
funcid oid	OID of the function (reference pg_proc.oid)
calls bigint	Delta number of calls since last sample
total_time double precision	Delta total time since last sample
self_time double precision	Delta self time since last sample
trg_fn boolean	True if the data type of the function is trigger type

**F.34.2.1.27. sample\_stat\_user\_func\_total**

Sample statistic for user functions, group by server\_id,sample\_id,datid,trg\_fn.

**Table F.42. samples Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of database
calls bigint	Total number of calls since last sample
total_time double precision	Total function time since last sample
trg_fn boolean	True if the data type of the function is trigger type

**F.34.2.1.28. sample\_stat\_cluster**

Sample statistic for cluster.

**Table F.43. sample\_stat\_cluster Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	

<b>Column Type</b>	<b>Description</b>
Sample id	Sample id
checkpoints_timed bigint	Delta checkpoints timed since last sample
checkpoints_req bigint	Delta requested checkpoints since last sample
checkpoint_write_time double precision	Delta accumulated checkpoint write time since last sample, in milliseconds
checkpoint_sync_time double precision	Delta accumulated checkpoint sync time since last sample, in milliseconds
buffers_checkpoint bigint	Delta buffer written checkpoints since last sample
buffers_clean bigint	Delta number of dirty buffer written since last sample
maxwritten_clean bigint	Delta number of max written since last sample (count 1 once number of written >= bgwriter_lru_maxpages)
buffers_backend bigint	Delta number of buffer written requested by backend since last sample
buffers_backend_fsync bigint	Delta number of fsync done by backend since last sample
buffers_alloc bigint	Delta number of buffer allocated since last sample
stats_reset timestamp with time zone	Last timestamp that reset pg stat
wal_size bigint	Delta wal size since last sample (wal_size calculated by pg_wal_lsn_diff)

#### F.34.2.1.29. sample\_stat\_archiver

Sample statistic for archive actions including success and failure count and timestamp.

**Table F.44. sample\_stat\_archiver Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
archived_count integer	Last archive succeed count
last_archived_wal integer	Last archive wal file
last_archived_time integer	Last archive timestamp
failed_count integer	Last archive failed count
last_failed_wal integer	Last archive failed wal file



Column Type	Description
last_failed_time integer	Last archive failed timestamp
stats_reset integer	Timestamp of last reset for archive stat

### F.34.2.1.30. sample\_stat\_tables\_failures

Sample statistic for tables failures in calculating disk space.

**Table F.45. sample\_stat\_tables\_failures Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of database
relid oid	OID of the table (reference pg_class.oid)
size_failed boolean	True indicates a failure in calculating the disk space for the table
toastsize_failed boolean	True indicates a failure in calculating the disk space for the toast table

### F.34.2.1.31. sample\_stat\_indexes\_failures

Sample statistic for indexes failures.

**Table F.46. sample\_stat\_indexes\_failures Columns**

Column Type	Description
server_id integer	Server id
sample_id integer	Sample id
datid oid	OID of the database
indexrelid oid	OID of index (reference pg_index.indexrelid)
size_failed boolean	True indicates a failure in calculating the disk space for the index

### F.34.2.1.32. lt\_stat\_backend\_type\_id\_text

This table is utilized to pair the id and display text of each backend type. The backend type could be autovacuum launcher, autovacuum worker, client backend, background worker, background writer etc. Once a new backend type was added in postgresql, We have to add it in this table also. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.47. lt\_stat\_backend\_type\_id\_text Columns**

Column Type	Description
backend_type integer	Id of the backend type
backend_type_text text	Display text for the backend type

**F.34.2.1.33. lt\_stat\_cost\_type\_id\_text**

This table is utilized to pair the id and display text of each cost type. The cost type could be DB Time, DB Wait, DB CPU. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.48. lt\_stat\_cost\_type\_id\_text Columns**

Column Type	Description
cost_type integer	Id of the cost type
cost_type_text text	Display text for the cost type

**F.34.2.1.34. lt\_stat\_wait\_evt\_id\_text**

This table is utilized to pair the id and display text of each wait event type. Available since LightDB 23.2 with lt\_profile 0.3.7 .

**Table F.49. lt\_stat\_wait\_evt\_id\_text Columns**

Column Type	Description
evt_id integer	Id of the wait event type
evt_id_text text	Display text for the wait event type

**F.34.2.1.35. lt\_stat\_wait\_evt\_sub\_id\_text**

This table is utilized to pair the id and display text of each wait event type. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.50. lt\_stat\_wait\_evt\_sub\_id\_text Columns**

Column Type	Description
evt_id integer	Id of the wait event (reference lt_stat_wait_evt_id_text.evt_id)
evt_sub_id integer	Id of wait event type
evt_sub_id_text text	Display text for the wait event

**F.34.2.1.36. lt\_stat\_cost\_1s**

Sample statistic of accumulated cost time for DB Time, DB Wait. New sample would be inserted into this table by interval of 1 second. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.51. lt\_stat\_cost\_1s Columns**

<b>Column Type</b>	<b>Description</b>
bg_type INT	Id of backend type of this sample
cost_type INT	Id of cost type of this sample
evt_id INT	Id of wait event type of this sample
evt_sub_id INT	Id of wait event of this sample
cost BIGINT	Total spent time captured on this sample for the event, in microsecond

**F.34.2.1.37. lt\_stat\_cost\_60s**

Sample statistic for DB Wait related cost time. Accumulated in 1 minute by default, the archive action would be triggered in function call "collect\_activity\_profile" which would be scheduled every single minute by a default setting. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.52. lt\_stat\_cost\_60s Columns**

<b>Column Type</b>	<b>Description</b>
bg_type INT	Id of backend type of this sample
cost_type INT	Id of cost type of this sample
evt_id INT	Id of wait event type of this sample
evt_sub_id INT	Id of wait event of this sample
cost BIGINT	Total accumulated cost time captured on this archive cycle for the event, in microsecond

**F.34.2.1.38. lt\_stat\_cost\_600s**

Sample statistic for DB Wait related cost . Accumulated in 10 minutes by default, the archive action would be triggered in function call "take\_sample" which would be scheduled every 10 minutes by a default setting . The rows in this table would be CASCADE deleted by deleting rows from samples table. Available since LightDB 23.2 with lt\_profile 0.3.7.

**Table F.53. lt\_stat\_cost\_600s Columns**

<b>Column Type</b>	<b>Description</b>
server_id integer	Server id
sample_id integer	Sample id
bg_type INT	Id of backend type of this sample

Column Type	Description
cost_type INT	Id of cost type of this sample
evt_id INT	Id of wait event type of this sample
evt_sub_id INT	Id of wait event of this sample
cost BIGINT	Total accumulated cost time captured on this sample for the event, in microsecond

### F.34.3. Prerequisites

Although *lt\_profile* is usually installed in the target cluster, it also can collect performance data from other clusters. Hence, we have prerequisites for *lt\_profile* database, and for *servers*.

#### F.34.3.1. *lt\_profile* database prerequisites

*lt\_profile* extension depends on extensions *plpgsql*, *dblink* and *ltfce*.

#### F.34.3.2. Servers prerequisites

Consider setting following Statistics Collector parameters:

```
track_activities = on
track_counts = on
track_io_timing = on
track_functions = all/pl
```

To obtain statement statistics in reports, then database, mentioned in server connection string must have *lt\_stat\_statements* extension configured. Set *lt\_stat\_statements* parameters to meet your needs (see LightDB documentation):

- *lt\_stat\_statements.max* - low setting for this parameter may cause some statements statistics to be wiped out before sample is taken. Report will warn you if your *lt\_stat\_statements.max* is seems to be undersized.
- *lt\_stat\_statements.track* = 'top' - all value will affect accuracy of %Total fields for statements-related sections of a report.

### F.34.4. Creating Extensions

The most easy way is to install everything in public schema of a database:

```
lightdb@postgres=# CREATE EXTENSION dblink;
lightdb@postgres=# CREATE EXTENSION lt_stat_statements;
lightdb@postgres=# CREATE EXTENSION lt_stat_activity;
lightdb@postgres=# CREATE EXTENSION system_stats;
lightdb@postgres=# CREATE SCHEMA IF NOT EXISTS lt_catalog;
lightdb@postgres=# CREATE EXTENSION ltfce SCHEMA lt_catalog;
lightdb@postgres=# CREATE EXTENSION lt_profile;
```

If you want to install *lt\_profile* in other schema, just create it, and install extension in that schema:

```
lightdb@postgres=# CREATE EXTENSION dblink;
```

```
lightdb@postgres=# CREATE EXTENSION lt_stat_statements;
lightdb@postgres=# CREATE EXTENSION lt_stat_activity;
lightdb@postgres=# CREATE EXTENSION system_stats;
lightdb@postgres=# CREATE SCHEMA IF NOT EXISTS lt_catalog;
lightdb@postgres=# CREATE EXTENSION ltfce SCHEMA lt_catalog;
lightdb@postgres=# CREATE SCHEMA profile;
lightdb@postgres=# CREATE EXTENSION lt_profile SCHEMA profile;
```

All objects will be created in schema, defined by `SCHEMA` clause. Installation in dedicated schema is the recommended way - the extension will create its own tables, views, sequences and functions. It is a good idea to keep them separate. If you don't want to specify schema qualifier when using module, consider changing `search_path` setting.

## F.34.5. Privileges

Using `lt_profile` with a superuser privileges does not have any issues, but if you want to avoid using superuser permissions, here is the guide:

### F.34.5.1. On `lt_profile` database

Create an unprivileged user:

```
create role profile_usr login password 'pwd';
```

Create a schema for `lt_profile` installation:

```
create schema profile authorization profile_usr;
```

Grant usage permission on schema, where `dblink` extension resides:

```
grant usage on schema public to profile_usr;
```

Create the extension using `profile_usr` account:

```
lightdb@postgres=> create extension lt_profile schema profile;
```

### F.34.5.2. On server database

Create a user for `lt_profile` to connect:

```
create role profile_mon login password 'pwd_mon';
```

Make sure this user have permissions to connect to any database in a cluster (by default, it is), and `lt_hba.conf` will permit such connection from `lt_profile` database host. Also, we need `pg_read_all_stats` privilege, and execute privilege on `pg_stat_statements_reset`:

```
grant pg_read_all_stats to profile_mon;
grant execute on function pg_stat_statements_reset TO profile_mon;
```

### F.34.5.3. Server setup at `lt_profile` database

Non-superusers can't establish connection without a password. Best way to provide password is using a password file.

N.B. `lt_profile` will connect to all databases on a server, thus password file must use a wildcard as a database name.

As an insecure way, you can provide a password in connection string:

```
select server_connstr('local', 'dbname=postgres port=5432
user=profile_mon password=pwd_mon');
```

## F.34.6. Using `lt_profile`

### F.34.6.1. Setting extension parameters

You can define extension parameters in `lightdb.conf`. Default values:

- `lt_profile.topn = 10` - Number of top objects (statements, relations, etc.), to be reported in each sorted report table. Also, this parameter affects size of a sample - the more objects you want to appear in your report, the more objects we need to keep in a sample.
- `lt_profile.max_sample_age = 7` - Retention time of samples in days. Samples, aged `lt_profile.max_sample_age` days and more will be automatically deleted on next `take_sample()` call.
- `lt_profile.track_sample_timings = on` - when this parameter is on, `lt_profile` will track detailed sample taking timings.

### F.34.6.2. Managing servers

Once installed, extension will create one enabled *local* server - this is for cluster, where extension is installed.

Servers management functions:

- **`create_server(server name, server_connstr text, server_enabled boolean = TRUE, max_sample_age integer = NULL, description text = NULL)`** - creates a new server description  
Function arguments:
  - `server` - server name (must be unique)
  - `server_connstr` - server connection string
  - `enabled` - server enable flag. When is set, server will be included in the common `take_sample()` call
  - `max_sample_age` - server sample retention parameter overrides global `lt_profile.max_sample_age` setting for this server
  - `description` - server description text. Will be included in reports
- **`drop_server(server name)`** Drops a server and all its samples.
- **`enable_server(server name)`** Includes server in common `take_sample()` call.
- **`disable_server(server name)`** Excludes server from common `take_sample()` call.
- **`rename_server(server name, new_name name)`** Renames a server.
- **`set_server_max_sample_age(server name, max_sample_age integer)`** Set new retention period (in days) for a server. `max_sample_age` is integer value. To reset a server `max_sample_age` setting set it to `NULL`.
- **`set_server_db_exclude(server name, exclude_db name[])`** Set exclude databases list for a server. Used in cases, when you unable to connect to some databases in cluster (for example in Amazon RDS instances).
- **`set_server_connstr(server name, new_connstr text)`** Set new connection string for a server.
- **`set_server_description(server name, description text)`** Set new server description.
- **`show_servers()`** Display existing servers.

Server creation example:

```
SELECT server_new('omega','host=name_or_ip dbname=postgres
port=5432');
```

### F.34.6.3. Rare relation sizes collection

LightDB relation size functions may take considerable amount of time to collect sizes of all relations in a database. Also those functions require *AccessExclusiveLock* on a relation. However daily relation sizes collection may be quite enough for you. *lt\_profile* can skip relation sizes collection while taking samples guided by server size collection policy. Policy is defined as a daily window when relation size collection is permitted, and a minimal gap between two samples with relation sizes collected. Thus when size collection policy is defined sample taking function will collect relation sizes only when sample is taken in a window and previous sample with sizes is older then gap. Function *set\_server\_size\_sampling* defines this policy:

- *set\_server\_size\_sampling(server name, window\_start time with time zone = NULL, window\_duration interval hour to second = NULL, sample\_interval interval day to minute = NULL)*
  - *server* - server name
  - *window\_start* - size collection window start time
  - *window\_duration* - size collection window duration
  - *sample\_interval* - minimum time gap between two samples with relation sizes collected Size collection policy is defined only when all three parameters are set.

Example:

```
SELECT set_server_size_sampling('local','23:00+03',interval '2
hour',interval '8 hour');
```

Function *show\_servers\_size\_sampling* show defined sizes collection policy for all servers:

```
lightdb@postgres=# SELECT * FROM show_servers_size_sampling();
server_name | window_start | window_end | window_duration |
sample_interval
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
local      | 23:00:00+03 | 01:00:00+03 | 02:00:00      |
08:00:00
```

When you build a report between samples either of which lacks relation sizes data then relation growth sections will be excluded from report. However, *with\_growth* parameter of report generation functions will expand report bounds to nearest samples with relation sizes data collected. Relation sizes is needed for calculating sequentially scanned volume for tables and explicit vacuum load for indexes. When rare relation sizes collection is used, corresponding report sections data is based on linear interpolation.

### F.34.6.4. Samples

Every sample contains statistic information about database workload since previous sample.

#### F.34.6.4.1. Sample functions

- **take\_sample()** Function *take\_sample()* will collect a sample for all *enabled* servers. Server samples will be taken serially one by one. Function returns a table:

```
server      name,
result      text,
elapsed     interval
```

Where:

- *server* is a server name
- *result* is a result of taken sample. It can be 'OK' if sample was taken successively, and will contain error text in case of exception
- *elapsed* is a time elapsed taking a sample for *server* Such return makes it easy to control samples creation using SQL query.
- **take\_sample\_subset([sets\_cnt integer], [current\_set integer])** Due to serial samples processing *take\_sample()* function can take considerable amount of time. Function *take\_sample\_subset()* will take samples for a subset of enabled servers. It is convenient for parallel samples collection. *sets\_cnt* is number of servers subsets. *current\_set* is a subset to process, taking values between 0 and *sets\_cnt - 1* inclusive. Function returns a table:

```
server      name ,
result     text ,
elapsed    interval
```

Where:

- *server* is a server name
- *result* is a result of taken sample. It can be 'OK' if sample was taken successively, and will contain error text in case of exception
- *elapsed* is a time elapsed taking a sample for *server*
- **take\_sample(server name [, skip\_sizes boolean])** Will collect a sample for specified server. Use it, for example, when you want to use different sampling frequencies, or if you want to take explicit sample on a server.
  - *server* - name of a server to take sample
  - *skip\_sizes* - override server relation size collection policy. Policy applies only when *skip\_size* argument is omitted or set to null. *false* value of *skip\_sizes* argument cause take sample with relation sizes, while *true* will cause skipping relation sizes collection during a sample.
- **show\_samples([server name,] [days integer])** Returns a table, containing existing samples of a *server* (*local* server assumed if *server* is omitted) for *days* last days (all existing samples if omitted):

```
sample      integer ,
sample_time timestamp (0) with time zone ,
dbstats_reset timestamp (0) with time zone ,
clustats_reset timestamp (0) with time zone ,
archstats_reset timestamp (0) with time zone
```

Where:

- *sample* is a sample identifier
- *sample\_time* is a time when this sample was taken
- *dbstats\_reset*, *clustats\_reset* and *archstats\_reset* is usual null, but will contain *pg\_stat\_database*, *pg\_stat\_bgwriter* and *pg\_stat\_archiver* statistics reset timestamp if it was happend since previous sample Sample-collecting functions are also supports the server repository - it will delete obsolete samples and baselines with respect to *retention policy*.

#### F.34.6.4.2. Taking samples

You must create at least 2 samples to be able to build your first report between 1st and 2nd samples. Samples for all enabled servers are taken by calling *take\_sample()* function. There is no need in



frequent samples creation - usual essential frequency is one or two samples per hour. You can use cron-like tool to schedule samples creation. Example with 30 min period:

```
* /30 * * * * ltsql -c 'SELECT take_sample()' > /dev/null 2>&1
```

However, such call has no error checking on *take\_sample()* function results. Consider using more smart usage of *take\_sample()* function, providing results to your monitoring system.

Function will return 'OK' for all servers with successfully taken samples, and show error text for failed servers:

```
select * from take_sample();
  server |                                     result
-----+-----
ok_node | OK
        |                                     | 00:00:00.48
fail_node | could not establish connection
        |                                     +| 00:00:00
        | SQL statement "SELECT
dblink_connect('server_connection',server_connstr)" +|
PERFORM      | PL/pgSQL function take_sample(integer) line 69 at
        |                                     +|
line 27 at assignment+|
        | PL/pgSQL function take_sample_subset(integer,integer)
        | SQL function "take_sample" statement 1
        |                                     +|
        | FATAL: database "nodb" does not exist
        |
(2 rows)
```

### F.34.6.4.3. Sample data retention

We can't store sample data forever, thus we have a retention policy. You can define retentions on three levels:

- Setting parameter *lt\_profile.max\_sample\_age* in *lightdb.conf* file. This is a common retention, it is effective if none of others is defined.
- Define server *max\_sample\_age* setting while creating a server, or using *set\_server\_max\_sample\_age()* function for existing server. This setting overrides global *lt\_profile.max\_sample\_age* setting for a specific server.
- Create a baseline (see below). Baseline will override retention period for included samples with highest priority.

### F.34.6.4.4. Listing samples

Use *show\_samples()* function to get list of existing samples in the repository. This function will show detected statistics reset times.

### F.34.6.4.5. Sample taking timings

*lt\_profile* will collect detailed sample taking timing statistics when parameter *lt\_profile.track\_sample\_timings* is on. Results can be obtained from *v\_sample\_timings* view. *v\_sample\_timings* fields description:

- *server\_name* - sampled server name

- *sample\_id* - sample identifier
- *sample\_time* - when the sample was taken
- *event* - sample taking stage
- *time\_spent* - amount of time spent in the event

Event descriptions:

- **total** - Taking the sample (all stages).
- **connect** - Making dblink connection to the server.
- **get server environment** - Getting server GUC parameters, available extensions, etc.
- **collect database stats** - Querying the `pg_stat_database` view for statistics on databases.
- **calculate database stats** - Calculating differential statistics on databases since the previous sample.
- **collect tablespace stats** - Querying the `pg_tablespace` view for statistics on tablespaces.
- **collect statement stats** - Collecting statistics on statements using the `lt_stat_statements` extension.
- **query pg\_stat\_bgwriter** - Collecting cluster statistics using the `pg_stat_bgwriter` view.
- **query pg\_stat\_archiver** - Collecting cluster statistics using the `pg_stat_archiver` view.
- **collect object stats** - Collecting statistics on database objects. Includes following events:
  - **db:dbname collect tables stats** - Collecting statistics on tables for the *dbname* database.
  - **db:dbname collect indexes stats** - Collecting statistics on indexes for the *dbname* database.
  - **db:dbname collect functions stats** - Collecting statistics on functions for the *dbname* database.
- **maintain repository** - Executing support routines.
- **calculate tablespace stats** - Calculating differential statistics on tablespaces.
- **calculate object stats** - Calculating differential statistics on database objects. Includes following events:
  - **calculate tables stats** - Calculating differential statistics on tables of all databases.
  - **calculate indexes stats** - Calculating differential statistics on indexes of all databases.
  - **calculate functions stats** - Calculating differential statistics on functions of all databases.
- **calculate cluster stats** - Calculating cluster differential statistics.
- **calculate archiver stats** - Calculating archiver differential statistics.
- **delete obsolete samples** - Deleting obsolete baselines and samples.

### F.34.6.5. Baselines

Baseline is a named sample sequence, having its own retention setting. Baseline can be used in report-building functions as a sample interval. Undefined baseline retention means infinite retention. You can use baselines to save information about database workload on certain time period. For example, you may want to save samples, gathered during load testing, or during regular load on your system for further reference. Baseline management functions:

- **create\_baseline([server name,] baseline\_name varchar(25), start\_id integer, end\_id integer [, days integer])** - create a baseline
  - *server* - server name. *local* server is assumed if omitted
  - *name* - baseline name. Each baseline must have unique name within a server.
  - *start\_id, end\_id* - first and last samples, included in baseline.
  - *days* - baseline retention time. Defined in integer days since *now()*. This parameter may be omitted (or set to *null*), meaning infinite retention.
- **create\_baseline([server name,] baseline\_name varchar(25), time\_range tstzrange [, days integer])** - create a baseline
  - *server* - server name. *local* server is assumed if omitted
  - *name* - baseline name. Each baseline must have unique name within a server.
  - *time\_range* - baseline time interval. Baseline will include all available samples, overlapping this interval.
  - *days* - baseline retention time. Defined in integer days since *now()*. This parameter may be omitted (or be set to *null*), meaning infinite retention.
- **drop\_baseline([server name,] name varchar(25))** - drop a baseline
  - *server* - server name. *local* server is assumed if omitted
  - *name* - baseline name to drop. Dropping a baseline does not mean immediate drop of all its samples, they are just excluded from baseline, thus is not more covered with baseline retention.
- **keep\_baseline([server name,] name varchar(25) [, days integer])** - change retention of baselines
  - *server* - server name. *local* server is assumed if omitted
  - *name* - baseline name. This parameter may be omitted (or be set to *null*) to change retention of all existing baselines.
  - *days* - retention time of a baseline in days since *now()*. Also, may be omitted (or set to *null*) to set infinite retention.
- **show\_baselines([server name])** - displays existing baselines. Call this function to get information about existing baselines (names, sample intervals, and retention times)
  - *server* - server name. *local* server is assumed if omitted

```
lightdb@postgres=# SELECT * FROM baseline_show('local');
```

## F.34.6.6. Data export and import

Collected samples can be exported from instance of *lt\_profile* extension and then loaded into another one. This feature is useful when you want to move servers from one instance to another, or when you need to send collected data to your support team.

### F.34.6.6.1. Data export

Data is exported as a regular table by function `export_data()`. You can use any method to export this table from your database. For example, you can use *copy* command of *ltsql* to obtain single *.csv* file:

```
lightdb@postgres=# \copy (select * from export_data()) to
'export.csv'
```

By default `export_data()` function will export all samples of all configured servers. However you can limit export to only one server, and further limit sample range too:

- `export_data([server name, [min_sample_id integer,] [max_sample_id integer]] [, obfuscate_queries boolean])` - export collected data
  - `server` is a server name. All servers is assumed if omitted
  - `min_sample_id` and `max_sample_id` - export bounding sample identifiers (inclusive). Null value of `min_sample_id` bound cause export of all samples till `max_sample_id`, and null value of `max_sample_id` cause export of all samples since `min_sample_id`.
  - `obfuscate_queries` - use this parameter only when you want to hide query texts - they will be exported as MD5 hash.

### F.34.6.6.2. Data import

Data can be imported from local table only, thus previously exported data is need to be loaded first. In our case with `copy` command:

```
lightdb@postgres=# CREATE TABLE import (section_id bigint, row_data
  json);
CREATE TABLE
lightdb@postgres=# \copy import from 'export.csv'
COPY 6437
```

Now we can perform data import, providing this table to `import_data()` function:

```
lightdb@postgres=# SELECT * FROM import_data('import');
```

Although server descriptions is also imported, your local `lt_profile` servers with matching names will prohibit import operations. Consider temporarily rename those servers. If you'll need to import new data for previously imported servers, they will be matched by system identifier, so fell free to rename imported sever as you wish. All servers are imported in `disabled` state. `import_data()` function takes only the imported table:

- `import_data(data regclass)`
  - `data` - table containing exported data This function returns number of rows actually loaded in extension tables. After successful import operation you can drop `import` table.

### F.34.6.7. Reports

Reports are generated in HTML markup by reporting functions, which containing statistical information about instance workload during report interval.

#### F.34.6.7.1. PWR report functions

- `get_pwr([server name,] start_id integer, end_id integer [, description text [, with_growth boolean]])` - generate PWR report by sample identifiers
- `get_pwr([server name,] time_range tstzrange [, description text [, with_growth boolean]])` - generate PWR report for the shortest sample interval, covering provided `time_range`.
- `get_pwr([server name], baseline varchar(25) [, description text [, with_growth boolean]])` - generate PWR report, using baseline as samples interval
- `get_pwr_latest([server name])` - generate PWR report for two latest samples Function arguments:
  - `server` - server name. `local` server is assumed if omitted

- *start\_id* - interval begin sample identifier
- *end\_id* - interval end sample identifier
- *time\_range* - time range (*tstzrange* type)
- *baseline* - a baseline name
- *with\_growth* - a flag, requesting interval expansion to nearest bounds with relation growth data available. Default value is *false*
- *description* - a text memo, it will be included in report as a report description

### F.34.6.7.2. PSH report functions

- **get\_psh([server name,] start\_id integer, end\_id integer [, description text [, with\_growth boolean]])** - generate PSH report by sample identifiers
- **get\_psh([server name,] time\_range tstzrange [, description text [, with\_growth boolean]])** - generate PSH report for the shortest sample interval, covering provided *time\_range*.
- **get\_psh([server name], baseline varchar(25) [, description text [, with\_growth boolean]])** - generate PSH report, using baseline as samples interval
- **get\_psh\_latest([server name])** - generate PSH report for two latest samples Function arguments:
  - *server* - server name. *local* server is assumed if omitted
  - *start\_id* - interval begin sample identifier
  - *end\_id* - interval end sample identifier
  - *time\_range* - time range (*tstzrange* type)
  - *baseline* - a baseline name
  - *with\_growth* - a flag, requesting interval expansion to nearest bounds with relation growth data available. Default value is *false*
  - *description* - a text memo, it will be included in report as a report description

Report generation example:

```
$ ltsql -Aqtc "SELECT get_pwr(480,482)" -o report_480_482.html
```

For any other server, use it's name:

```
$ ltsql -Aqtc "SELECT get_pwr('omega',12,14)" -o
report_omega_12_14.html
```

Report generation using time ranges:

```
ltsql -Aqtc "select get_psh(tstzrange('2020-05-13
11:51:35+03', '2020-05-13 11:52:18+03'))" -o report_range.html
```

Also, time ranges is useful for generating periodic reports. Let's build last 24-hour report:

```
ltsql -Aqtc "select get_psh(tstzrange(now() - interval '1
day',now()))" -o last24h_report.html
```

Now you can view report file using any web browser.

## F.34.7. Sections of PWR report

Report tables and their columns are described in this section.

### F.34.7.1. Server statistics

#### F.34.7.1.1. CPU usage statistics

Contains cpu usage statistics such as user cpu, system cpu, idle cpu and iowait at the begin and end of report.

- *%User* - user cpu percent
- *%System* - system cpu percent
- *%Idle* - idle cpu percent
- *%IO Wait* - io wait cpu percent

#### F.34.7.1.2. Database memory usage statistics

Contains memory usage statistics of LightDB at the begin and end of report.

- *Host memory (MB)* - total physical memory of the host
- *Shared memory use (MB)* - shared memory used in LightDB, which is used by all processes of a LightDB server
- *Local memory use (MB)* - local memory used in LightDB, which is allocated by each backend process for its own use
- *Host memory used for shared memory+local memory (%)* - shared memory and local memory as a percentage of total host memory

#### F.34.7.1.3. Database statistics

Contains per-database statistics during report interval, based on *pg\_stat\_database* view.

- *Database* - database name
- *Transactions* - database transaction statistics
  - *Commits* - number of committed transactions (*xact\_commit*)
  - *Rollbacks* - number of rolled back transactions (*xact\_rollback*)
  - *Deadlocks* - number of deadlocks detected (*deadlocks*)
- *Block statistics* - database blocks read and hit statistics
  - *Hit(%)* - buffer cache hit ratio
  - *Read* - number of disk blocks read in this database (*blks\_read*)
  - *Hit* - number of times disk blocks were found already in the buffer cache (*blks\_hit*)
- *Tuples* - tuples statistics section
  - *Returned* - number of returned tuples (*tup\_returned*)
  - *Fetches* - number of fetched tuples (*tup\_fetched*)

- *Inserted* - inserted tuples count (*tup\_inserted*)
- *Updated* - number of updated tuples (*tup\_updated*)
- *Deleted* - number of deleted tuples (*tup\_deleted*)
- *Temp files* - temporary files statistics
  - *Size* - total amount of data written to temporary files by queries in this database (*temp\_bytes*)
  - *Files* - number of temporary files created by queries in this database (*temp\_files*)
- *Size* - database size at the end of report interval (*pg\_database\_size()*)
- *Growth* - database growth during report interval (*pg\_database\_size()* difference)

#### **F.34.7.1.4. Statement statistics by database**

Contains per-database aggregated total statistics of *pg\_stat\_statements* data (if *lt\_stat\_statements* extension was available during report interval)

- *Database* - database name
- *Calls* - total count of all statements executions (sum of *calls*)
- *Time (s)* - time spent in seconds
  - *Plan* - time spent planning (sum of *total\_plan\_time*) - available since *lt\_stat\_statements* 1.8
  - *Exec* - time spent executing (sum of *total\_time* or *total\_exec\_time*)
  - *Read* - time spent reading blocks (sum of *blk\_read\_time*)
  - *Write* - time spent writing blocks (sum of *blk\_write\_time*)
  - *Trigger* - time spent executing trigger functions
- *Fetches blocks* - total blocks fetched from disk and buffer cache
  - *Shared* - total fetched shared blocks count (sum of *shared\_blks\_read* + *shared\_blks\_hit*)
  - *Local* - total fetched local blocks count (sum of *local\_blks\_read* + *local\_blks\_hit*)
- *Dirtied blocks* - total blocks dirtied in database
  - *Shared* - total number of shared blocks dirtied in the database (sum of *shared\_blks\_dirtied*)
  - *Local* - total number of local blocks dirtied in the database (sum of *local\_blks\_dirtied*)
- *Temp blocks* - blocks used for operations (like joins and sorts)
  - *Read* - blocks read (sum of *temp\_blks\_read*)
  - *Write* - blocks written (sum of *temp\_blks\_written*)
- *Local blocks* - blocks used for temporary tables
  - *Read* - blocks read (sum of *local\_blks\_read*)
  - *Write* - blocks written (sum of *local\_blks\_written*)
- *Statements* - total count of captured statements

- *WAL size* - total amount of WAL generated by statements (sum of *wal\_bytes*)

### F.34.7.1.5. Cluster statistics

This table contains data from *pg\_stat\_bgwriter* view

- *Scheduled checkpoints* - total number of checkpoints, completed on schedule due to *checkpoint\_timeout* parameter (*checkpoints\_timed* field)
- *Requested checkpoints* - total number of other checkpoints: due to values of *max\_wal\_size*, *archive\_timeout* and CHECKPOINT commands (*checkpoints\_req* field)
- *Checkpoint write time (s)* - total time spent writing checkpoints in seconds (*checkpoint\_write\_time* field)
- *Checkpoint sync time (s)* - total time spent syncing checkpoints in seconds (*checkpoint\_sync\_time* field)
- *Checkpoints buffers written* - total number of buffers, written by checkpointer (*buffers\_checkpoint* field)
- *Background buffers written* - total number of buffers, written by background writer process (*buffers\_clean* field)
- *Backend buffers written* - total number of buffers, written by backends (*buffers\_backend* field)
- *Backend fsync count* - total number of backend fsync calls (*buffers\_backend\_fsync* field)
- *Bgwriter interrupts (too many buffers)* - total count of background writer interrupts due to reaching value of the *bgwriter\_lru\_maxpages* parameter.
- *Number of buffers allocated* - total count of buffers allocated (*buffers\_alloc* field)
- *WAL generated* - total amount of WAL generated (based on *pg\_current\_wal\_lsn()*)
- *WAL segments archived* - archived WAL segments count (based on *archived\_count* of *pg\_stat\_archiver* view)
- *WAL segments archive failed* - WAL segment archive failures count (based on *failed\_count* of *pg\_stat\_archiver* view)

### F.34.7.1.6. Tablespace statistics

This table contains information about tablespaces sizes and growth:

- *Tablespace* - tablespace name
- *Path* - tablespace path
- *Size* - tablespace size as it was at time of last sample in report interval
- *Growth* - tablespace growth during report interval

## F.34.7.2. Wait event statistics

This report section contains tables of top wait events statistics during report interval sorted by wait time.

### F.34.7.2.1. Main wait event type categories

- *IO* - Various file read/write activities during the query of sql statements.
- *LW Lock* - LW lock for a variable or LW lock acquire.



### F.34.7.2.2. Main wait event categories

- *WALSync* - Fsync XLOG file.
- *WALWrite* - Write Pages to XLOG file.
- *LockManager* - Used for the predicate locking target and lock shared hash tables to reduce contention.
- *WALInsert* - LW lock, Acquire a WAL insertion lock, for inserting to WAL.
- *DataFileExtend* - Add a block to the specified relation.
- *DataFileRead* - Read the specified block from a relation.
- *DataFileTruncate* - Truncate relation to specified number of blocks.
- *BufFileRead* - Load some data into buffer.
- *ProcArray* - LW lock for memory access across multi-process, such as ProcGlobal, ShmemVariableCache, MyPgXact, procArray.
- *RelationMapRead* - load data from the shared or local map file.
- *SLRUSync* - Physical write of a page from a buffer slot.
- *SLRUWrite* - Physical flush of a page from a buffer slot after writing.
- *RegisterSyncRequest* - RegisterSyncRequest.
- *XidGen* - LW lock, Set and return the next transaction ID.
- *XactSLRU* - LW lock, for xlog, clog related memory data.

### F.34.7.2.3. Top wait event type by wait time

This table contains top *lt\_profile.topn* wait event types sorted by wait time.

- *Wait Event Type* - Type of wait event, each type may contain several wait events.
- *Wait Time(s)* - Total wait time for all wait events of this type.
- *%Total Wait Time* - Total wait time of this type as a percentage of total wait time for all types of events in a cluster.

### F.34.7.2.4. Top wait event by wait time

This table contains top *lt\_profile.topn* wait events sorted by wait time.

- *Wait Event* - The specific event that process waiting for.
- *Wait Event Type* - Type of this event.
- *Wait Time(s)* - Total wait time of all this event.
- *%Total Wait Time* - Total wait time of all this event as a percentage of total wait time for all types of events in a cluster.

### F.34.7.3. SQL Query statistics

This report section contains tables of top statements during report interval sorted by several important statistics. Data is captured from *pg\_stat\_statements* view if it was available at the time of samples.

### F.34.7.3.1. Top SQL by elapsed time

This table contains top *lt\_profile.topn* statements sorted by elapsed time *total\_plan\_time + total\_exec\_time* of *pg\_stat\_statements* view.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *%Total* - total time of this statement as a percentage of total time of all statements in a cluster
- *Time (s)* - time spent in this statement (in seconds)
  - *Elapsed* - total time, spent in this statement (*total\_plan\_time + total\_exec\_time*)
  - *Plan* - time spent in planning this statement (*total\_plan\_time* field)
  - *Exec* - time spent executing this query (*total\_exec\_time* field)
- *I/O time (s)*:
  - *Read* - time spent reading blocks (*blk\_read\_time* field)
  - *Write* - time spent writing blocks (*blk\_write\_time* field)
- *Plans* - number of times the statement was planned (*plans* field)
- *Executions* - number of times the statement was executed (*calls* field)

### F.34.7.3.2. Top SQL by planning time

Top *lt\_profile.topn* statements sorted by *total\_plan\_time* field of *pg\_stat\_statements* view

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Plan elapsed (s)* - time spent in planning this statement (*total\_plan\_time* field)
- *%Elapsed* - plan time of this statement as a percentage of statement elapsed time
- *Plan times (ms)* - detailed plan time statistics of this statement (in milliseconds)
  - *Mean* - mean time spent planning this statement (*mean\_plan\_time* field)
  - *Min* - minimum time spent planning this statement (*min\_plan\_time* field)
  - *Max* - maximum time spent planning this statement (*max\_plan\_time* field)
  - *StdErr* - population standard deviation of time spent planning this statement (*stddev\_plan\_time* field)
- *Plans* - number of times this statement was planned (*plans* field)
- *Executions* - number of times this statement was executed (*calls* field)

### F.34.7.3.3. Top SQL by execution time

Top *lt\_profile.topn* statements sorted by *total\_time* (or *total\_exec\_time*) field of *pg\_stat\_statements* view

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Exec (s)* - time spent executing this statement (*total\_exec\_time* field)
- *%Elapsed* - execution time of this statement as a percentage of statement elapsed time
- *%Total* - exec time of this statement as a percentage of total elapsed time of all statements in a cluster
- *I/O time (s)*:
  - *Read* - time spent reading blocks (*blk\_read\_time* field)
  - *Write* - time spent writing blocks (*blk\_write\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Execution times (ms)* - detailed execution time statistics of this statement (in milliseconds)
  - *Mean* - mean time spent executing this statement (*mean\_exec\_time* field)
  - *Min* - minimum time spent executing this statement (*min\_exec\_time* field)
  - *Max* - maximum time spent executing this statement (*max\_exec\_time* field)
  - *StdErr* - population standard deviation of time spent executing this statement (*stddev\_exec\_time* field)
- *Executions* - number of times this statement was executed (*calls* field)

### F.34.7.3.4. Top SQL by executions

Top *lt\_profile.topn* statements sorted by *calls* field of *pg\_stat\_statements* view

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Executions* - count of statement executions (*calls* field)
- *%Total* - *calls* of this statement as a percentage of total *calls* of all statements in a cluster
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Mean(ms)* - mean time spent in the statement, in milliseconds (*mean\_time* or *mean\_exec\_time* field)
- *Min(ms)* - minimum time spent in the statement, in milliseconds (*min\_time* or *min\_exec\_time* field)
- *Max(ms)* - maximum time spent in the statement, in milliseconds (*max\_time* or *max\_exec\_time* field)
- *StdErr(ms)* - population standard deviation of time spent in the statement, in milliseconds (*stddev\_time* or *stddev\_exec\_time* field)

- *Elapsed(s)* - amount of time spent executing this query, in seconds (*total\_time* or *total\_exec\_time* field)

### F.34.7.3.5. Top SQL by I/O wait time

Top *lt\_profile.topn* statements sorted by read and write time (*blk\_read\_time* + *blk\_write\_time*)

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *IO(s)* - amount of time spent on reading and writing (I/O time) by this statement in seconds (*blk\_read\_time* + *blk\_write\_time*)
- *Read(s)* - amount of time spent on reading by this statement in seconds (*blk\_read\_time*)
- *Write(s)* - amount of time spent on writing by this statement in seconds (*blk\_write\_time*)
- *%Total* - I/O time of this statement as a percentage of total I/O time for all statements in a cluster
- *Reads* - number of blocks read by this statement divided in three sub-columns:
  - *Shared* - shared reads (*shared\_blks\_read* field)
  - *Local* - local reads (*local\_blks\_read* field)
  - *Temp* - temp reads (*temp\_blks\_read* field)
- *Writes* - number of blocks written by this statement divided in three sub-columns:
  - *Shared* - shared writes (*shared\_blks\_written* field)
  - *Local* - local writes (*local\_blks\_written* field)
  - *Temp* - temp writes (*temp\_blks\_written* field)
- *Elapsed(s)* - amount of time spent executing this query, in seconds (*total\_time* or *total\_exec\_time* field)
- *Executions* - number of executions for this statement (*calls* field)

### F.34.7.3.6. Top SQL by shared blocks fetched

Top *lt\_profile.topn* statements sorted by read and hit blocks, helping to detect the most data processing statements.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Fetched* - number of fetched blocks (expression: *shared\_blks\_hit* + *shared\_blks\_read*)
- *%Total* - blocks fetched for this statement as a percentage of total blocks fetched for all statements in a cluster
- *Hits(%)* - percentage of blocks got from buffers within all blocks got

- *Elapsed(s)* - amount of time spent in this statement, in seconds (*total\_time* or *total\_exec\_time* + *total\_plan\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Executions* - number of executions for this statement (*calls* field)

#### F.34.7.3.7. Top SQL by shared blocks read

Top *lt\_profile.topn* statements sorted by shared reads, helping to detect most read intensive statements.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Reads* - number of shared read blocks for this statement (*shared\_blks\_read* field)
- *%Total* - shared reads for this statement as a percentage of total shared reads for all statements in a cluster
- *Hits(%)* - percentage of blocks got from buffers within all blocks got
- *Elapsed(s)* - amount of time spent in this statement, in seconds (*total\_time* or *total\_exec\_time* + *total\_plan\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Executions* - number of executions for this statement (*calls* field)

#### F.34.7.3.8. Top SQL by shared blocks dirtied

Top *lt\_profile.topn* statements sorted by shared dirtied buffer count, helping to detect most data changing statements.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Dirtied* - number of shared blocks dirtied by this statement (*shared\_blks\_dirtied* field)
- *%Total* - shared blocks dirtied by this statement as a percentage of total shared blocks dirtied by all statements in a cluster
- *Hits(%)* - percentage of blocks got from buffers within all blocks got
- *Elapsed(s)* - amount of time spent in this statement, in seconds (*total\_time* or *total\_exec\_time* + *total\_plan\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Executions* - number of executions for this statement (*calls* field)

#### F.34.7.3.9. Top SQL by shared blocks written

Top *lt\_profile.topn* statements, which had to perform writes sorted by written blocks count.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Written* - number of blocks written by this statement (*shared\_blks\_written* field)
- *%Total* - number of blocks written by this statement as a percentage of total blocks written by all statements in a cluster
- *%BackendW* - number of blocks written by this statement as a percentage of all blocks written in a cluster by backends (*buffers\_backend* field of *pg\_stat\_bgwriter* view)
- *Hits(%)* - percentage of blocks got from buffers within all blocks got
- *Elapsed(s)* - amount of time spent in this statement, in seconds (*total\_time* or *total\_exec\_time* + *total\_plan\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Executions* - number of executions for this statement (*calls* field)

#### F.34.7.3.10. Top SQL by WAL size

Top *lt\_profile.topn* statements, sorted by WAL generated (available since *lt\_stat\_statements* v1.8)

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *WAL* - amount of WAL generated by the statement (*wal\_bytes* field)
- *%Total* - amount of WAL generated by the statement as a percentage of total WAL generated in cluster (*pg\_current\_wal\_lsn()* increment)
- *Dirtied* - number of shared blocks dirtied by this statement (*shared\_blks\_dirtied* field)
- *WAL full page images* - total number of WAL full page images generated by the statement (*wal\_fpi* field)
- *WAL records* - total amount of WAL bytes generated by the statement (*wal\_bytes* field)

#### F.34.7.3.11. Top SQL by temp usage

Top *lt\_profile.topn* statements sorted by temp I/O, calculated as the sum of *temp\_blks\_read*, *temp\_blks\_written*, *local\_blks\_read* and *local\_blks\_written* fields

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Database* - Statement database name (derived from *dbid* field)
- *Local fetched* - number of retrieved local blocks (expression: *local\_blks\_hit* + *local\_blks\_read*)
- *Hits(%)* - percentage of local blocks got from temp buffers within all local blocks got

- *Local blocks* - I/O statistics of blocks used in temporary tables
  - *Write* - number of written local blocks (*local\_blks\_written*)
  - *%Total* - *local\_blks\_written* of this statement as a percentage of total *local\_blks\_written* for all statements in a cluster
  - *Read* - number of read local blocks (*local\_blks\_read*)
  - *%Total* - *local\_blks\_read* of this statement as a percentage of total *local\_blks\_read* for all statements in a cluster
- *Temp blocks* - I/O statistics of blocks used in operations (like sorts and joins)
  - *Write* - number of written temp blocks (*temp\_blks\_written*)
  - *%Total* - *temp\_blks\_written* of this statement as a percentage of total *temp\_blks\_written* for all statements in a cluster
  - *Read* - number of read local blocks (*temp\_blks\_read*)
  - *%Total* - *temp\_blks\_read* of this statement as a percentage of total *temp\_blks\_read* for all statements in a cluster
- *Elapsed(s)* - amount of time spent in this statement, in seconds (*total\_time* or *total\_exec\_time* + *total\_plan\_time* field)
- *Rows* - number of rows retrieved or affected by the statement (*rows* field)
- *Executions* - number of executions for this statement (*calls* field)

### F.34.7.3.12. Complete list of SQL texts

Query texts of all statements mentioned in report. You can use *Query ID* link in any statistic table to get there and see query text.

## F.34.7.4. Schema object statistics

This section of report contains top database objects, using statistics from Statistics Collector views.

### F.34.7.4.1. Top tables by estimated sequentially scanned volume

Top database tables sorted by estimated volume, read by sequential scans. Based on *pg\_stat\_all\_tables* view. Here you can search for tables, possibly lacks some index on it.

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *~SeqBytes* - estimated volume, read by sequential scans. Calculated as a sum of *relation size* multiplied by *seq\_scan* for all samples of a report.
- *SeqScan* - number of sequential scans performed on the table (*seq\_scan* field)
- *IndexScan* - number of index scans initiated on this table (*idx\_scan* field)
- *IndexFetch* - number of live rows fetched by index scans (*idx\_tup\_fetch* field)
- *Inserted* - number of rows inserted (*n\_tup\_ins* field)

- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)

#### F.34.7.4.2. Top tables by blocks fetched

Fetches block is a block being processed from disk (read), or from shared buffers (hit). Tables in this list are sorted by sum of fetched blocks for table relation, its indexes, TOAST of a table (if exists), and TOAST index (if exists). This section can focus your attention on tables with excessive blocks processing. Based on data of *pg\_statio\_all\_tables* view.

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Heap* - statistics for relation blocks fetched (*heap\_blks\_read + heap\_blks\_hit*)
- *Index* - statistics for all relation indexes blocks fetched (*idx\_blks\_read + idx\_blks\_hit*)
- *TOAST* - statistics for TOAST-table blocks fetched (*toast\_blks\_read + toast\_blks\_hit*)
- *TOAST-Index* - statistics for TOAST index blocks fetched (*tidx\_blks\_read + tidx\_blks\_hit*)

Each statistic field in this table is divided in two columns:

- *Blocks* - number of blocks fetched for relation heap, index, TOAST or TOAST index
- *%Total* - blocks fetched for relation heap, index, TOAST or TOAST index as a percentage of all blocks fetched in a whole cluster

#### F.34.7.4.3. Top tables by blocks read

Top tables sorted by block reads. Tables in this list are sorted by sum of block reads for table, its indexes, TOAST of a table (if exists), and TOAST index (if exists). This section can focus your attention on tables with excessive blocks reading. Based on data of *pg\_statio\_all\_tables* view.

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Heap* - statistics for relation block reads (*heap\_blks\_read*)
- *Index* - statistics for all relation indexes blocks reads (*idx\_blks\_read*)
- *TOAST* - statistics for TOAST-table block reads (*toast\_blks\_read*)
- *TOAST-Index* - statistics for TOAST index block reads (*tidx\_blks\_read*)

Each read statistic in this table is divided in two columns:

- *Blocks* - number of block reads for relation heap, index, TOAST or TOAST index
- *%Total* - block reads for relation heap, index, TOAST or TOAST index as a percentage of all block reads in a whole cluster



#### F.34.7.4.4. Top DML tables

Top tables sorted by amount of DML-affected rows, i.e. sum of *n\_tup\_ins*, *n\_tup\_upd* and *n\_tup\_del* (including TOAST tables).

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Inserted* - number of rows inserted (*n\_tup\_ins* field)
- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)
- *SeqScan* - number of sequential scans performed on the table (*seq\_scan* field)
- *SeqFetch* - number of live rows fetched by sequential scans (*seq\_tup\_read* field)
- *IndexScan* - number of index scans initiated on this table (*idx\_scan* field)
- *IndexFetch* - number of live rows fetched by index scans (*idx\_tup\_fetch* field)

#### F.34.7.4.5. Top tables by updated/deleted tuples

Top tables sorted by amount of operations, causing autovacuum load, i.e. sum of *n\_tup\_upd* and *n\_tup\_del* (including TOAST tables). Consider fine-tune of vacuum-related parameters based on provided vacuum and analyze run statistics.

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *Vacuum* - number of times this table has been manually vacuumed (not counting VACUUM FULL) (*vacuum\_count* field)
- *AutoVacuum* - number of times this table has been vacuumed by the autovacuum daemon (*autovacuum\_count* field)
- *Analyze* - number of times this table has been manually analyzed (*analyze\_count* field)
- *AutoAnalyze* - number of times this table has been analyzed by the autovacuum daemon (*autoanalyze\_count* field)

#### F.34.7.4.6. Top growing tables

Top tables sorted by growth

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Size* - table size, as it was at the moment of last sample in report interval
- *Growth* - table growth
- *Inserted* - number of rows inserted (*n\_tup\_ins* field)
- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)

#### **F.34.7.4.7. Top indexes by blocks fetched**

Fetches block is a block being processed from disk (read), or from shared buffers (hit). Based on data of *pg\_statio\_all\_indexes* view.

- *Database* - database name of the index
- *Tablespace* - tablespace name, where the index is located
- *Schema* - schema name of the index
- *Table* - table name
- *Index* - index name
- *Scans* - number of scans, performed on index (*idx\_scan* field)
- *Blocks* - blocks fetched from this index (*idx\_blks\_read* + *idx\_blks\_hit*)
- *%Total* - blocks fetched for this index as a percentage of all blocks fetched in a whole cluster

#### **F.34.7.4.8. Top indexes by blocks read**

Top indexes sorted by block reads. Based on data of *pg\_statio\_all\_indexes* view.

- *Database* - database name of the index
- *Tablespace* - tablespace name, where the index is located
- *Schema* - schema name of the index
- *Table* - table name
- *Index* - index name
- *Scans* - number of scans, performed on index (*idx\_scan* field)
- *Block Reads* - number of disk blocks read from this index (*idx\_blks\_read*)
- *%Total* - block reads from this index as a percentage of all block reads in a whole cluster
- *Hits(%)* - percentage of index blocks got from buffer cache within all index blocks fetched for this index

#### F.34.7.4.9. Top growing indexes

Top indexes sorted by growth

- *Database* - database name of the index
- *Tablespace* - tablespace name, where the index is located
- *Schema* - schema name of the index
- *Table* - table name
- *Index* - index name
- *Index* - index statistics
  - *Size* - index size, as it was at the moment of last sample in report interval
  - *Growth* - index growth during report interval
- *Table* - underlying table statistics
  - *Inserted* - number of rows inserted into underlying table (*n\_tup\_ins* field)
  - *Updated* - number of rows updated in underlying table (without HOT) (*n\_tup\_upd* - *n\_tup\_hot\_upd*)
  - *Deleted* - number of rows deleted from underlying table (*n\_tup\_del* field)

#### F.34.7.4.10. Unused indexes

Non-scanned indexes during report interval sorted by DML operations on underlying tables, causing index support. Constraint indexes are excluded.

- *Database* - database name of the index
- *Tablespace* - tablespace name, where the index is located
- *Schema* - schema name of the index
- *Table* - table name
- *Index* - index name
- *Index* - index statistics
  - *Size* - index size, as it was at the moment of last sample in report interval
  - *Growth* - index growth during report interval
- *Table* - underlying table statistics
  - *Inserted* - number of rows inserted into underlying table (*n\_tup\_ins* field)
  - *Updated* - number of rows updated in underlying table (without HOT) (*n\_tup\_upd* - *n\_tup\_hot\_upd*)
  - *Deleted* - number of rows deleted from underlying table (*n\_tup\_del* field)

#### F.34.7.5. User function statistics

This report section contains top functions in cluster, based on *pg\_stat\_user\_functions* view.

### F.34.7.5.1. Top functions by total time

Top functions sorted by time elapsed.

- *Database* - database name of the function
- *Schema* - schema name of the index
- *Function* - function name
- *Executions* - number of times this function has been called (*calls* field)
- *Time (s)* - function timing statistics in seconds
  - *Total* - total time spent in this function and all other functions called by it (*total\_time* field)
  - *Self* - total time spent in this function itself, not including other functions called by it (*self\_time* field)
  - *Mean* - mean time of single function execution
  - *Mean self* - mean self time of single function execution

### F.34.7.5.2. Top functions by executions

Top functions sorted by executions count.

- *Database* - database name of the function
- *Schema* - schema name of the index
- *Function* - function name
- *Executions* - number of times this function has been called (*calls* field)
- *Time (s)* - function timing statistics in seconds
  - *Total* - total time spent in this function and all other functions called by it (*total\_time* field)
  - *Self* - total time spent in this function itself, not including other functions called by it (*self\_time* field)
  - *Mean* - mean time of single function execution
  - *Mean self* - mean self time of single function execution

### F.34.7.5.3. Top trigger functions by total time

Top trigger functions sorted by time elapsed.

- *Database* - database name of the function
- *Schema* - schema name of the index
- *Function* - function name
- *Executions* - number of times this function has been called (*calls* field)
- *Time (s)* - function timing statistics in seconds
  - *Total* - total time spent in this function and all other functions called by it (*total\_time* field)
  - *Self* - total time spent in this function itself, not including other functions called by it (*self\_time* field)

- *Mean* - mean time of single function execution
- *Mean self* - mean self time of single function execution

## F.34.7.6. Vacuum-related statistics

### F.34.7.6.1. Top tables by vacuum operations

Top tables sorted by vacuums (manual and automatic) processed

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Vacuum count* - number of times this table has been manually vacuumed (not counting VACUUM FULL) (*vacuum\_count* field)
- *Autovacuum count* - number of times this table has been vacuumed by the autovacuum daemon (*autovacuum\_count* field)
- *Inserted* - number of rows inserted (*n\_tup\_ins* field)
- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)

### F.34.7.6.2. Top tables by analyze operations

Top tables sorted by analyze run (manual and automatic) count

- *Database* - database name of the table
- *Tablespace* - tablespace name, where the table is located
- *Schema* - schema name of the table
- *Table* - table name
- *Analyze count* - number of times this table has been manually analyzed (*analyze\_count* field)
- *Autoanalyze count* - number of times this table has been analyzed by the autovacuum daemon (*autoanalyze\_count* field)
- *Inserted* - number of rows inserted (*n\_tup\_ins* field)
- *Updated* - number of rows updated (including HOT) (*n\_tup\_upd* field)
- *Deleted* - number of rows deleted (*n\_tup\_del* field)
- *HOT Updated* - number of rows HOT updated (*n\_tup\_hot\_upd* field)

### F.34.7.6.3. Top indexes by estimated vacuum I/O load

This table provides estimation of implicit vacuum load caused by table indexes. Here is top indexes sorted by count of vacuums performed on underlying table multiplied by index size.

- *Database* - database name of the index
- *Tablespace* - tablespace name, where the index is located
- *Schema* - schema name of the index
- *Table* - table name
- *Index* - index name
- *~Vacuum bytes* - vacuum load estimation calculated as  $(vacuum\_count + autovacuum\_count) * index\_size$
- *Vacuum count* - number of times this table has been manually vacuumed (not counting VACUUM FULL) (*vacuum\_count* field)
- *Autovacuum count* - number of times this table has been vacuumed by the autovacuum daemon (*autovacuum\_count* field)
- *Index size* - average index size during report interval
- *Resize* - average relation size during report interval

#### **F.34.7.6.4. Top tables by dead tuples ratio**

This section contains modified tables with last vacuum run. Statistics is valid for last sample in report interval. Based on *pg\_stat\_all\_tables* view.

Top tables, sized 5 MB and more, sorted by dead tuples ratio.

- *Database* - database name of the table
- *Schema* - schema name of the table
- *Table* - table name
- *Live* - estimated number of live rows (*n\_live\_tup*)
- *Dead* - estimated number of dead rows (*n\_dead\_tup*)
- *%Dead* - dead rows of the table as a percentage of all rows in the table
- *Last AutoVacuum* - last time when this table was vacuumed by the autovacuum daemon (*last\_autovacuum*)
- *Size* - table size, as it was at the moment of last report sample.

#### **F.34.7.6.5. Top tables by modified tuples ratio**

This section contains modified tables with last vacuum run. Statistics is valid for last sample in report interval. Based on *pg\_stat\_all\_tables* view.

Top tables, sized 5 MB and more, sorted by modified tuples ratio.

- *Database* - database name of the table
- *Schema* - schema name of the table
- *Table* - table name
- *Live* - estimated number of live rows (*n\_live\_tup*)
- *Dead* - estimated number of dead rows (*n\_dead\_tup*)

- *Mod* - estimated number of rows modified since this table was last analyzed (*n\_mod\_since\_analyze*)
- *%Mod* - modified rows of the table as a percentage of all rows in the table
- *Last AutoAnalyze* - last time when this table was analyzed by the autovacuum daemon
- *Size* - table size, as it was at the moment of last report sample.

### F.34.7.7. Cluster settings during the report interval

This section of a report contains LightDB GUC parameters, and values of functions *version()*, *pg\_postmaster\_start\_time()*, *pg\_conf\_load\_time()* and field *system\_identifier* of *pg\_control\_system()* function during report interval.

- *Setting* - name of a parameter
- *reset\_val* - *reset\_val* field of *pg\_settings* view. Bold font is used to show settings, changed during report interval.
- *Unit* - setting unit
- *Source* - configuration file, where this setting was defined, line number after semicolon.
- *Notes* - This field will contain timestamp of a sample, when this value was observed first time during report interval.

### F.34.7.8. Kernel settings during the report interval

This section of a report contains several important linux kernel parameters.

- *Setting* - name of a parameter
- *Value* - value of a parameter.
- *Source* - configuration file, where this setting was defined.

### F.34.7.9. What you need to remember...

1. LightDB collects execution statistics **after** execution is complete. If single execution of a statement lasts for several samples, it will affect statistics of only last sample (when it was completed). And you can't get statistics on still running statements. Also, maintenance processes like vacuum and checkpointer will update statistics only on completion.
2. Resetting any LightDB statistics may affect accuracy of a next sample.
3. Exclusive locks on relations conflicts with calculating relation size. Sample won't collect relation sizes of relations with AccessExclusiveLock held by any session. However, a session can acquire AccessExclusiveLock on relation during sample processing. To workaround this problem, *lock\_timeout* is set to 3s, so if *take\_sample()* function will be unable to acquire a lock for 3 seconds, it will fail, and no sample will be generated.

## F.34.8. Sections of PSH report

Report tables and their columns are described in this section.

### F.34.8.1. Top Wait Events

#### F.34.8.1.1. Top User Events

This table contains top *lt\_profile.topn* user wait event sorted by wait time.

- *Wait Event* - The specific event that process waiting for.
- *Wait Event Type* - Type of this event.
- *Wait Time(s)* - Total wait time of all this event.
- *%Total Wait Time* - Total wait time of all this event as a percentage of total wait time for all types of events in a cluster.

### F.34.8.1.2. Top Background Events

This table contains top *lt\_profile.topn* background wait event sorted by wait time.

- *Wait Event* - The specific event that process waiting for.
- *Wait Event Type* - Type of this event.
- *Wait Time(s)* - Total wait time of all this event.
- *%Total Wait Time* - Total wait time of all this event as a percentage of total wait time for all types of events in a cluster.

## F.34.8.2. Top SQL

### F.34.8.2.1. Top SQL with Top Events

Top wait events sorted by wait time for the top statements sorted by *total\_exec\_time* field of *pg\_stat\_statements* view.

- *Query ID* - Query identifier as a hash of database, user and query text. Compatible with *ltcenter* utility. Native *pg\_stat\_statements* field *qieryid* in hexadecimal notation is shown in square brackets.
- *SQL Text* - First 100 characters of the complete query.
- *Exec (s)* - time spent executing this statement (*total\_exec\_time* field).
- *%Total* - exec time of this statement as a percentage of total elapsed time of all statements in a cluster
- *Wait Event* - The specific event that process waiting for.
- *Wait Time(s)* - Total wait time of the event in this query.

### F.34.8.2.2. Complete list of SQL texts

Query texts of all statements mentioned in report. You can use *Query ID* link in any statistic table to get there and see query text.

## F.35. It\_qualstats

The *It\_qualstats* is a LightDB extension keeping statistics on predicates found in `WHERE` statements and `JOIN` clauses.

This is useful if you want to be able to analyze what are the most-often executed quals (predicates) on your database.

It also allows you to identify correlated columns, by identifying which columns are most frequently queried together.

The extension works by looking for known patterns in queries. Currently, this includes:

- Binary `OpExpr` where at least one side is a column from a table. Whenever possible, the predicate will be swapped so that `CONST OP VAR` expressions are turned into `VAR COMMUTED_OP`



CONST. AND and OR expression members are counted as separate entries. Ex: WHERE column1 = 2, WHERE column1 = column2, WHERE 3 = column3

- `ScalarArrayOpExpr` where the left side is a VAR, and the right side is an array constant. Those will be counted one time per element in the array. Ex: WHERE column1 IN (2, 3) will be counted as 2 occurrences for the (column1, '=') operator pair
- `BooleanTest` where the expression is a simple boolean column reference Ex: WHERE column1 IS TRUE Please not that clauses like WHERE columns1, WHERE NOT column1 won't be processed by `lt_qualstats` (yet)

This extension also saves the first query text, as-is, for each distinct queryid executed, with a limit of `lt_qualstats.max` entries.

Please not that the gathered data are not saved when the LightDB server is restarted.

## F.35.1. Configuration

The following GUCs can be configured, in `lightdb.conf`:

- `lt_qualstats.enabled` (boolean, default true): whether or not `lt_qualstats` should be enabled
- `lt_qualstats.track_constants` (boolean, default true): whether or not `lt_qualstats` should keep track of each constant value individually. Disabling this GUC will considerably reduce the number of entries necessary to keep track of predicates.
- `lt_qualstats.max`: the maximum number of predicated and query text tracked (defaults to 1000)
- `lt_qualstats.resolve_oids` (boolean, default false): whether or not `lt_qualstats` should resolve oids at query time, or just store the oids. Enabling this parameter makes the data analysis much more easy, since a connection to the database where the query was executed won't be necessary, but it will eat much more space (624 bytes per entry instead of 176). Additionally, this will require some catalog lookups, which aren't free.
- `lt_qualstats.track_pg_catalog` (boolean, default false): whether or not `lt_qualstats` should compute predicates on object in `pg_catalog` schema.
- `lt_qualstats.sample_rate` (double, default -1): the fraction of queries that should be sampled. For example, 0.1 means that only one out of ten queries will be sampled. The default (-1) means automatic, and results in a value of  $1 / \text{max\_connections}$ , so that statistically, concurrency issues will be rare.

## F.35.2. Updating the extension

Note that as all extensions configured in `shared_preload_libraries`, most of the changes are only applied once LightDB is restarted with the new shared library. The extension object itself only provides SQL wrappers to access internal data structures.

Also note that `lt_qualstats` doesn't provide extension upgrade scripts, as there's no data saved in any of the objects created. Therefore, you need to first drop the extension then create it again to get the new version.

## F.35.3. Usage

- Create the extension in any database:

```
CREATE EXTENSION lt_qualstats;
```

### F.35.3.1. Functions

The extension defines the following functions:

- `pg_qualstats`: returns the counts for every qualifier, identified by the expression hash. This hash identifies each expression.
- `userid`: oid of the user who executed the query.
- `dbid`: oid of the database in which the query has been executed.
- `lrelid`, `lattnum`: oid of the relation and attribute number of the VAR on the left hand side, if any.
- `opno`: oid of the operator used in the expression
- `rrelid`, `rattnum`: oid of the relation and attribute number of the VAR on the right hand side, if any.
- `qualid`: normalized identifier of the parent "AND" expression, if any. This identifier is computed excluding the constants. This is useful for identifying predicates which are used together.
- `uniquequalid`: unique identifier of the parent "AND" expression, if any. This identifier is computed including the constants.
- `qualnodeid`: normalized identifier of this simple predicate. This identifier is computed excluding the constants.
- `uniquequalnodeid`: unique identifier of this simple predicate. This identifier is computed including the constants.
- `occurences`: number of time this predicate has been invoked, ie. number of related query execution.
- `execution_count`: number of time this predicate has been executed, ie. number of rows it processed.
- `nbfiltered`: number of tuples this predicate discarded.
- `constant_position`: location of the constant in the original query string, as reported by the parser.
- `queryid`: if `pg_stats_statements` is installed, the `queryid` identifying this query, otherwise NULL.
- `constvalue`: a string representation of the right-hand side constant, if any, truncated to 80 bytes. Require to be superuser or member of `pg_read_all_stats`, "" will be showed instead.
- `eval_type`: evaluation type. 'f' for a predicate evaluated after a scan or 'i' for an index predicate.

Example:

```
ro=# select * from pg_qualstats;
userid # dbid # lrelid # lattnum #
opno # rrelid # rattnum # qualid # uniquequalid # qualnodeid #
uniquequalnodeid # occurences # execution_count # nbfiltered #
constant_position # queryid # constvalue # eval_type
```

```

-----+-----+-----
+-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
+-----+-----
10 # 16384 # 16385 # 2 # 98
# # # # # 115075651 #
1858640877 # 1 # 100000 # 99999 #
29 # # 'line 1'::text # f
10 # 16384 # 16391 # 2 # 98
# 16385 # 2 # # # 497379130 #
497379130 # 1 # 0 # 0 #
# # # f

```

- `pg_qualstats_index_advisor(min_filter, min_selectivity, forbidden_am)`: Perform a global index suggestion. By default, only predicates filtering at least 1000 rows and 30% of the rows in average will be considered, but this can be passed as parameter. You can also provide an array of index access method if you want to avoid some.

Example:

```

SELECT v
FROM json_array_elements(
pg_qualstats_index_advisor(min_filter
=> 50)->'indexes') v
ORDER BY v::text COLLATE "C";
v
-----
"CREATE INDEX ON public.adv USING btree
(id1)"
"CREATE INDEX ON public.adv USING btree
(val, id1, id2, id3)"
"CREATE INDEX ON public.pgqs USING btree
(id)"
(3 rows)

SELECT v
FROM json_array_elements(
pg_qualstats_index_advisor(min_filter
=> 50)->'unoptimised') v
ORDER BY v::text COLLATE "C";
v
-----
"adv.val ~~* ?"
(1 row)

```

- `pg_qualstats_deparse_qual`: format a stored predicate in the form `tablename. columnname operatorname ?`. This is mostly for the global index advisor.
- `pg_qualstats_get_idx_col`: for the given predicate, retrieve the underlying column name and all the possible operator class. This is mostly for the global index advisor.
- `pg_qualstats_get_qualnode_rel`: for the given predicate, return the underlying table, fully qualified. This is mostly for the global index advisor
- `pg_qualstats_example_queries`: return all the stored query texts.

- `pg_qualstats_example_query`: return the stored query text for the given queryid if any, otherwise NULL.
- `pg_qualstats_names`: return all the stored query texts.
- `pg_qualstats_reset`: reset the internal counters and forget about every encountered qual.

### F.35.3.2. Views

In addition to that, the extension defines some views on top of the `pg_qualstats` function:

- `pg_qualstats`: filters calls to `pg_qualstats()` by the current database.
- `pg_qualstats_pretty`: performs the appropriate joins to display a readable aggregated form for every attribute from the `pg_qualstats` view

Example:

```

ro=# select * from pg_qualstats_pretty;
      left_schema | left_table |
left_column | operator | right_schema | right_table |
right_column | occurrences | execution_count | nbfiltered
-----+-----+-----+-----+
+-----+-----+-----+-----+
      public | ltbench_accounts | aid |
| pg_catalog.= | 5 | 5000000 | 4999995 |
      public | ltbench_tellers | tid |
| pg_catalog.= | 10 | 10000000 | 9999990 |
      public | ltbench_branches | bid |
| pg_catalog.= | 10 | 2000000 | 1999990 |
      public | t1 | id |
| pg_catalog.= | public | t2 | id_t1 |
      1 | 10000 | 9999

```

- `pg_qualstats_all`: sums the counts for each attribute / operator pair, regardless of its position as an operand (LEFT or RIGHT), grouping together attributes used in AND clauses.

Example:

```

ro=# select * from pg_qualstats_all;
      dbid | relid | userid | queryid |
| attnums | opno | qualid | occurrences | execution_count |
nbfiltered | qualnodeid
-----+-----+-----+-----+
+-----+-----+-----+-----+
      16384 | 16385 | 10 | {2} |
| 98 | 1 | 100000 | 99999 |
115075651
      16384 | 16391 | 10 | {2} |
| 98 | 2 | 0 | 0 |
497379130

```

- `pg_qualstats_by_query`: returns only predicates of the form VAR OPERATOR CONSTANT, aggregated by queryid.

## F.36. It\_show\_plans

`lt_show_plans` is a module which shows the query plans of all currently running SQL statements. You can select the output format of plans: TEXT or JSON.

When the server starts, `lt_show_plans` makes a hashtable on the shared-memory in order to temporarily store query plans. The hashtable size cannot be changed, so the plans are not stored if the hashtable is full.

### F.36.1. Configuration Parameters

`lt_show_plans.plan_format`

It controls the output format of query plans. It can be selected either `text` or `json`. Default is `text`.

`lt_show_plans.max_plan_length`

It sets the maximum length of query plans. Default is 8192 [byte]. Note that this parameter must be set to an integer.

`lt_show_plans.show_level`

It controls the level of query plans. You can select one of `all`, `top` and `none`. "all" shows all level of the query plan. For example, when you execute a function defined by PL/pgSQL, the caller SQL statement (level 0) and the internal SQL statements in the function (level 1) are shown. "top" shows the top level of the query plan. "none" does not store the query plans, so the `lt_show_plans` view does not show anything. Default is `none`.

### F.36.2. Usage

You must add the line shown below in your `lightdb.conf` (See `lt_show_plans.show_level` above).

```
shared_preload_libraries = 'lt_show_plans'
lt_show_plans.show_level = 'top'
```

After starting your server, you must issue `CREATE EXTENSION` statement shown below.

```
testdb=# CREATE EXTENSION lt_show_plans;
```

After issuing, you must call the enable function shown below.

```
testdb=# select pg_show_plans_enable();
```

By issuing the following query, it shows the query plan and related information of the currently running SQL statements.

```
testdb=# SELECT * FROM pg_show_plans;
 pid | level | userid | dbid |
 plan
-----+-----+-----+-----
```

```
-----
```

```

11473 |      0 |      10 | 16384 | Function Scan on pg_show_plans
(cost=0.00..10.00 rows=1000 width=56)
11504 |      0 |      10 | 16384 | Function Scan on print_item
(cost=0.25..10.25 rows=1000 width=524)
11504 |      1 |      10 | 16384 | Result (cost=0.00..0.01 rows=1
width=4)
(3 rows)

```

pg\_show\_plans View:

- pid: the pid of the process which the query is running.
- level: the level of the query which runs the query. Top level is 0.
- userid: the userid of the user which runs the query.
- dbid: the database id of the database which the query is running.
- plan: the query plan of the running query.

If you need the query plans of running SQL statements and also the corresponding query string, you issue the following query which is combined with pg\_show\_plans and pg\_stat\_activity.

```

testdb=# \x
Expanded display is on.
testdb=# SELECT p.pid, p.level, p.plan, a.query FROM pg_show_plans
 p
  LEFT JOIN pg_stat_activity a
    ON p.pid = a.pid AND p.level = 0 ORDER BY p.pid, p.level;
-[ RECORD
 1 ]-----
pid   | 11473
level | 0
plan  | Sort (cost=72.08..74.58 rows=1000 width=80)
      |      +
      |      Sort Key: pg_show_plans.pid, pg_show_plans.level
      |      +
      |      -> Hash Left Join (cost=2.25..22.25 rows=1000 width=80)
      |      +
      |      Hash Cond: (pg_show_plans.pid = s.pid)
      |      +
      |      Join Filter: (pg_show_plans.level = 0)
      |      +
      |      -> Function Scan on pg_show_plans
(cost=0.00..10.00 rows=1000 width=48)      +
      |      -> Hash (cost=1.00..1.00 rows=100 width=44)
      |      +
      |      -> Function Scan on pg_stat_get_activity s
(cost=0.00..1.00 rows=100 width=44)
query | SELECT p.pid, p.level, p.plan, a.query FROM pg_show_plans p
      |      +
      |      LEFT JOIN pg_stat_activity a
      |      +
      |      ON p.pid = a.pid AND p.level = 0 ORDER BY p.pid,
p.level;
-[ RECORD
 2 ]-----
pid   | 11517
level | 0

```

```

plan | Function Scan on print_item (cost=0.25..10.25 rows=1000
      width=524)
query | SELECT * FROM print_item(1,20);
-[ RECORD
  3 ]-----
pid    | 11517
level  | 1
plan   | Result (cost=0.00..0.01 rows=1 width=4)
query  |

```

### F.36.3. Functions

- `pg_show_plans_disable()` disables the feature. Only superuser can execute it.
- `pg_show_plans_enable()` enables the feature. Only superuser can execute it.

## F.37. It\_sm

### F.37.1. What is It\_sm?

The `It_sm` extension provides SM cryptographic functions for LightDB, including `sm2`, `sm3`, `sm4` algorithms. Data can be encrypted and decrypted using the above algorithm.

Notice the current `It_sm` extension is an experimental trial version.

### F.37.2. function usage

#### F.37.2.1. SM2

SM2 is asymmetric encryption, there is a pair of keys, the private key is used for encryption, and the public key is used for decryption.

SM2 has a total of four functions:

- `gm_sm2_genprikey(local_storage bool)` return text generate the SM2 private key for encrypting data. The input parameter `true` indicates that the key is stored in the database, and the return value is `true` at this time. The input parameter `false` indicates that the key is imported from the outside when the database is restarted, and the return value is the private key string of text type.

```

-- Generate SM2 private key using local storage
SELECT gm_sm2_genprikey(true);
gm_sm2_genprikey
-----
true

-- Generate SM2 private key using external import
SELECT gm_sm2_genprikey(false);
gm_sm2_genprikey
-----
-----BEGIN EC PRIVATE KEY-----
+
MHcCAQEEIMattGsrutK0T7YftJ/nRL3HzUTSoBuW
+178TYuthSEXoAoGCCqBHM9V+
AYItouQDQgAEv12xwVT9SD4/
qOqB8EYZkbMy12APj3sOBHq0krHUSlQ0UbVocJls+

```

```
v1JkxGQSJ+EGXbmuhRErwiAu9gTd8+umlw==
+
-----END EC PRIVATE KEY-----
+
```

- `gm_sm2_genpubkey((local_storage bool)` return text generate the SM2 public key for decrypting data. The input parameter `true` indicates that the key is stored in the database, and the return value is `true` at this time. The input parameter `false` indicates that the key is imported from the outside when the database is restarted, and the return value is the private key string of text type. Note that the private key must be generated using the `gm_sm2_genprikey()` function before the public key can be generated using this function.

```
-- Generate SM2 public key using local storage
SELECT gm_sm2_genpubkey(true);
gm_sm2_genprikey
-----
true

-- Generate SM2 public key using external import
SELECT gm_sm2_genpubkey(false);
gm_sm2_genpubkey
-----
-----BEGIN PUBLIC KEY-----
+
MFkwEwYHKoZIzj0CAQYIKoEcz1UBgi0DQgAEv12xwVT9SD4/
qOqB8EYZkbMyl2AP+
j3sOBHq0krHUSlQ0UbV0cJlsv1JkxGQSJ+EGXbmuhRErwiAu9gTd8+umlw==
+
-----END PUBLIC KEY-----
+
```

- `gm_sm2_encrypt(plaintext bytea)` return `bytea` encrypt `plaintext` into `ciphertext`, input parameter as `plaintext` and return value as `ciphertext`.

```
-- Encrypt plaintext to generate ciphertext
select gm_sm2_encrypt('####LightDB_001');

gm_sm2_encrypt
-----
\x043f115fde4ad84ca331e6d6edbeb806d09ffa6094f8d52a57a39c7c6c587bcd06eb72146f3
```

- `gm_sm2_decrypt(ciphertext bytea)` return `bytea` decrypt the `ciphertext` into `plaintext`, the input parameter is the `ciphertext` and the return value is the `plaintext`.

```
-- Decrypt ciphertext to generate plaintext
select
gm_sm2_decrypt('\x043f115fde4ad84ca331e6d6edbeb806d09ffa6094f8d52a57a39c7c6c587bcd06eb72146f3')
gm_sm2_decrypt
-----
```



```
\xe68192e7949fe794b5e5ad904c6967687444425f303031

-- Convert the decrypted binary plaintext to display
select
convert_from('\xe68192e7949fe794b5e5ad904c6967687444425f303031',
'SQL_ASCII');
      convert_from
-----
####LightDB_001
```

### F.37.2.2. SM3

SM3 is a cryptographic hash algorithm, mainly used for digital signature and verification, message authentication code generation and verification, random number generation, etc.

SM3 has a total of one function:

- `gm_sm3_encrypt(plaintext bytea)` return `bytea` encrypt plaintext message to digest message, the input parameter is the plaintext message and the return value is the digest message.

```
-- plaintext message to generate digest message
select gm_sm3_encrypt('LightDB_002');
      gm_sm3_encrypt
-----

\x9de35b686bec17533e9ded7abfb039320bb08abbcec74eb0f44cf52b09e255c1
```

### F.37.2.3. SM4

SM4 is symmetric encryption, using CTR-128bit mode, there is a key for encryption and decryption.

SM4 has a total of three functions:

- `gm_sm4_genkey((local_storage bool)` return `text` generate the SM4 key for encrypting and decrypting data. The input parameter `true` indicates that the key is stored in the database, and the return value is `true` at this time. The input parameter `false` indicates that the key is imported from the outside when the database is restarted, and the return value is the key string of `text` type.

```
-- Generate SM4 key using local storage
select gm_sm4_genkey(true);
      gm_sm4_genkey
-----
true

-- Generate SM4 key using external import
select gm_sm4_genkey(false);
      gm_sm4_genkey
-----
A98B1904E5A74CDA5B2135519B941703
```

- `gm_sm4_encrypt(plaintext bytea)` return `bytea` encrypt plaintext into ciphertext, input parameter as plaintext and return value as ciphertext.

```
-- Encrypt plaintext to generate ciphertext
select gm_sm4_encrypt('###LightDB_003');
           gm_sm4_encrypt
-----
\x33e7117d0ce6f38ec2b78bfab08b991628771bedeeecf8
```

- gm\_sm4\_decrypt(ciphertext bytea) return bytea decrypt the ciphertext into plaintext, the input parameter is the ciphertext and the return value is the plaintext.

```
-- Decrypt ciphertext to generate plaintext
select
gm_sm4_decrypt('\x33e7117d0ce6f38ec2b78bfab08b991628771bedeeecf8');
           gm_sm4_decrypt
-----
\xe68192e7949fe794b5e5ad904c6967687444425f303033

-- Convert the decrypted binary plaintext to display
select
convert_from('\xe68192e7949fe794b5e5ad904c6967687444425f303033',
'SQL_ASCII');
           convert_from
-----
###LightDB_003
```

## F.37.3. key management

lt\_sm support two key management methods:

- The key is stored locally, and the input parameter is true in the use key generation function. After the key is generated, the encryption and decryption functions can be used.
- The key is imported from outside, and the input parameter of the generate key function is false. If the database is restarted, support for external import of key files.

```
-- When using lt_ctl, specify the -Y parameter to pass in the
key file
lt_ctl -D ./data -Y ./keyfile start
```

Among them, the key file needs to contain the keywords of username, database, sm2 private key, sm2 public key, sm4 key, use : separate keyword and value:

```
-- key file format, the corresponding pre-keyword and ':'
must contain
username:lightdb
database:postgres
sm2 private key:-----BEGIN EC PRIVATE KEY-----
MHcCAQEEIC4cBmYiht3Kf4e/
xQMNR3C2pLkafZ8Lm9lUxae937SjoAoGCCqBHM9V

AYItOUDQgAEdqAwhgrpt7NNBVKWuyXy8ltIcl1YQhyum1GE3G4QK3lfVBCgSYF
O5+fNfThTlppVC+Q1lwJ/QJmciYVEDzY8A==
```

```

-----END EC PRIVATE KEY-----
sm2 public key:-----BEGIN PUBLIC KEY-----

MFkwEwYHKoZIzj0CAQYIKoEcz1UBgi0DQgAEdqAwhgrpt7NNBVKWuyXy8ltI1c11
YQhyum1GE3G4QK31fVBCgSYF05+fNfThT1ppVC+Q1lwJ/QJmciYVEDzY8A==
-----END PUBLIC KEY-----
sm4 key:2DB5E313E60A123DBB1A517B5355A7AC

```

## F.38. It\_sql\_inspect

The `lt_sql_inspect` module provides two features: SQL best practices and SQL interception

### F.38.1. SQL best practices

#### F.38.1.1. Overview

This feature will provides rules to standardize sql writing.

There are two parts to this: LightDB DDL Specification Check and LightDB DML Specification Check.

#### F.38.1.2. Configuration Parameters

`lightdb_best_practice_mode` (String)

`lightdb_best_practice_mode` is used to specify the rules to check sql.

Now it support following rules:  
`keyword_not_allowed`,`bad_datatype`,`must_have_pk`,`must_have_gmt`,`no_more_100cols`,`no_paging`.

This setting can be changed within individual sessions.

`lightdb_best_practice_level` (String)

`lightdb_best_practice_level` is used to specify the message level when check failed.

It is used for both SQL best practices and SQL interception.

This setting can be changed within individual sessions.

#### F.38.1.3. LightDB DDL Specification Check

When you use DDL statements, LightDB will first check whether your statements comply with the specification.

At present, there are five checks: keyword check (including table name, field name, library name and index name), field type check (float,double,text,real, uuid,bytea,boolean,bit,character), whether the table must contain primary key, whether the table contains fields of creation time and last modification time, and the number of columns for operation does not exceed 100.The DDL statement specification supports:

```

CREATE DATABASE...
CREATE TABLE...
CREATE INDEX...
ALTER TABLE...

```

The keyword list can be referenced "[www.hs.net/lightdb/docs/current/sql-keywords-appendix.html](http://www.hs.net/lightdb/docs/current/sql-keywords-appendix.html)"

When you use nonstandard statements, you will report warnings or errors directly. For example:

```
create database text;
WARNING: LightDB DDL check warn! keyword not allowed with [db
name]:text

create table text(id int);
WARNING: LightDB DDL check warn! keyword not allowed with [table
name]:text
WARNING: LightDB DDL check warn! keyword not allowed with [column
name]:id
WARNING: LightDB DDL check warn! no primary key!
WARNING: LightDB DDL check warn! no gmt_create or no gmt_modified!
```

Where 'text' is a nonstandard database name, So report a warning. When creating a table, the table name is not standard, the column name is not standard, does not contain the primary key, does not contain the creation time and the last modification time, and the fields are warned. Of course, there is the upper limit of 100 operation columns, which is not listed here.

By default, DDL syntax checking is not enabled, There are two ways to turn it on. Global modification by modifying the configuration file:

```
lightdb_best_practice_level = 'warn'
lightdb_best_practice_mode = 'all'
```

A value of 'warn' for `lightdb_best_practice_level` indicates that the error level is warning. A value of 'error' indicates an error. When a nonstandard statement is detected, an error is reported directly#

```
create database text;
ERROR: LightDB DDL check error! keyword not allowed with [db
name]:text
```

If `lightdb_best_practice_mode` is configured as 'all', it means to check 5 types at the same time. Of course, you can combine the checks you want to configure at will, for example:

```
lightdb_best_practice_mode = 'keyword_not_allowed,must_have_pk'
```

The above configuration means that only keywords and primary keys are checked.

Another configuration method is session level modification:

```
set lightdb_best_practice_level to 'warn';
set lightdb_best_practice_mode to 'all';
```

There are five kinds of fully open here, and there is another way:

```
set lightdb_best_practice_mode to
'keyword_not_allowed,bad_datatype,must_have_pk,must_have_gmt,no_more_100cols';
```

#### F.38.1.4. LightDB DML Specification Check

When you use DML statements, LightDB will first check whether your statements comply with the specification.

At present, there is one check, no paging check: Remind the user when the user SQL does not specify query criteria or paging. The usage of these checks is described in detail below.

- `no_paging` check. Check is required in the following scenarios:
  - When the query statement has no `where` condition, no `limit` or no `offset`.
  - When the update statement has no `where` condition.
  - When the delete statement has no `where` condition.

How to use it? `lightdb_best_practice_level` and `lightdb_best_practice_mode` in the configuration file need to be configured.

By default, DML syntax checking is not enabled. Global modification by modifying the configuration file:

```
lightdb_best_practice_level = 'error'  
lightdb_best_practice_mode = 'all'
```

A value of 'warn' for `lightdb_best_practice_level` indicates that the error level is warning. A value of 'error' indicates an error. When a nonstandard statement is detected, an error is reported directly#

```
select * from table1;  
ERROR: LightDB DML check error! select sql not where/limit/offset  
clause!
```

If `lightdb_best_practice_mode` is configured as 'all', it means to check all types at the same time. Of course, you can combine the checks you want to configure at will, for example:

```
lightdb_best_practice_mode = 'no_paging'
```

## F.38.2. SQL interception

### F.38.2.1. Overview

This feature will intercept risk sql that match the specified rule in `lt_sql_inspect.secure_mode`.

Only SQL that operates on the specified database will be blocked, using `lt_sql_inspect.secure_enable_db` to specify the database

You can define a time frame by `lt_sql_inspect.secure_enable_time`, and only in this time frame sql will be intercepted. The time frame can only be within a day.

`lightdb_best_practice_level` controls the log level when SQL is intercepted. default is 'warn'. A value of 'warn' for `lightdb_best_practice_level` indicates that the error level is warning. A value of 'error' indicates an error.

Refer to `lt_sql_inspect.secure_mode` for detail rules.

### F.38.2.2. Configuration Parameters

`lt_sql_inspect.secure_mode` (String)

`lt_sql_inspect.secure_mode` specifies some SQL execution rules, such as intercepting SQL that meets the criteria. You can specify multiple rules, separated by commas. The following rules are supported: `select_without_where`, `update_without_where`, `delete_without_where`, `no_paging`, `high_risk_ddl`.

This setting can be changed within individual sessions.

- `select_without_where`: Block a select query that queries only one table when it has no where condition, no limit and no offset.
- `update_without_where`: Block a update query that queries only one table when it has no where condition, no limit and no offset.
- `delete_without_where`: Block a delete query that queries only one table when it has no where condition, no limit and no offset.
- `no_paging`: Equivalent to using `select_without_where`, `update_without_where`, and `delete_without_where` together.
- `high_risk_ddl`: Block following ddl: drop table, truncate table, alter table add/drop column, alter table add/drop Constraint, alter table modify column(null/not null, default/no default, type).

`lt_sql_inspect.secure_enable_time` (String)

`lt_sql_inspect.secure_enable_time` specifies the time frame, and only in this time frame, sql will be intercepted.

Format is 'start\_time - end\_time'(example: '09:00 - 18:00' ).

This parameter can only be set in the `lightdb.conf` file or on the server command line, and can be reload.

`lt_sql_inspect.secure_db` (String)

`lt_sql_inspect.secure_enable_db` specifies the databases, and only on these databases, sql will be intercepted.

You can specify multiple databases, separated by commas.

This parameter can only be set in the `lightdb.conf` file or on the server command line, and can be reload.

## F.38.2.3. Rules

### F.38.2.3.1. `select_without_where`

DQL involving only one table without where, limit and offset will be blocked.

When querying table under `pg_catalog`, `lt_catalog` or `ltcluster` scheme, sql will not be blocked. Note that when the `lightdb_best_practice_level` is error, the query of table in other schemas(include tables created by extension) that meet the requirements will report errors.

```
lightdb@lt_test=# set
  lt_sql_inspect.secure_mode=select_without_where;
SET
lightdb@lt_test=# select * from t1;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
        scan or modification may be performed on the table "t1"
lightdb@lt_test=# select * from (select * from t1);
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
        scan or modification may be performed on the table "t1"
lightdb@lt_test=# select * from t1 limit 1;
key1 | key2
-----+-----
(0 rows)
```

```
lightdb@lt_test=# select * from t1 offset 1;
key1 | key2
-----+-----
(0 rows)
```

DQL involving multi-table will not be blocked.

```
lightdb@lt_test=# select * from t1, t2;
key1 | key2 | key1
-----+-----+-----
(0 rows)
```

This also applies to the view just like a subquery.

```
lightdb@lt_test=# create view t1_v as select * from t1;
CREATE VIEW
lightdb@lt_test=# select * from t1_v;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
        scan or modification may be performed on the table "t1"
lightdb@lt_test=# select * from t1_v where key1=1;
key1 | key2
-----+-----
(0 rows)
```

### F.38.2.3.2. update\_without\_where

Be similar to select\_without\_where, but for update statement.

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode =
'update_without_where';
SET
lightdb@lt_test=# update t1 set key1=1;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
        scan or modification may be performed on the table "t1"
lightdb@lt_test=# update t1 set key1=1 limit 1;
UPDATE 0
lightdb@lt_test=# update t1 set key1=1 offset 1;
UPDATE 0
lightdb@lt_test=# update t1 set key1=1 from t2 ;
UPDATE 0
lightdb@lt_test=# update t1 set key1=1 from t2 where
        t1.key1=t2.key1;
UPDATE 0
```

### F.38.2.3.3. delete\_without\_where

Be similar to select\_without\_where, but for delete statement.

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode =
'delete_without_where';
SET
lightdb@lt_test=# delete from t1 ;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
scan or modification may be performed on the table "t1"
lightdb@lt_test=# delete from t1 where key1=1;
DELETE 0
lightdb@lt_test=# delete from t1 limit 1;
DELETE 0
lightdb@lt_test=# delete from t1 offset 1;
DELETE 0
lightdb@lt_test=# delete from t1 using t2;
DELETE 0
lightdb@lt_test=# delete from t1 using t2 where t1.key1=t2.key1;
DELETE 0
```

#### F.38.2.3.4. no\_paging

Equivalent to using `select_without_where`, `update_without_where`, and `delete_without_where` together.

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode=no_paging;
SET
lightdb@lt_test=#
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
scan or modification may be performed on the table "t1"
lightdb@lt_test=# update t1 set key1=1;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
scan or modification may be performed on the table "t1"
lightdb@lt_test=# delete from t1 ;
ERROR:  lt_sql_inspect: SQL cannot execute, because a full table
scan or modification may be performed on the table "t1"
```

#### F.38.2.3.5. high\_risk\_ddl

Currently the following ddl will be considered as a high risk ddl, and will be intercepted.

- drop table

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# drop table t1;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

- truncate table

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# truncate table t1;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```



- alter table add column

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# alter table t1 add column key3 int;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

- alter table drop column

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# alter table t1 drop column key1;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

- alter table add constraint

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# alter table t1 add constraint t_uq
unique(key1);
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

- alter table drop constraint

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# alter table t1 drop constraint t_uq;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

- alter table modify/alter column(only the types in the following example will be blocked, including null/not-null, default/non-default, and type).

```
lightdb@lt_test=# set lt_sql_inspect.secure_mode = high_risk_ddl;
SET
lightdb@lt_test=# alter table t1 modify key2 bigint;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 alter key2 type text;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 modify key2 null;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
```

```
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 alter key2 drop not null;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 modify key2 not null;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 alter key2 set not null;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 modify key2 default 10;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 alter key2 set default 10;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
lightdb@lt_test=# alter table t1 alter key2 drop default;
ERROR:  lt_sql_inspect: SQL cannot execute, because it is a high
risk ddl
lightdb@lt_test=#
```

## F.39. It\_standby\_forward

`lt_standby_forward` is a module which forwards SQL statements from a hot standby to primary, providing a facility to reduce loading of primary, and to allow clients query from standby. For example, clients can send INSERT, CREATE to a hot standby.

### F.39.1. Configuration Parameters

`lt_standby_forward.enable_forward`

It controls whether this feature is enabled or not user. Default is `off`. Set this option on standby, or for a single session.

### F.39.2. Usage

You must add the line shown below in your `lightdb.conf`.

```
shared_preload_libraries = 'lt_standby_forward'
```

### F.39.3. Authentication

`lt_standby_forward` uses `primary_conninfo` to connect to primary, appending current dbname and username (i.e. the db and user used to connect to standby) to `primary_conninfo`. The connection info looks like

```
primary_conninfo dbname=a_db user=a_user
application_name=lt_standby_forward options='-c opt1=value1 -c
opt2=value2'
```

It is not supported to set password. Config `lt_hba.conf` on primary, or put password in `passfile` on standby to avoid typing password.

## F.39.4. Features/Limitations

- Forwards DELETE, UPDATE, INSERT, SELECT with modifying CTE to primary.
- Forwards SELECT/CALL statements containing volatile function to primary, otherwise executes on standby.
- Executes read only transactions on standby, otherwise forwards to primary.
- DDL is not allowed in transactions.
- View is rewritten (expanded) on standby before forwarding to primary. Query fails if view contains objects cannot be accessed by current user.
- Executes SET on both sides, execute show on standby. Don't SET xxx\_timeout after connection established, set these parameters with ltsql/jdbc parameter options. For ltsql/jdbc options, only statement\_timeout, lock\_timeout and idle\_in\_transaction\_session\_timeout will be pass to primary.
- COPY FROM is not supported.
- CREATE TEMP/UNLOGGED TABLE is not supported.
- Utility commands not mentioned above are forwarded to primary.

## F.40. lt\_stat\_activity

This extension for LightDB add `lt_stat_activity` view.

### F.40.1. Concepts

This extension provides the `lt_stat_activity` view, which contains all `pg_stat_activity` fields and adds the `query_id` field, which is consistent with the `query_id` in `pg_stat_statements`. When waiting events occur, `lt_stat_activity` and `pg_stat_statements` can be used to analyze together by `query_id`.

### F.40.2. Prerequisites

`lt_stat_activity` extension depends on extension `lt_stat_statements`.

### F.40.3. Creating Extensions

you must add `lt_stat_activity` in `shared_preload_libraries`, and restart server is needed after modify `shared_preload_libraries`.

```
# lightdb.conf
shared_preload_libraries = 'lt_stat_statements,lt_stat_activity'
```

```
lightdb@postgres=# CREATE EXTENSION lt_stat_statements;
lightdb@postgres=# CREATE EXTENSION lt_stat_activity;
```

You can define extension parameters in `lightdb.conf`.

`lt_stat_activity.track = top` - default, track top level query.

`lt_stat_activity.track = none` - `query_id` field in `lt_stat_activity` is always null.

## F.41. lt\_stat\_statements

The `lt_stat_statements` module provides a means for tracking planning and execution statistics of all SQL statements executed by a server.

The module must be loaded by adding `lt_stat_statements` to `shared_preload_libraries` in `lightdb.conf`, because it requires additional shared memory. This means that a server restart is needed to add or remove the module.

When `lt_stat_statements` is loaded, it tracks statistics across all databases of the server. To access and manipulate these statistics, the module provides a view, `pg_stat_statements`, and the utility functions `pg_stat_statements_reset` and `pg_stat_statements`. These are not available globally but can be enabled for a specific database with `CREATE EXTENSION lt_stat_statements`.

### F.41.1. The pg\_stat\_statements View

The statistics gathered by the module are made available via a view named `pg_stat_statements`. This view contains one row for each distinct database ID, user ID and query ID (up to the maximum number of distinct statements that the module can track). The columns of the view are shown in Table F.54.

**Table F.54. pg\_stat\_statements Columns**

Column	Type	Description
<code>userid</code>	<code>oid</code>	(references <code>pg_authid.oid</code> ) OID of user who executed the statement
<code>dbid</code>	<code>oid</code>	(references <code>pg_database.oid</code> ) OID of database in which the statement was executed
<code>queryid</code>	<code>bigint</code>	Internal hash code, computed from the statement's parse tree
<code>query</code>	<code>text</code>	Text of a representative statement
<code>plans</code>	<code>bigint</code>	Number of times the statement was planned (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>total_plan_time</code>	<code>double precision</code>	Total time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>min_plan_time</code>	<code>double precision</code>	Minimum time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>max_plan_time</code>	<code>double precision</code>	Maximum time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>mean_plan_time</code>	<code>double precision</code>	Mean time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>stddev_plan_time</code>	<code>double precision</code>	Population standard deviation of time spent planning the statement, in milliseconds (if <code>lt_stat_statements.track_planning</code> is enabled, otherwise zero)
<code>calls</code>	<code>bigint</code>	Number of times the statement was executed

<b>Column Type</b>	<b>Description</b>
total_exec_time double precision	Total time spent executing the statement, in milliseconds
min_exec_time double precision	Minimum time spent executing the statement, in milliseconds
max_exec_time double precision	Maximum time spent executing the statement, in milliseconds
mean_exec_time double precision	Mean time spent executing the statement, in milliseconds
stddev_exec_time double precision	Population standard deviation of time spent executing the statement, in milliseconds
rows bigint	Total number of rows retrieved or affected by the statement
shared_blks_hit bigint	Total number of shared block cache hits by the statement
shared_blks_read bigint	Total number of shared blocks read by the statement
shared_blks_dirtied bigint	Total number of shared blocks dirtied by the statement
shared_blks_written bigint	Total number of shared blocks written by the statement
local_blks_hit bigint	Total number of local block cache hits by the statement
local_blks_read bigint	Total number of local blocks read by the statement
local_blks_dirtied bigint	Total number of local blocks dirtied by the statement
local_blks_written bigint	Total number of local blocks written by the statement
temp_blks_read bigint	Total number of temp blocks read by the statement
temp_blks_written bigint	Total number of temp blocks written by the statement
blk_read_time double precision	Total time the statement spent reading blocks, in milliseconds (if track_io_timing is enabled, otherwise zero)
blk_write_time double precision	Total time the statement spent writing blocks, in milliseconds (if track_io_timing is enabled, otherwise zero)
wal_records bigint	Total number of WAL records generated by the statement
wal_fpi bigint	Total number of WAL full page images generated by the statement
wal_bytes numeric	Total amount of WAL generated by the statement in bytes

For security reasons, only superusers and members of the `pg_read_all_stats` role are allowed to see the SQL text and `queryid` of queries executed by other users. Other users can see the statistics, however, if the view has been installed in their database.

Plannable queries (that is, `SELECT`, `INSERT`, `UPDATE`, and `DELETE`) are combined into a single `pg_stat_statements` entry whenever they have identical query structures according to an internal hash calculation. Typically, two queries will be considered the same for this purpose if they are semantically equivalent except for the values of literal constants appearing in the query. Utility commands (that is, all other commands) are compared strictly on the basis of their textual query strings, however.

When a constant's value has been ignored for purposes of matching the query to other queries, the constant is replaced by a parameter symbol, such as `$1`, in the `pg_stat_statements` display. The rest of the query text is that of the first query that had the particular `queryid` hash value associated with the `pg_stat_statements` entry.

In some cases, queries with visibly different texts might get merged into a single `pg_stat_statements` entry. Normally this will happen only for semantically equivalent queries, but there is a small chance of hash collisions causing unrelated queries to be merged into one entry. (This cannot happen for queries belonging to different users or databases, however.)

Since the `queryid` hash value is computed on the post-parse-analysis representation of the queries, the opposite is also possible: queries with identical texts might appear as separate entries, if they have different meanings as a result of factors such as different `search_path` settings.

Consumers of `pg_stat_statements` may wish to use `queryid` (perhaps in combination with `dbid` and `userid`) as a more stable and reliable identifier for each entry than its query text. However, it is important to understand that there are only limited guarantees around the stability of the `queryid` hash value. Since the identifier is derived from the post-parse-analysis tree, its value is a function of, among other things, the internal object identifiers appearing in this representation. This has some counterintuitive implications. For example, `lt_stat_statements` will consider two apparently-identical queries to be distinct, if they reference a table that was dropped and recreated between the executions of the two queries. The hashing process is also sensitive to differences in machine architecture and other facets of the platform. Furthermore, it is not safe to assume that `queryid` will be stable across major versions of LightDB.

As a rule of thumb, `queryid` values can be assumed to be stable and comparable only so long as the underlying server version and catalog metadata details stay exactly the same. Two servers participating in replication based on physical WAL replay can be expected to have identical `queryid` values for the same query. However, logical replication schemes do not promise to keep replicas identical in all relevant details, so `queryid` will not be a useful identifier for accumulating costs across a set of logical replicas. If in doubt, direct testing is recommended.

The parameter symbols used to replace constants in representative query texts start from the next number after the highest `$n` parameter in the original query text, or `$1` if there was none. It's worth noting that in some cases there may be hidden parameter symbols that affect this numbering. For example, PL/pgSQL uses hidden parameter symbols to insert values of function local variables into queries, so that a PL/pgSQL statement like `SELECT i + 1 INTO j` would have representative text like `SELECT i + $2`.

The representative query texts are kept in an external disk file, and do not consume shared memory. Therefore, even very lengthy query texts can be stored successfully. However, if many long query texts are accumulated, the external file might grow unmanageably large. As a recovery method if that happens, `lt_stat_statements` may choose to discard the query texts, whereupon all existing entries in the `pg_stat_statements` view will show null `query` fields, though the statistics associated with each `queryid` are preserved. If this happens, consider reducing `lt_stat_statements.max` to prevent recurrences.

`plans` and `calls` aren't always expected to match because planning and execution statistics are updated at their respective end phase, and only for successful operations. For example, if a statement is successfully planned but fails during the execution phase, only its planning statistics will be updated. If planning is skipped because a cached plan is used, only its execution statistics will be updated.

## F.41.2. Functions

`pg_stat_statements_reset(userid Oid, dbid Oid, queryid bigint)`  
returns void

`pg_stat_statements_reset` discards statistics gathered so far by `lt_stat_statements` corresponding to the specified `userid`, `dbid` and `queryid`. If any of the parameters are not specified, the default value 0(invalid) is used for each of them and the statistics that match with other parameters will be reset. If no parameter is specified or all the specified parameters are 0(invalid), it will discard all statistics. By default, this function can only be executed by superusers. Access may be granted to others using GRANT.

`pg_stat_statements(showtext boolean)` returns setof record

The `pg_stat_statements` view is defined in terms of a function also named `pg_stat_statements`. It is possible for clients to call the `pg_stat_statements` function directly, and by specifying `showtext := false` have query text be omitted (that is, the OUT argument that corresponds to the view's `query` column will return nulls). This feature is intended to support external tools that might wish to avoid the overhead of repeatedly retrieving query texts of indeterminate length. Such tools can instead cache the first query text observed for each entry themselves, since that is all `lt_stat_statements` itself does, and then retrieve query texts only as needed. Since the server stores query texts in a file, this approach may reduce physical I/O for repeated examination of the `pg_stat_statements` data.

## F.41.3. Configuration Parameters

`lt_stat_statements.max` (integer)

`lt_stat_statements.max` is the maximum number of statements tracked by the module (i.e., the maximum number of rows in the `pg_stat_statements` view). If more distinct statements than that are observed, information about the least-executed statements is discarded. The default value is 5000. This parameter can only be set at server start.

`lt_stat_statements.track` (enum)

`lt_stat_statements.track` controls which statements are counted by the module. Specify `top` to track top-level statements (those issued directly by clients), `all` to also track nested statements (such as statements invoked within functions), or `none` to disable statement statistics collection. The default value is `top`. Only superusers can change this setting.

`lt_stat_statements.track_utility` (boolean)

`lt_stat_statements.track_utility` controls whether utility commands are tracked by the module. Utility commands are all those other than `SELECT`, `INSERT`, `UPDATE` and `DELETE`. The default value is `on`. Only superusers can change this setting.

`lt_stat_statements.track_planning` (boolean)

`lt_stat_statements.track_planning` controls whether planning operations and duration are tracked by the module. Enabling this parameter may incur a noticeable performance penalty, especially when statements with identical query structure are executed by many concurrent connections which compete to update a small number of `pg_stat_statements` entries. The default value is `off`. Only superusers can change this setting.

`lt_stat_statements.save` (boolean)

`lt_stat_statements.save` specifies whether to save statement statistics across server shutdowns. If it is `off` then statistics are not saved at shutdown nor reloaded at server start. The default value is `on`. This parameter can only be set in the `lightdb.conf` file or on the server command line.

The module requires additional shared memory proportional to `lt_stat_statements.max`. Note that this memory is consumed whenever the module is loaded, even if `lt_stat_statements.track` is set to none.

These parameters must be set in `lightdb.conf`. Typical usage might be:

```
# lightdb.conf
shared_preload_libraries = 'lt_stat_statements'

lt_stat_statements.max = 10000
lt_stat_statements.track = all
```

## F.41.4. Sample Output

```
bench=# SELECT pg_stat_statements_reset();

$ ltbench -i bench
$ ltbench -c10 -t300 bench

bench=# \x
bench=# SELECT query, calls, total_exec_time, rows, 100.0 *
        shared_blks_hit /
        nullif(shared_blks_hit + shared_blks_read, 0) AS
        hit_percent
        FROM pg_stat_statements ORDER BY total_exec_time DESC
        LIMIT 5;
-[ RECORD 1 ]----+-----
query          | UPDATE ltbench_branches SET bbalance = bbalance +
  $1 WHERE bid = $2
calls          | 3000
total_exec_time | 25565.855387
rows           | 3000
hit_percent    | 100.0000000000000000
-[ RECORD 2 ]----+-----
query          | UPDATE ltbench_tellers SET tbalance = tbalance +
  $1 WHERE tid = $2
calls          | 3000
total_exec_time | 20756.669379
rows           | 3000
hit_percent    | 100.0000000000000000
-[ RECORD 3 ]----+-----
query          | copy ltbench_accounts from stdin
calls          | 1
total_exec_time | 291.865911
rows           | 100000
hit_percent    | 100.0000000000000000
-[ RECORD 4 ]----+-----
query          | UPDATE ltbench_accounts SET abalance = abalance +
  $1 WHERE aid = $2
calls          | 3000
total_exec_time | 271.232977
rows           | 3000
```



```

hit_percent      | 98.8454011741682975
-[ RECORD 5 ]---+-----
-----
query            | alter table ltbench_accounts add primary key
  (aid)
calls            | 1
total_exec_time  | 160.588563
rows             | 0
hit_percent      | 100.0000000000000000

bench=# SELECT pg_stat_statements_reset(0,0,s.queryid) FROM
pg_stat_statements AS s
        WHERE s.query = 'UPDATE ltbench_branches SET bbalance =
        bbalance + $1 WHERE bid = $2';

bench=# SELECT query, calls, total_exec_time, rows, 100.0 *
        shared_blks_hit /
        nullif(shared_blks_hit + shared_blks_read, 0) AS
hit_percent
        FROM pg_stat_statements ORDER BY total_exec_time DESC
LIMIT 5;
-[ RECORD 1 ]---+-----
-----
query            | UPDATE ltbench_tellers SET tbalance = tbalance +
  $1 WHERE tid = $2
calls            | 3000
total_exec_time  | 20756.669379
rows             | 3000
hit_percent      | 100.0000000000000000
-[ RECORD 2 ]---+-----
-----
query            | copy ltbench_accounts from stdin
calls            | 1
total_exec_time  | 291.865911
rows             | 100000
hit_percent      | 100.0000000000000000
-[ RECORD 3 ]---+-----
-----
query            | UPDATE ltbench_accounts SET abalance = abalance +
  $1 WHERE aid = $2
calls            | 3000
total_exec_time  | 271.232977
rows             | 3000
hit_percent      | 98.8454011741682975
-[ RECORD 4 ]---+-----
-----
query            | alter table ltbench_accounts add primary key
  (aid)
calls            | 1
total_exec_time  | 160.588563
rows             | 0
hit_percent      | 100.0000000000000000
-[ RECORD 5 ]---+-----
-----
query            | vacuum analyze ltbench_accounts
calls            | 1
total_exec_time  | 136.448116

```

```

rows          | 0
hit_percent   | 99.9201915403032721

bench=# SELECT pg_stat_statements_reset(0,0,0);

bench=# SELECT query, calls, total_exec_time, rows, 100.0 *
        shared_blks_hit /
        nullif(shared_blks_hit + shared_blks_read, 0) AS
hit_percent
        FROM pg_stat_statements ORDER BY total_exec_time DESC
LIMIT 5;
-[ RECORD 1 ]-----+-----
query          | SELECT pg_stat_statements_reset(0,0,0)
calls          | 1
total_exec_time | 0.189497
rows          | 1
hit_percent    |
-[ RECORD 2 ]-----+-----
query          | SELECT query, calls, total_exec_time, rows, $1 *
        shared_blks_hit /
        +
        nullif(shared_blks_hit +
        shared_blks_read, $2) AS hit_percent+
        FROM pg_stat_statements ORDER BY
total_exec_time DESC LIMIT $3
calls          | 0
total_exec_time | 0
rows          | 0
hit_percent    |

```

## F.41.5. Authors

Takahiro Itagaki <itagaki.takahiro@oss.ntt.co.jp>. Query normalization added by Peter Geoghegan <peter@2ndquadrant.com>.

## F.42. lt\_tempfile

lt\_tempfile provides a number of support functions to managing temporary files generated when work memory is not enough. For more detail, please refer to work\_mem and lightdb\_keep\_temp\_file.

**Table F.55. lt\_tempfile Functions**

Function	Description
lt_catalog.lt_remove_temp_file(mode text) → setof record	removing temporary file. 's' is used for the current session, '*' is used for all session. For example: select lt_remove_temp_file('*').
lt_catalog.lt_list_temp_file(mode text) → boolean	listing temporary file. 's' is used for the current session, '*' is used for all session. For example: select lt_remove_temp_file('*').

`lt_remove_temp_file` removes the temporary file in the `LTDATA/base/ltsql_tmp/keep` directory. Returns true on success, false if the specified file is not present or the `lt_remove_temp_file()` call fails; other cases throw errors.

`lt_list_temp_file` returns the start timestamps, path names and Number of temporary files of all the files in the `LTDATA/base/ltsql_tmp` directory.

## F.43. It\_trgm

The `lt_trgm` module provides functions and operators for determining the similarity of alphanumeric text based on trigram matching, as well as index operator classes that support fast searching for similar strings.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

### F.43.1. Trigram (or Trigraph) Concepts

A trigram is a group of three consecutive characters taken from a string. We can measure the similarity of two strings by counting the number of trigrams they share. This simple idea turns out to be very effective for measuring the similarity of words in many natural languages.

#### Note

`lt_trgm` ignores non-word characters (non-alphanumerics) when extracting trigrams from a string. Each word is considered to have two spaces prefixed and one space suffixed when determining the set of trigrams contained in the string. For example, the set of trigrams in the string “cat” is “ c”, “ ca”, “cat”, and “at ”. The set of trigrams in the string “foo|bar” is “ f”, “ fo”, “foo”, “oo ”, “ b”, “ ba”, “bar”, and “ar ”.

### F.43.2. Functions and Operators

The functions provided by the `lt_trgm` module are shown in Table F.56, the operators in Table F.57.

**Table F.56. `lt_trgm` Functions**

Function	Description
<code>similarity(text, text) → real</code>	Returns a number that indicates how similar the two arguments are. The range of the result is zero (indicating that the two strings are completely dissimilar) to one (indicating that the two strings are identical).
<code>show_trgm(text) → text[]</code>	Returns an array of all the trigrams in the given string. (In practice this is seldom useful except for debugging.)
<code>word_similarity(text, text) → real</code>	Returns a number that indicates the greatest similarity between the set of trigrams in the first string and any continuous extent of an ordered set of trigrams in the second string. For details, see the explanation below.
<code>strict_word_similarity(text, text) → real</code>	

Function	Description
	Same as <code>word_similarity</code> , but forces extent boundaries to match word boundaries. Since we don't have cross-word trigrams, this function actually returns greatest similarity between first string and any continuous extent of words of the second string.
<code>show_limit () → real</code>	Returns the current similarity threshold used by the <code>%</code> operator. This sets the minimum similarity between two words for them to be considered similar enough to be misspellings of each other, for example. ( <i>Deprecated</i> ; instead use <code>SHOW lt_trgm.similarity_threshold</code> .)
<code>set_limit (real) → real</code>	Sets the current similarity threshold that is used by the <code>%</code> operator. The threshold must be between 0 and 1 (default is 0.3). Returns the same value passed in. ( <i>Deprecated</i> ; instead use <code>SET lt_trgm.similarity_threshold</code> .)

Consider the following example:

```
# SELECT word_similarity('word', 'two words');
word_similarity
-----
                0.8
(1 row)
```

In the first string, the set of trigrams is { " w", " wo", "wor", "ord", "rd " }. In the second string, the ordered set of trigrams is { " t", " tw", "two", "wo ", " w", " wo", "wor", "ord", "rds", "ds " }. The most similar extent of an ordered set of trigrams in the second string is { " w", " wo", "wor", "ord" }, and the similarity is 0.8.

This function returns a value that can be approximately understood as the greatest similarity between the first string and any substring of the second string. However, this function does not add padding to the boundaries of the extent. Thus, the number of additional characters present in the second string is not considered, except for the mismatched word boundaries.

At the same time, `strict_word_similarity` selects an extent of words in the second string. In the example above, `strict_word_similarity` would select the extent of a single word 'words', whose set of trigrams is { " w", " wo", "wor", "ord", "rds", "ds " }.

```
# SELECT strict_word_similarity('word', 'two words'),
       similarity('word', 'words');
strict_word_similarity | similarity
-----+-----
                0.571429 |    0.571429
(1 row)
```

Thus, the `strict_word_similarity` function is useful for finding the similarity to whole words, while `word_similarity` is more suitable for finding the similarity for parts of words.

**Table F.57. `lt_trgm` Operators**

Operator	Description
<code>text % text → boolean</code>	Returns true if its arguments have a similarity that is greater than the current similarity threshold set by <code>lt_trgm.similarity_threshold</code> .

<b>Operator</b>	<b>Description</b>
<code>text &lt;% text → boolean</code>	Returns <code>true</code> if the similarity between the trigram set in the first argument and a continuous extent of an ordered trigram set in the second argument is greater than the current word similarity threshold set by <code>lt_trgm.word_similarity_threshold</code> parameter.
<code>text %&gt; text → boolean</code>	Commutator of the <code>&lt;%</code> operator.
<code>text &lt;&lt;% text → boolean</code>	Returns <code>true</code> if its second argument has a continuous extent of an ordered trigram set that matches word boundaries, and its similarity to the trigram set of the first argument is greater than the current strict word similarity threshold set by the <code>lt_trgm.strict_word_similarity_threshold</code> parameter.
<code>text %&gt;&gt; text → boolean</code>	Commutator of the <code>&lt;&lt;%</code> operator.
<code>text &lt;-&gt; text → real</code>	Returns the “distance” between the arguments, that is one minus the <code>similarity()</code> value.
<code>text &lt;&lt;-&gt; text → real</code>	Returns the “distance” between the arguments, that is one minus the <code>word_similarity()</code> value.
<code>text &lt;-&gt;&gt; text → real</code>	Commutator of the <code>&lt;&lt;-&gt;</code> operator.
<code>text &lt;&lt;&lt;-&gt; text → real</code>	Returns the “distance” between the arguments, that is one minus the <code>strict_word_similarity()</code> value.
<code>text &lt;-&gt;&gt;&gt; text → real</code>	Commutator of the <code>&lt;&lt;&lt;-&gt;</code> operator.

### F.43.3. GUC Parameters

`lt_trgm.similarity_threshold` (real)

Sets the current similarity threshold that is used by the `%` operator. The threshold must be between 0 and 1 (default is 0.3).

`lt_trgm.word_similarity_threshold` (real)

Sets the current word similarity threshold that is used by the `<%` and `%>` operators. The threshold must be between 0 and 1 (default is 0.6).

`lt_trgm.strict_word_similarity_threshold` (real)

Sets the current strict word similarity threshold that is used by the `<<%` and `%>>` operators. The threshold must be between 0 and 1 (default is 0.5).

### F.43.4. Index Support

The `lt_trgm` module provides GiST and GIN index operator classes that allow you to create an index over a text column for the purpose of very fast similarity searches. These index types support the

above-described similarity operators, and additionally support trigram-based index searches for LIKE, ILIKE, ~ and ~\* queries. (These indexes do not support equality nor simple comparison operators, so you may need a regular B-tree index too.)

Example:

```
CREATE TABLE test_trgm (t text);
CREATE INDEX trgm_idx ON test_trgm USING GIST (t gist_trgm_ops);
```

or

```
CREATE INDEX trgm_idx ON test_trgm USING GIN (t gin_trgm_ops);
```

`gist_trgm_ops` GiST opclass approximates a set of trigrams as a bitmap signature. Its optional integer parameter `siglen` determines the signature length in bytes. The default length is 12 bytes. Valid values of signature length are between 1 and 2024 bytes. Longer signatures lead to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

Example of creating such an index with a signature length of 32 bytes:

```
CREATE INDEX trgm_idx ON test_trgm USING GIST (t
  gist_trgm_ops(siglen=32));
```

At this point, you will have an index on the `t` column that you can use for similarity searching. A typical query is

```
SELECT t, similarity(t, 'word') AS sml
  FROM test_trgm
 WHERE t % 'word'
 ORDER BY sml DESC, t;
```

This will return all values in the text column that are sufficiently similar to `word`, sorted from best match to worst. The index will be used to make this a fast operation even over very large data sets.

A variant of the above query is

```
SELECT t, t <-> 'word' AS dist
  FROM test_trgm
 ORDER BY dist LIMIT 10;
```

This can be implemented quite efficiently by GiST indexes, but not by GIN indexes. It will usually beat the first formulation when only a small number of the closest matches is wanted.

Also you can use an index on the `t` column for word similarity or strict word similarity. Typical queries are:

```
SELECT t, word_similarity('word', t) AS sml
  FROM test_trgm
 WHERE 'word' <% t
 ORDER BY sml DESC, t;
```

and

```
SELECT t, strict_word_similarity('word', t) AS sml
  FROM test_trgm
```

```
WHERE 'word' <<% t
ORDER BY sml DESC, t;
```

This will return all values in the text column for which there is a continuous extent in the corresponding ordered trigram set that is sufficiently similar to the trigram set of *word*, sorted from best match to worst. The index will be used to make this a fast operation even over very large data sets.

Possible variants of the above queries are:

```
SELECT t, 'word' <<-> t AS dist
FROM test_trgm
ORDER BY dist LIMIT 10;
```

and

```
SELECT t, 'word' <<<-> t AS dist
FROM test_trgm
ORDER BY dist LIMIT 10;
```

This can be implemented quite efficiently by GiST indexes, but not by GIN indexes.

Beginning in LightDB 9.1, these index types also support index searches for LIKE and ILIKE, for example

```
SELECT * FROM test_trgm WHERE t LIKE '%foo%bar';
```

The index search works by extracting trigrams from the search string and then looking these up in the index. The more trigrams in the search string, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

Beginning in LightDB 9.3, these index types also support index searches for regular-expression matches (~ and ~\* operators), for example

```
SELECT * FROM test_trgm WHERE t ~ '(foo|bar)';
```

The index search works by extracting trigrams from the regular expression and then looking these up in the index. The more trigrams that can be extracted from the regular expression, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

For both LIKE and regular-expression searches, keep in mind that a pattern with no extractable trigrams will degenerate to a full-index scan.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere.

## F.43.5. Text Search Integration

Trigram matching is a very useful tool when used in conjunction with a full text index. In particular it can help to recognize misspelled input words that will not be matched directly by the full text search mechanism.

The first step is to generate an auxiliary table containing all the unique words in the documents:

```
CREATE TABLE words AS SELECT word FROM
    ts_stat('SELECT to_tsvector(''simple'', bodytext) FROM
documents');
```

where `documents` is a table that has a text field `bodytext` that we wish to search. The reason for using the `simple` configuration with the `to_tsvector` function, instead of using a language-specific configuration, is that we want a list of the original (unstemmed) words.

Next, create a trigram index on the word column:

```
CREATE INDEX words_idx ON words USING GIN (word gin_trgm_ops);
```

Now, a `SELECT` query similar to the previous example can be used to suggest spellings for misspelled words in user search terms. A useful extra test is to require that the selected words are also of similar length to the misspelled word.

### Note

Since the `words` table has been generated as a separate, static table, it will need to be periodically regenerated so that it remains reasonably up-to-date with the document collection. Keeping it exactly current is usually unnecessary.

## F.43.6. References

GiST Development Site <http://www.sai.msu.su/~megera/postgres/gist/>

Tsearch2 Development Site <http://www.sai.msu.su/~megera/postgres/gist/tsearch/V2/>

## F.43.7. Authors

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## F.44. `lt_visibility`

The `lt_visibility` module provides a means for examining the visibility map (VM) and page-level visibility information of a table. It also provides functions to check the integrity of a visibility map and to force it to be rebuilt.

Three different bits are used to store information about page-level visibility. The all-visible bit in the visibility map indicates that every tuple in the corresponding page of the relation is visible to every current and future transaction. The all-frozen bit in the visibility map indicates that every tuple in the page is frozen; that is, no future vacuum will need to modify the page until such time as a tuple is inserted, updated, deleted, or locked on that page. The page header's `PD_ALL_VISIBLE` bit has the same meaning as the all-visible bit in the visibility map, but is stored within the data page itself rather than in a separate data structure. These two bits will normally agree, but the page's all-visible bit can sometimes be set while the visibility map bit is clear after a crash recovery. The reported values can also disagree because of a change that occurs after `lt_visibility` examines the visibility map and before it examines the data page. Any event that causes data corruption can also cause these bits to disagree.

Functions that display information about `PD_ALL_VISIBLE` bits are much more costly than those that only consult the visibility map, because they must read the relation's data blocks rather than



only the (much smaller) visibility map. Functions that check the relation's data blocks are similarly expensive.

## F.44.1. Functions

`pg_visibility_map(relation regclass, blkno bigint, all_visible OUT boolean, all_frozen OUT boolean)` returns record

Returns the all-visible and all-frozen bits in the visibility map for the given block of the given relation.

`pg_visibility(relation regclass, blkno bigint, all_visible OUT boolean, all_frozen OUT boolean, pd_all_visible OUT boolean)` returns record

Returns the all-visible and all-frozen bits in the visibility map for the given block of the given relation, plus the PD\_ALL\_VISIBLE bit of that block.

`pg_visibility_map(relation regclass, blkno OUT bigint, all_visible OUT boolean, all_frozen OUT boolean)` returns setof record

Returns the all-visible and all-frozen bits in the visibility map for each block of the given relation.

`pg_visibility(relation regclass, blkno OUT bigint, all_visible OUT boolean, all_frozen OUT boolean, pd_all_visible OUT boolean)` returns setof record

Returns the all-visible and all-frozen bits in the visibility map for each block of the given relation, plus the PD\_ALL\_VISIBLE bit of each block.

`pg_visibility_map_summary(relation regclass, all_visible OUT bigint, all_frozen OUT bigint)` returns record

Returns the number of all-visible pages and the number of all-frozen pages in the relation according to the visibility map.

`pg_check_frozen(relation regclass, t_ctid OUT tid)` returns setof tid

Returns the TIDs of non-frozen tuples stored in pages marked all-frozen in the visibility map. If this function returns a non-empty set of TIDs, the visibility map is corrupt.

`pg_check_visible(relation regclass, t_ctid OUT tid)` returns setof tid

Returns the TIDs of non-all-visible tuples stored in pages marked all-visible in the visibility map. If this function returns a non-empty set of TIDs, the visibility map is corrupt.

`pg_truncate_visibility_map(relation regclass)` returns void

Truncates the visibility map for the given relation. This function is useful if you believe that the visibility map for the relation is corrupt and wish to force rebuilding it. The first VACUUM executed on the given relation after this function is executed will scan every page in the relation and rebuild the visibility map. (Until that is done, queries will treat the visibility map as containing all zeroes.)

By default, these functions are executable only by superusers and members of the `pg_stat_scan_tables` role, with the exception of `pg_truncate_visibility_map(relation regclass)` which can only be executed by superusers.

## F.44.2. Author

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## F.45. Itaudit

### F.45.1. Introduction

The LightDB Audit Extension (Itaudit) provides detailed session and/or object audit logging via the standard LightDB logging facility.

The goal of the Itaudit is to provide LightDB users with capability to produce audit logs often required to comply with government, financial, or ISO certifications.

An audit is an official inspection of an individual's or organization's accounts, typically by an independent body. The information gathered by Itaudit is properly called an audit trail or audit log. The term audit log is used in this documentation.

### F.45.2. Why Itaudit?

Basic statement logging can be provided by the standard logging facility with `log_statement = all`. This is acceptable for monitoring and other usages but does not provide the level of detail generally required for an audit. It is not enough to have a list of all the operations performed against the database. It must also be possible to find particular statements that are of interest to an auditor. The standard logging facility shows what the user requested, while Itaudit focuses on the details of what happened while the database was satisfying the request.

For example, an auditor may want to verify that a particular table was created inside a documented maintenance window. This might seem like a simple job for `grep`, but what if you are presented with something like this (intentionally obfuscated) example:

```
DO $$
BEGIN
    EXECUTE 'CREATE TABLE import' || 'ant_table (id INT)';
END $$;
```

Standard logging will give you this:

```
LOG: statement: DO $$
BEGIN
    EXECUTE 'CREATE TABLE import' || 'ant_table (id INT)';
END $$;
```

It appears that finding the table of interest may require some knowledge of the code in cases where tables are created dynamically. This is not ideal since it would be preferable to just search on the table name. This is where Itaudit comes in. For the same input, it will produce this output in the log:

```
AUDIT: SESSION,33,1,FUNCTION,DO,,,"DO $$
BEGIN
    EXECUTE 'CREATE TABLE import' || 'ant_table (id INT)';
END $$;"
AUDIT: SESSION,33,2,DDL,CREATE
TABLE,TABLE,public.important_table,CREATE TABLE important_table
(id INT)
```

Not only is the DO block logged, but substatement 2 contains the full text of the CREATE TABLE with the statement type, object type, and full-qualified name to make searches easy.

When logging SELECT and DML statements, Itaudit can be configured to log a separate entry for each relation referenced in a statement. No parsing is required to find all statements that touch a particular

table. In fact, the goal is that the statement text is provided primarily for deep forensics and should not be required for an audit.

### F.45.3. Usage Considerations

Depending on settings, it is possible for `ltaudit` to generate an enormous volume of logging. Be careful to determine exactly what needs to be audit logged in your environment to avoid logging too much.

For example, when working in an OLAP environment it would probably not be wise to audit log inserts into a large fact table. The size of the log file will likely be many times the actual data size of the inserts because the log file is expressed as text. Since logs are generally stored with the OS this may lead to disk space being exhausted very quickly. In cases where it is not possible to limit audit logging to certain tables, be sure to assess the performance impact while testing and allocate plenty of space on the log volume. This may also be true for OLTP environments. Even if the insert volume is not as high, the performance impact of audit logging may still noticeably affect latency.

To limit the number of relations audit logged for `SELECT` and `DML` statements, consider using object audit logging (see Object Auditing). Object audit logging allows selection of the relations to be logged allowing for reduction of the overall log volume. However, when new relations are added they must be explicitly added to object audit logging. A programmatic solution where specified tables are excluded from logging and all others are included may be a good option in this case.

### F.45.4. Settings

Settings may be modified only by a superuser. Allowing normal users to change their settings would defeat the point of an audit log.

Settings can be specified globally (in `lightdb.conf` or using `ALTER SYSTEM ... SET`), at the database level (using `ALTER DATABASE ... SET`), or at the role level (using `ALTER ROLE ... SET`). Note that settings are not inherited through normal role inheritance and `SET ROLE` will not alter a user's `ltaudit` settings. This is a limitation of the roles system and not inherent to `ltaudit`.

The `ltaudit` extension must be loaded in `shared_preload_libraries`. Otherwise, an error will be raised at load time and no audit logging will occur. In addition, `CREATE EXTENSION ltaudit` must be called before `ltaudit.log` is set. If the `ltaudit` extension is dropped and needs to be recreated then `ltaudit.log` must be unset first otherwise an error will be raised.

#### F.45.4.1. ltaudit.log

Specifies which classes of statements will be logged by session audit logging. Possible values are:

- **READ**: `SELECT` and `COPY` when the source is a relation or a query.
- **WRITE**: `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, and `COPY` when the destination is a relation.
- **FUNCTION**: Function calls and `DO` blocks.
- **ROLE**: Statements related to roles and privileges: `GRANT`, `REVOKE`, `CREATE/ALTER/DROP ROLE`.
- **DDL**: All `DDL` that is not included in the `ROLE` class.
- **MISC**: Miscellaneous commands, e.g. `DISCARD`, `FETCH`, `CHECKPOINT`, `VACUUM`, `SET`.
- **MISC\_SET**: Miscellaneous `SET` commands, e.g. `SET ROLE`.
- **ALL**: Include all of the above.

Multiple classes can be provided using a comma-separated list and classes can be subtracted by prefacing the class with a `-` sign (see Session Audit Logging).

The default is none.

### F.45.4.2. `ltaudit.log_catalog`

Specifies that session logging should be enabled in the case where all relations in a statement are in `pg_catalog`. Disabling this setting will reduce noise in the log from tools like `ltsql` and `PgAdmin` that query the catalog heavily.

The default is on.

### F.45.4.3. `ltaudit.log_client`

Specifies whether log messages will be visible to a client process such as `ltsql`. This setting should generally be left disabled but may be useful for debugging or other purposes.

Note that `ltaudit.log_level` is only enabled when `ltaudit.log_client` is on.

The default is off.

### F.45.4.4. `ltaudit.log_level`

Specifies the log level that will be used for log entries (see message levels for valid levels) but note that `ERROR`, `FATAL`, and `PANIC` are not allowed). This setting is used for regression testing and may also be useful to end users for testing or other purposes.

Note that `ltaudit.log_level` is only enabled when `ltaudit.log_client` is on; otherwise the default will be used.

The default is `log`.

### F.45.4.5. `ltaudit.log_parameter`

Specifies that audit logging should include the parameters that were passed with the statement. When parameters are present they will be included in CSV format after the statement text.

The default is off.

### F.45.4.6. `ltaudit.log_relation`

Specifies whether session audit logging should create a separate log entry for each relation (`TABLE`, `VIEW`, etc.) referenced in a `SELECT` or DML statement. This is a useful shortcut for exhaustive logging without using object audit logging.

The default is off.

### F.45.4.7. `ltaudit.log_statement_once`

Specifies whether logging will include the statement text and parameters with the first log entry for a statement/substatement combination or with every entry. Disabling this setting will result in less verbose logging but may make it more difficult to determine the statement that generated a log entry, though the statement/substatement pair along with the process id should suffice to identify the statement text logged with a previous entry.

The default is off.

### F.45.4.8. `ltaudit.role`

Specifies the master role to use for object audit logging. Multiple audit roles can be defined by granting them to the master role. This allows multiple groups to be in charge of different aspects of audit logging.

There is no default.

## F.45.5. Session Audit Logging

Session audit logging provides detailed logs of all statements executed by a user in the backend.

### F.45.5.1. Configuration

Session logging is enabled with the `ltaudit.log` setting.

Enable session logging for all DML and DDL and log all relations in DML statements:

```
set ltaudit.log = 'write, ddl';
set ltaudit.log_relation = on;
```

Enable session logging for all commands except MISC and raise audit log messages as NOTICE:

```
set ltaudit.log = 'all, -misc';
set ltaudit.log_level = notice;
```

### F.45.5.2. Example

In this example session audit logging is used for logging DDL and SELECT statements. Note that the insert statement is not logged since the WRITE class is not enabled

*SQL:*

```
set ltaudit.log = 'read, ddl';

create table account
(
    id int,
    name text,
    password text,
    description text
);

insert into account (id, name, password, description)
values (1, 'user1', 'HASH1', 'blah, blah');

select *
from account;
```

*Log Output:*

```
AUDIT: SESSION,1,1,DDL,CREATE TABLE,TABLE,public.account,create
table account
(
    id int,
    name text,
    password text,
    description text
);,<not logged>
AUDIT: SESSION,2,1,READ,SELECT,,,select *
from account,,<not logged>
```

## F.45.6. Object Audit Logging

Object audit logging logs statements that affect a particular relation. Only `SELECT`, `INSERT`, `UPDATE` and `DELETE` commands are supported. `TRUNCATE` is not included in object audit logging.

Object audit logging is intended to be a finer-grained replacement for `ltaudit.log = 'read, write'`. As such, it may not make sense to use them in conjunction but one possible scenario would be to use session logging to capture each statement and then supplement that with object logging to get more detail about specific relations.

### F.45.6.1. Configuration

Object-level audit logging is implemented via the roles system. The `ltaudit.role` setting defines the role that will be used for audit logging. A relation (`TABLE`, `VIEW`, etc.) will be audit logged when the audit role has permissions for the command executed or inherits the permissions from another role. This allows you to effectively have multiple audit roles even though there is a single master role in any context.

Set `ltaudit.role` to `auditor` and grant `SELECT` and `DELETE` privileges on the `account` table. Any `SELECT` or `DELETE` statements on the `account` table will now be logged:

```
set ltaudit.role = 'auditor';

grant select, delete
  on public.account
  to auditor;
```

### F.45.6.2. Example

In this example object audit logging is used to illustrate how a granular approach may be taken towards logging of `SELECT` and DML statements. Note that logging on the `account` table is controlled by column-level permissions, while logging on the `account_role_map` table is table-level.

*SQL:*

```
set ltaudit.role = 'auditor';

create table account
(
  id int,
  name text,
  password text,
  description text
);

grant select (password)
  on public.account
  to auditor;

select id, name
  from account;

select password
  from account;

grant update (name, password)
```

```
    on public.account
    to auditor;

update account
    set description = 'yada, yada';

update account
    set password = 'HASH2';

create table account_role_map
(
    account_id int,
    role_id int
);

grant select
    on public.account_role_map
    to auditor;

select account.password,
       account_role_map.role_id
from account
     inner join account_role_map
       on account.id = account_role_map.account_id
```

*Log Output:*

```
AUDIT: OBJECT,1,1,READ,SELECT,TABLE,public.account,select password
       from account,<not logged>
AUDIT: OBJECT,2,1,WRITE,UPDATE,TABLE,public.account,update account
       set password = 'HASH2',<not logged>
AUDIT: OBJECT,3,1,READ,SELECT,TABLE,public.account,select
       account.password,
       account_role_map.role_id
       from account
       inner join account_role_map
         on account.id = account_role_map.account_id,<not
logged>
AUDIT: OBJECT,3,1,READ,SELECT,TABLE,public.account_role_map,select
       account.password,
       account_role_map.role_id
       from account
       inner join account_role_map
         on account.id = account_role_map.account_id,<not
logged>
```

## F.45.7. Format

Audit entries are written to the standard logging facility and contain the following columns in comma-separated format. Output is compliant CSV format only if the log line prefix portion of each log entry is removed.

- **AUDIT\_TYPE** - SESSION or OBJECT.
- **STATEMENT\_ID** - Unique statement ID for this session. Each statement ID represents a backend call. Statement IDs are sequential even if some statements are not logged. There may be multiple entries for a statement ID when more than one relation is logged.

- **SUBSTATEMENT\_ID** - Sequential ID for each sub-statement within the main statement. For example, calling a function from a query. Sub-statement IDs are continuous even if some sub-statements are not logged. There may be multiple entries for a sub-statement ID when more than one relation is logged.
- **CLASS** - e.g. READ, ROLE (see `ltaudit.log`).
- **COMMAND** - e.g. ALTER TABLE, SELECT.
- **OBJECT\_TYPE** - TABLE, INDEX, VIEW, etc. Available for SELECT, DML and most DDL statements.
- **OBJECT\_NAME** - The fully-qualified object name (e.g. public.account). Available for SELECT, DML and most DDL statements.
- **STATEMENT** - Statement executed on the backend.
- **PARAMETER** - If `ltaudit.log_parameter` is set then this field will contain the statement parameters as quoted CSV or <none> if there are no parameters. Otherwise, the field is <not logged>.

Use `log_line_prefix` to add any other fields that are needed to satisfy your audit log requirements. A typical log line prefix might be `'%m %u %d [%p]: '` which would provide the date/time, user name, database name, and process id for each audit log.

## F.45.8. Caveats

Object renames are logged under the name they were renamed to. For example, renaming a table will produce the following result:

```
ALTER TABLE test RENAME TO test2;
```

```
AUDIT: SESSION,36,1,DDL,ALTER TABLE,TABLE,public.test2,ALTER TABLE  
test RENAME TO test2,<not logged>
```

It is possible to have a command logged more than once. For example, when a table is created with a primary key specified at creation time the index for the primary key will be logged independently and another audit log will be made for the index under the create entry. The multiple entries will however be contained within one statement ID.

Autovacuum and Autoanalyze are not logged.

Statements that are executed after a transaction enters an aborted state will not be audit logged. However, the statement that caused the error and any subsequent statements executed in the aborted transaction will be logged as ERRORS by the standard logging facility.

## F.46. Itcrypto

The `ltpcrypto` module provides cryptographic functions for LightDB.

This module is considered “trusted”, that is, it can be installed by non-superusers who have CREATE privilege on the current database.

### F.46.1. General Hashing Functions

#### F.46.1.1. `digest()`

`digest(data text, type text)` returns `bytea`



`digest(data bytea, type text)` returns `bytea`

Computes a binary hash of the given *data*. *type* is the algorithm to use. Standard algorithms are `md5`, `sha1`, `sha224`, `sha256`, `sha384` and `sha512`. If `ltdcrypto` was built with `OpenSSL`, more algorithms are available, as detailed in Table F.61.

If you want the digest as a hexadecimal string, use `encode()` on the result. For example:

```
CREATE OR REPLACE FUNCTION sha1(bytea) returns text AS $$
    SELECT encode(digest($1, 'sha1'), 'hex')
$$ LANGUAGE SQL STRICT IMMUTABLE;
```

### F.46.1.2. `hmac()`

`hmac(data text, key text, type text)` returns `bytea`

`hmac(data bytea, key bytea, type text)` returns `bytea`

Calculates hashed MAC for *data* with key *key*. *type* is the same as in `digest()`.

This is similar to `digest()` but the hash can only be recalculated knowing the key. This prevents the scenario of someone altering data and also changing the hash to match.

If the key is larger than the hash block size it will first be hashed and the result will be used as key.

## F.46.2. Password Hashing Functions

The functions `crypt()` and `gen_salt()` are specifically designed for hashing passwords. `crypt()` does the hashing and `gen_salt()` prepares algorithm parameters for it.

The algorithms in `crypt()` differ from the usual MD5 or SHA1 hashing algorithms in the following respects:

1. They are slow. As the amount of data is so small, this is the only way to make brute-forcing passwords hard.
2. They use a random value, called the *salt*, so that users having the same password will have different encrypted passwords. This is also an additional defense against reversing the algorithm.
3. They include the algorithm type in the result, so passwords hashed with different algorithms can co-exist.
4. Some of them are adaptive — that means when computers get faster, you can tune the algorithm to be slower, without introducing incompatibility with existing passwords.

Table F.58 lists the algorithms supported by the `crypt()` function.

**Table F.58. Supported Algorithms for `crypt()`**

Algorithm	Max Password Length	Adaptive?	Salt Bits	Output Length	Description
<code>bf</code>	72	yes	128	60	Blowfish-based, variant 2a
<code>md5</code>	unlimited	no	48	34	MD5-based <code>crypt</code>
<code>xdes</code>	8	yes	24	20	Extended DES

Algorithm	Max Password Length	Adaptive?	Salt Bits	Output Length	Description
des	8	no	12	13	Original UNIX crypt

### F.46.2.1. crypt ( )

`crypt(password text, salt text)` returns `text`

Calculates a crypt(3)-style hash of *password*. When storing a new password, you need to use `gen_salt()` to generate a new *salt* value. To check a password, pass the stored hash value as *salt*, and test whether the result matches the stored value.

Example of setting a new password:

```
UPDATE ... SET pswhash = crypt('new password', gen_salt('md5'));
```

Example of authentication:

```
SELECT (pswhash = crypt('entered password', pswhash)) AS pswmatch
FROM ... ;
```

This returns `true` if the entered password is correct.

### F.46.2.2. gen\_salt ( )

`gen_salt(type text [, iter_count integer ])` returns `text`

Generates a new random salt string for use in `crypt()`. The salt string also tells `crypt()` which algorithm to use.

The *type* parameter specifies the hashing algorithm. The accepted types are: `des`, `xdes`, `md5` and `bf`.

The *iter\_count* parameter lets the user specify the iteration count, for algorithms that have one. The higher the count, the more time it takes to hash the password and therefore the more time to break it. Although with too high a count the time to calculate a hash may be several years — which is somewhat impractical. If the *iter\_count* parameter is omitted, the default iteration count is used. Allowed values for *iter\_count* depend on the algorithm and are shown in Table F.59.

**Table F.59. Iteration Counts for crypt ( )**

Algorithm	Default	Min	Max
xdes	725	1	16777215
bf	6	4	31

For `xdes` there is an additional limitation that the iteration count must be an odd number.

To pick an appropriate iteration count, consider that the original DES crypt was designed to have the speed of 4 hashes per second on the hardware of that time. Slower than 4 hashes per second would probably dampen usability. Faster than 100 hashes per second is probably too fast.

Table F.60 gives an overview of the relative slowness of different hashing algorithms. The table shows how much time it would take to try all combinations of characters in an 8-character password, assuming

that the password contains either only lower case letters, or upper- and lower-case letters and numbers. In the `crypt-bf` entries, the number after a slash is the `iter_count` parameter of `gen_salt`.

**Table F.60. Hash Algorithm Speeds**

Algorithm	Hashes/sec	For [a-z]	For [A-Za-z0-9]	Duration relative to md5 hash
<code>crypt-bf/8</code>	1792	4 years	3927 years	100k
<code>crypt-bf/7</code>	3648	2 years	1929 years	50k
<code>crypt-bf/6</code>	7168	1 year	982 years	25k
<code>crypt-bf/5</code>	13504	188 days	521 years	12.5k
<code>crypt-md5</code>	171584	15 days	41 years	1k
<code>crypt-des</code>	23221568	157.5 minutes	108 days	7
<code>sha1</code>	37774272	90 minutes	68 days	4
<code>md5 (hash)</code>	150085504	22.5 minutes	17 days	1

Notes:

- The machine used is an Intel Mobile Core i3.
- `crypt-des` and `crypt-md5` algorithm numbers are taken from John the Ripper v1.6.38 `-test` output.
- `md5 hash` numbers are from `mdcrack 1.2`.
- `sha1` numbers are from `lcrack-20031130-beta`.
- `crypt-bf` numbers are taken using a simple program that loops over 1000 8-character passwords. That way I can show the speed with different numbers of iterations. For reference: `john -test` shows 13506 loops/sec for `crypt-bf/5`. (The very small difference in results is in accordance with the fact that the `crypt-bf` implementation in `ltcrypto` is the same one used in John the Ripper.)

Note that “try all combinations” is not a realistic exercise. Usually password cracking is done with the help of dictionaries, which contain both regular words and various mutations of them. So, even somewhat word-like passwords could be cracked much faster than the above numbers suggest, while a 6-character non-word-like password may escape cracking. Or not.

## F.46.3. PGP Encryption Functions

The functions here implement the encryption part of the OpenPGP (RFC 4880) standard. Supported are both symmetric-key and public-key encryption.

An encrypted PGP message consists of 2 parts, or *packets*:

- Packet containing a session key — either symmetric-key or public-key encrypted.
- Packet containing data encrypted with the session key.

When encrypting with a symmetric key (i.e., a password):

1. The given password is hashed using a String2Key (S2K) algorithm. This is rather similar to `crypt()` algorithms — purposefully slow and with random salt — but it produces a full-length binary key.
2. If a separate session key is requested, a new random key will be generated. Otherwise the S2K key will be used directly as the session key.

3. If the S2K key is to be used directly, then only S2K settings will be put into the session key packet. Otherwise the session key will be encrypted with the S2K key and put into the session key packet.

When encrypting with a public key:

1. A new random session key is generated.
2. It is encrypted using the public key and put into the session key packet.

In either case the data to be encrypted is processed as follows:

1. Optional data-manipulation: compression, conversion to UTF-8, and/or conversion of line-endings.
2. The data is prefixed with a block of random bytes. This is equivalent to using a random IV.
3. An SHA1 hash of the random prefix and data is appended.
4. All this is encrypted with the session key and placed in the data packet.

### F.46.3.1. `pgp_sym_encrypt ( )`

```
pgp_sym_encrypt(data text, psw text [, options text ]) returns
bytea
pgp_sym_encrypt_bytea(data bytea, psw text [, options text ])
returns bytea
```

Encrypt *data* with a symmetric PGP key *psw*. The *options* parameter can contain option settings, as described below.

### F.46.3.2. `pgp_sym_decrypt ( )`

```
pgp_sym_decrypt(msg bytea, psw text [, options text ]) returns text
pgp_sym_decrypt_bytea(msg bytea, psw text [, options text ])
returns bytea
```

Decrypt a symmetric-key-encrypted PGP message.

Decrypting *bytea* data with `pgp_sym_decrypt` is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with `pgp_sym_decrypt_bytea` is fine.

The *options* parameter can contain option settings, as described below.

### F.46.3.3. `pgp_pub_encrypt ( )`

```
pgp_pub_encrypt(data text, key bytea [, options text ]) returns
bytea
pgp_pub_encrypt_bytea(data bytea, key bytea [, options text ])
returns bytea
```

Encrypt *data* with a public PGP key *key*. Giving this function a secret key will produce an error.

The *options* parameter can contain option settings, as described below.

### F.46.3.4. `pgp_pub_decrypt ( )`

```
pgp_pub_decrypt(msg bytea, key bytea [, psw text [, options
text ]]) returns text
```

```
pgp_pub_decrypt_bytea(msg bytea, key bytea [, psw text [, options
text ]]) returns bytea
```

Decrypt a public-key-encrypted message. *key* must be the secret key corresponding to the public key that was used to encrypt. If the secret key is password-protected, you must give the password in *psw*. If there is no password, but you want to specify options, you need to give an empty password.

Decrypting *bytea* data with `pgp_pub_decrypt` is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with `pgp_pub_decrypt_bytea` is fine.

The *options* parameter can contain option settings, as described below.

### F.46.3.5. `pgp_key_id()`

```
pgp_key_id(bytea) returns text
```

`pgp_key_id` extracts the key ID of a PGP public or secret key. Or it gives the key ID that was used for encrypting the data, if given an encrypted message.

It can return 2 special key IDs:

- `SYMKEY`

The message is encrypted with a symmetric key.

- `ANYKEY`

The message is public-key encrypted, but the key ID has been removed. That means you will need to try all your secret keys on it to see which one decrypts it. `lscrypto` itself does not produce such messages.

Note that different keys may have the same ID. This is rare but a normal event. The client application should then try to decrypt with each one, to see which fits — like handling `ANYKEY`.

### F.46.3.6. `armor()`, `dearmor()`

```
armor(data bytea [, keys text[], values text[] ]) returns text
dearmor(data text) returns bytea
```

These functions wrap/unwrap binary data into PGP ASCII-armor format, which is basically Base64 with CRC and additional formatting.

If the *keys* and *values* arrays are specified, an *armor header* is added to the armored format for each key/value pair. Both arrays must be single-dimensional, and they must be of the same length. The keys and values cannot contain any non-ASCII characters.

### F.46.3.7. `pgp_armor_headers`

```
pgp_armor_headers(data text, key out text, value out text) returns
setof record
```

`pgp_armor_headers()` extracts the armor headers from *data*. The return value is a set of rows with two columns, key and value. If the keys or values contain any non-ASCII characters, they are treated as UTF-8.

### F.46.3.8. Options for PGP Functions

Options are named to be similar to GnuPG. An option's value should be given after an equal sign; separate options from each other with commas. For example:

```
pgp_sym_encrypt(data, psw, 'compress-algo=1, cipher-algo=aes256')
```

All of the options except `convert-crlf` apply only to encrypt functions. Decrypt functions get the parameters from the PGP data.

The most interesting options are probably `compress-algo` and `unicode-mode`. The rest should have reasonable defaults.

#### **F.46.3.8.1. cipher-algo**

Which cipher algorithm to use.

Values: `bf`, `aes128`, `aes192`, `aes256` (OpenSSL-only: `3des`, `cast5`)

Default: `aes128`

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

#### **F.46.3.8.2. compress-algo**

Which compression algorithm to use. Only available if LightDB was built with `zlib`.

Values:

0 - no compression

1 - ZIP compression

2 - ZLIB compression (= ZIP plus meta-data and block CRCs)

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

#### **F.46.3.8.3. compress-level**

How much to compress. Higher levels compress smaller but are slower. 0 disables compression.

Values: 0, 1-9

Default: 6

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

#### **F.46.3.8.4. convert-crlf**

Whether to convert `\n` into `\r\n` when encrypting and `\r\n` to `\n` when decrypting. RFC 4880 specifies that text data should be stored using `\r\n` line-feeds. Use this to get fully RFC-compliant behavior.

Values: 0, 1

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`, `pgp_sym_decrypt`, `pgp_pub_decrypt`

#### **F.46.3.8.5. disable-mdc**

Do not protect data with SHA-1. The only good reason to use this option is to achieve compatibility with ancient PGP products, predating the addition of SHA-1 protected packets to RFC 4880. Recent `gnupg.org` and `pgp.com` software supports it fine.

Values: 0, 1

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

#### **F.46.3.8.6. sess-key**

Use separate session key. Public-key encryption always uses a separate session key; this option is for symmetric-key encryption, which by default uses the S2K key directly.

Values: 0, 1  
Default: 0  
Applies to: pgp\_sym\_encrypt

#### **F.46.3.8.7. s2k-mode**

Which S2K algorithm to use.

Values:  
0 - Without salt. Dangerous!  
1 - With salt but with fixed iteration count.  
3 - Variable iteration count.  
Default: 3  
Applies to: pgp\_sym\_encrypt

#### **F.46.3.8.8. s2k-count**

The number of iterations of the S2K algorithm to use. It must be a value between 1024 and 65011712, inclusive.

Default: A random value between 65536 and 253952  
Applies to: pgp\_sym\_encrypt, only with s2k-mode=3

#### **F.46.3.8.9. s2k-digest-algo**

Which digest algorithm to use in S2K calculation.

Values: md5, sha1  
Default: sha1  
Applies to: pgp\_sym\_encrypt

#### **F.46.3.8.10. s2k-cipher-algo**

Which cipher to use for encrypting separate session key.

Values: bf, aes, aes128, aes192, aes256  
Default: use cipher-algo  
Applies to: pgp\_sym\_encrypt

#### **F.46.3.8.11. unicode-mode**

Whether to convert textual data from database internal encoding to UTF-8 and back. If your database already is UTF-8, no conversion will be done, but the message will be tagged as UTF-8. Without this option it will not be.

Values: 0, 1  
Default: 0  
Applies to: pgp\_sym\_encrypt, pgp\_pub\_encrypt

### F.46.3.9. Generating PGP Keys with GnuPG

To generate a new key:

```
gpg --gen-key
```

The preferred key type is “DSA and Elgamal”.

For RSA encryption you must create either DSA or RSA sign-only key as master and then add an RSA encryption subkey with `gpg --edit-key`.

To list keys:

```
gpg --list-secret-keys
```

To export a public key in ASCII-armor format:

```
gpg -a --export KEYID > public.key
```

To export a secret key in ASCII-armor format:

```
gpg -a --export-secret-keys KEYID > secret.key
```

You need to use `dearmor()` on these keys before giving them to the PGP functions. Or if you can handle binary data, you can drop `-a` from the command.

For more details see `man gpg`, The GNU Privacy Handbook<sup>4</sup> and other documentation on <https://www.gnupg.org/>.

### F.46.3.10. Limitations of PGP Code

- No support for signing. That also means that it is not checked whether the encryption subkey belongs to the master key.
- No support for encryption key as master key. As such practice is generally discouraged, this should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with `lscrypto`, but create new ones, as the usage scenario is rather different.

## F.46.4. Raw Encryption Functions

These functions only run a cipher over data; they don't have any advanced features of PGP encryption. Therefore they have some major problems:

1. They use user key directly as cipher key.
2. They don't provide any integrity checking, to see if the encrypted data was modified.
3. They expect that users manage all encryption parameters themselves, even IV.
4. They don't handle text.

So, with the introduction of PGP encryption, usage of raw encryption functions is discouraged.

---

<sup>4</sup> <https://www.gnupg.org/gph/en/manual.html>



`encrypt(data bytea, key bytea, type text)` returns `bytea`  
`decrypt(data bytea, key bytea, type text)` returns `bytea`

`encrypt_iv(data bytea, key bytea, iv bytea, type text)` returns `bytea`  
`decrypt_iv(data bytea, key bytea, iv bytea, type text)` returns `bytea`

Encrypt/decrypt data using the cipher method specified by *type*. The syntax of the *type* string is:

```
algorithm [ - mode ] [ /pad: padding ]
```

where *algorithm* is one of:

- `bf` — Blowfish
- `aes` — AES (Rijndael-128, -192 or -256)

and *mode* is one of:

- `cbc` — next block depends on previous (default)
- `ecb` — each block is encrypted separately (for testing only)

and *padding* is one of:

- `pkcs` — data may be any length (default)
- `none` — data must be multiple of cipher block size

So, for example, these are equivalent:

```
encrypt(data, 'fooz', 'bf')  
encrypt(data, 'fooz', 'bf-cbc/pad:pkcs')
```

In `encrypt_iv` and `decrypt_iv`, the *iv* parameter is the initial value for the CBC mode; it is ignored for ECB. It is clipped or padded with zeroes if not exactly block size. It defaults to all zeroes in the functions without this parameter.

## F.46.5. Random-Data Functions

`gen_random_bytes(count integer)` returns `bytea`

Returns *count* cryptographically strong random bytes. At most 1024 bytes can be extracted at a time. This is to avoid draining the randomness generator pool.

`gen_random_uuid()` returns `uuid`

Returns a version 4 (random) UUID. (Obsolete, this function is now also included in core LightDB.)

## F.46.6. Notes

### F.46.6.1. Configuration

`ltdcrypto` configures itself according to the findings of the main LightDB `configure` script. The options that affect it are `--with-zlib` and `--with-openssl`.

When compiled with zlib, PGP encryption functions are able to compress data before encrypting.

When compiled with OpenSSL, there will be more algorithms available. Also public-key encryption functions will be faster as OpenSSL has more optimized BIGNUM functions.

**Table F.61. Summary of Functionality with and without OpenSSL**

Functionality	Built-in	With OpenSSL
MD5	yes	yes
SHA1	yes	yes
SHA224/256/384/512	yes	yes
Other digest algorithms	no	yes (Note 1)
Blowfish	yes	yes
AES	yes	yes
DES/3DES/CAST5	no	yes
Raw encryption	yes	yes
PGP Symmetric encryption	yes	yes
PGP Public-Key encryption	yes	yes

When compiled against OpenSSL 3.0.0 and later versions, the legacy provider must be activated in the `openssl.cnf` configuration file in order to use older ciphers like DES or Blowfish.

Notes:

1. Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.

### F.46.6.2. NULL Handling

As is standard in SQL, all functions return NULL, if any of the arguments are NULL. This may create security risks on careless usage.

### F.46.6.3. Security Limitations

All `lcrypto` functions run inside the database server. That means that all the data and passwords move between `lcrypto` and client applications in clear text. Thus you must:

1. Connect locally or use SSL connections.
2. Trust both system and database administrator.

If you cannot, then better do crypto inside client application.

The implementation does not resist side-channel attacks<sup>5</sup>. For example, the time required for a `lcrypto` decryption function to complete varies among ciphertexts of a given size.

### F.46.6.4. Useful Reading

- <https://www.gnupg.org/gph/en/manual.html>

The GNU Privacy Handbook.

- <https://www.openwall.com/crypt/>

Describes the crypt-blowfish algorithm.

<sup>5</sup> [https://en.wikipedia.org/wiki/Side-channel\\_attack](https://en.wikipedia.org/wiki/Side-channel_attack)

- <https://www.iusmentis.com/security/passphrasefaq/>  
How to choose a good password.
- <http://world.std.com/~reinhold/diceware.html>  
Interesting idea for picking passwords.
- <http://www.interhack.net/people/cmcurtin/snake-oil-faq.html>  
Describes good and bad cryptography.

### F.46.6.5. Technical References

- <https://tools.ietf.org/html/rfc4880>  
OpenPGP message format.
- <https://tools.ietf.org/html/rfc1321>  
The MD5 Message-Digest Algorithm.
- <https://tools.ietf.org/html/rfc2104>  
HMAC: Keyed-Hashing for Message Authentication.
- <https://www.usenix.org/legacy/events/usenix99/provos.html>  
Comparison of crypt-des, crypt-md5 and bcrypt algorithms.
- [https://en.wikipedia.org/wiki/Fortuna\\_\(PRNG\)](https://en.wikipedia.org/wiki/Fortuna_(PRNG))  
Description of Fortuna CSPRNG.
- <https://jlcooke.ca/random/>  
Jean-Luc Cooke Fortuna-based `/dev/random` driver for Linux.

### F.46.7. Author

Marko Kreen <markokr@gmail.com>

`libcrypto` uses code from the following sources:

Algorithm	Author	Source origin
DES crypt	David Burren and others	FreeBSD libcrypt
MD5 crypt	Poul-Henning Kamp	FreeBSD libcrypt
Blowfish crypt	Solar Designer	www.openwall.com
Blowfish cipher	Simon Tatham	PuTTY
Rijndael cipher	Brian Gladman	OpenBSD sys/crypto
MD5 hash and SHA1	WIDE Project	KAME kame/sys/crypto
SHA256/384/512	Aaron D. Gifford	OpenBSD sys/crypto
BIGNUM math	Michael J. Fromberger	dartmouth.edu/~sting/sw/imath

### F.47. Itfce

`libfce` - All mode's compatibility functions and operators.

## F.47.1. Features Compatible with all mode

Features compatible with all mode are provided. Functions and operators are created under `lt_catalog`. The table below lists features that can be used in all mode.

**Table F.62. Functions**

Item	Overview
DATABASE	Return current schema as current database
LOCATE	Return the position of the substring in the string

**Table F.63. Operator type compatibility**

Item
LEFTARG:int2 RIGHTARG:text
LEFTARG:int4 RIGHTARG:text
LEFTARG:int8 RIGHTARG:text
LEFTARG:text RIGHTARG:int2
LEFTARG:text RIGHTARG:int4
LEFTARG:text RIGHTARG:int8
LEFTARG:text RIGHTARG:numeric
LEFTARG:numeric RIGHTARG:text

## F.47.2. Functions

- DATABASE
- LOCATE

### F.47.2.1. DATABASE

#### Description

Synonym for `current_schema()`. The concept of schema is similar to that of database in MySQL. You can specify the current schema by setting the `search_path`.

#### Syntax

```
database() RETURNS text
```

#### General rules

- Returns the name of the schema that is first in the search path (or a null value if the search path is empty).
- Like mysql, This is the schema that will be used for any tables or other named objects that are created without specifying a target schema.

#### Example

```
lightdb@lt_test=# select database();
database
```

```

-----
public
(1 row)

```

## F.47.2.2. LOCATE

### Description

Return the position of the first occurrence of substring.

### Syntax

```

LOCATE(substr TEXT,str TEXT) returns INTEGER
LOCATE(substr TEXT,str TEXT,POS INTEGER) returns INTEGER

```

### General rules

- The first syntax returns the position of the first occurrence of substring *substr* in string *str*.
- The second syntax returns the position of the first occurrence of substring *substr* in string *str*, starting at position *pos*.
- Returns 0 if *substr* is not in *str*.
- Returns NULL if any argument is NULL.

### Example

In the following example, position of 'bar' in 'foobarbar', starting at position 5. is returned.

```

SELECT LOCATE('bar', 'foobarbar', 5);
   locate
-----
        7
(1 row)

```

## F.47.3. Operator type compatibility

Add type overloading between text and Numeric Types(int2, int4, int8, numeric) for operators such as '+', '-', '\*', '/', '<', '<=', '>', '>=', '=', '<>' and '%'.

### Example

With it, you can directly add '1.1'::text with 1.

```

lightdb@test=# select '1.1'::text+1;
 ?column?
-----
        2.1
(1 row)

```

When in Oracle or MySQL compatible type (see `lightdb_syntax_compatible_type`), base on the rule that 'unknown' can convert to 'text' in some situations (see Chapter 10 for details), you can directly add '1.1' with 1.

```
lightdb@test=# select '1.1'+1;
?column?
-----
      2.1
(1 row)
```

## F.48. Itfincore

A set of functions to manage pages in memory from LightDB

A set of functions to handle low-level management of relations using mincore to explore cache memory.

### F.48.1. DESCRIPTION

With LightDB, each Table or Index is splitted in segments of (usually) 1GB, and each segment is splitted in pages in memory then in blocks for the filesystem.

Those functions let you know which and how many disk block from a relation are in the page cache of the operating system. It can provide the result as a VarBit and can be stored in a table. Then using this table, it is possible to restore the page cache state for each block of the relation, even in another server, thanks to Streaming Replication.

Other functions are used to set a *POSIX\_FADVISE* flag on the entire relation (each segment). The more usefull are probably *WILLNEED* and *DONTNEED* which push and pop blocks of each segments of a relation from page cache, respectively.

Each functions are call with at least a table name or an index name (or oid) as a parameter and walk each segment of the relation.

### F.48.2. EXAMPLES

Here are some examples of usage. If you want more details go to Documentation\_

#### F.48.2.1. Get current state of a relation

May be useful:

```
cedric=# select * from pgfincore('ltbench_accounts');
   relpath        | segment | os_page_size | rel_os_pages |
pages_mem | group_mem | os_pages_free | databit | pages_dirty |
group_dirty
-----+-----+-----+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+-----+-----+-----+
base/11874/16447  |         0 |          4096 |          262144 |
262144 |         1 |          81016 |              |             0 |
0
base/11874/16447.1 |         1 |          4096 |          65726 |
65726 |         1 |          81016 |              |             0 |
0
(2 rows)
```

Time: 31.563 ms

### F.48.2.2. Load a table or an index in OS Page Buffer

You may want to try to keep a table or an index into the OS Page Cache, or preload a table before your well know big query is executed (reducing the query time).

To do so, just execute the following query:

```
cedric=# select * from pgfadvise_willneed('ltbench_accounts');
      relpath          | os_page_size | rel_os_pages | os_pages_free
-----+-----+-----+-----
 base/11874/16447     |          4096 |          262144 |          169138
 base/11874/16447.1 |          4096 |           65726 |          103352
(2 rows)
```

Time: 4462,936 ms

- The column *os\_page\_size* report that page size is 4KB.
- The column *rel\_os\_pages* is the number of pages of the specified file.
- The column *os\_pages\_free* is the number of free pages in memory (for caching).

### F.48.2.3. Snapshot and Restore the OS Page Buffer state of a table or an index (or more)

You may want to restore a table or an index into the OS Page Cache as it was while you did the snapshot. For example if you have to reboot your server, then when LightDB start up the first queries might be slower because neither LightDB or the OS have pages in their respective cache about the relations involved in those first queries.

Executing a snapshot and a restore is very simple:

```
-- Snapshot
cedric=# create table pgfincore_snapshot as
cedric=# select 'ltbench_accounts'::text as relname,*,now() as
date_snapshot
cedric=# from pgfincore('ltbench_accounts',true);

-- Restore
cedric=# select * from pgfadvise_loader('ltbench_accounts', 0,
true, true,
(select databit from pgfincore_snapshot
where relname='ltbench_accounts' and
segment = 0));
      relpath          | os_page_size | os_pages_free | pages_loaded |
pages_unloaded
-----+-----+-----+-----+-----
 base/11874/16447     |          4096 |          80867 |          262144 |
0
(1 row)
```

Time: 35.349 ms

- The column *pages\_loaded* report how many pages have been read to memory (they may have already been in memoy)

- The column *pages\_unloaded* report how many pages have been removed from memory (they may not have already been in memoy);

## F.48.3. SYNOPSIS

`pgsysconf(OUT os_page_size bigint, OUT os_pages_free bigint, OUT os_total_pages bigint)`  
RETURNS record

`pgsysconf_pretty(OUT os_page_size text, OUT os_pages_free text, OUT os_total_pages text)`  
RETURNS record

`pgfadvise(IN relname regclass, IN fork text, IN action int, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_willneed(IN relname regclass, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_dontneed(IN relname regclass, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_normal(IN relname regclass, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_sequential(IN relname regclass, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_random(IN relname regclass, OUT relpath text, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT os_pages_free bigint)` RETURNS setof record

`pgfadvise_loader(IN relname regclass, IN fork text, IN segment int, IN load bool, IN unload bool, IN databit varbit, OUT relpath text, OUT os_page_size bigint, OUT os_pages_free bigint, OUT pages_loaded bigint, OUT pages_unloaded bigint)` RETURNS setof record

`pgfadvise_loader(IN relname regclass, IN segment int, IN load bool, IN unload bool, IN databit varbit, OUT relpath text, OUT os_page_size bigint, OUT os_pages_free bigint, OUT pages_loaded bigint, OUT pages_unloaded bigint)` RETURNS setof record

`pgfincore(IN relname regclass, IN fork text, IN getdatabit bool, OUT relpath text, OUT segment int, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT pages_mem bigint, OUT group_mem bigint, OUT os_pages_free bigint, OUT databit varbit, OUT pages_dirty bigint, OUT group_dirty bigint)` RETURNS setof record

`pgfincore(IN relname regclass, IN getdatabit bool, OUT relpath text, OUT segment int, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT pages_mem bigint, OUT group_mem bigint, OUT os_pages_free bigint, OUT databit varbit, OUT pages_dirty bigint, OUT group_dirty bigint)` RETURNS setof record

`pgfincore(IN relname regclass, OUT relpath text, OUT segment int, OUT os_page_size bigint, OUT rel_os_pages bigint, OUT pages_mem bigint, OUT group_mem bigint, OUT os_pages_free bigint, OUT databit varbit, OUT pages_dirty bigint, OUT group_dirty bigint)` RETURNS setof record

## F.48.4. DOCUMENTATION

### F.48.4.1. pgsysconf

This function output size of OS blocks, number of free page in the OS Page Buffer.



```
cedric=# select * from pgsysconf();
 os_page_size | os_pages_free | os_total_pages
-----+-----+-----
          4096 |          80431 |          4094174
```

#### F.48.4.2. pgsysconf\_pretty

The same as above, but with pretty output.

```
cedric=# select * from pgsysconf_pretty();
 os_page_size | os_pages_free | os_total_pages
-----+-----+-----
4096 bytes   | 314 MB       | 16 GB
```

#### F.48.4.3. pgfadvise\_WILLNEED

This function set *WILLNEED* flag on the current relation. It means that the Operating System will try to load as much pages as possible of the relation. Main idea is to preload files on server startup, perhaps using cache hit/miss ratio or most required relations/indexes.

```
cedric=# select * from pgfadvise_willneed('ltbench_accounts');
 relpath          | os_page_size | rel_os_pages | os_pages_free
-----+-----+-----+-----
base/11874/16447  |          4096 |          262144 |          80650
base/11874/16447.1 |          4096 |           65726 |          80650
```

#### F.48.4.4. pgfadvise\_DONTNEED

This function set *DONTNEED* flag on the current relation. It means that the Operating System will first unload pages of the file if it need to free some memory. Main idea is to unload files when they are not usefull anymore (instead of perhaps more interesting pages)

```
cedric=# select * from pgfadvise_dontneed('ltbench_accounts');
 relpath          | os_page_size | rel_os_pages | os_pages_free
-----+-----+-----+-----
base/11874/16447  |          4096 |          262144 |          342071
base/11874/16447.1 |          4096 |           65726 |          408103
```

#### F.48.4.5. pgfadvise\_NORMAL

This function set *NORMAL* flag on the current relation.

#### F.48.4.6. pgfadvise\_SEQUENTIAL

This function set *SEQUENTIAL* flag on the current relation.

#### F.48.4.7. pgfadvise\_RANDOM

This function set *RANDOM* flag on the current relation.

#### F.48.4.8. pgfadvise\_loader

This function allow to interact directly with the Page Cache. It can be used to load and/or unload page from memory based on a varbit representing the map of the pages to load/unload accordingly.

Work with relation `ltbench_accounts`, segment 0, arbitrary varbit map:

```
-- Loading and Unloading
cedric=# select * from pgfadvise_loader('ltbench_accounts', 0,
    true, true, B'111000');
    relpath      | os_page_size | os_pages_free | pages_loaded |
    pages_unloaded
-----+-----+-----+-----+
+-----+
base/11874/16447 |          4096 |          408376 |           3 |
              3

-- Loading
cedric=# select * from pgfadvise_loader('ltbench_accounts', 0,
    true, false, B'111000');
    relpath      | os_page_size | os_pages_free | pages_loaded |
    pages_unloaded
-----+-----+-----+-----+
+-----+
base/11874/16447 |          4096 |          408370 |           3 |
              0

-- Unloading
cedric=# select * from pgfadvise_loader('ltbench_accounts', 0,
    false, true, B'111000');
    relpath      | os_page_size | os_pages_free | pages_loaded |
    pages_unloaded
-----+-----+-----+-----+
+-----+
base/11874/16447 |          4096 |          408370 |           0 |
              3
```

### F.48.4.9. pgfincore

This function provide information about the file system cache (page cache).

```
cedric=# select * from pgfincore('ltbench_accounts');
    relpath      | segment | os_page_size | rel_os_pages |
    pages_mem | group_mem | os_pages_free | databit | pages_dirty |
    group_dirty
-----+-----+-----+-----+
+-----+
+-----+
base/11874/16447 |         0 |          4096 |          262144 |
  3 |         1 |         408444 |           0 |
  0
base/11874/16447.1 |         1 |          4096 |           65726 |
  0 |         0 |         408444 |           0 |
  0
```

For the specified relation it returns:

- `relpath` : the relation path
- `segment` : the segment number analyzed
- `os_page_size` : the size of one page
- `rel_os_pages` : the total number of pages of the relation

- `pages_mem` : the total number of relation's pages in page cache. (not the shared buffers from LightDB but the OS cache)
- `group_mem` : the number of groups of adjacent `pages_mem`
- `os_page_free` : the number of free page in the OS page cache
- `databit` : the varbit map of the file, because of its size it is useless to output Use `pgfincore("ltbench_accounts",true)` to activate it.
- `pages_dirty` : if `HAVE_FINCORE` constant is define and the platform provides the relevant information, like `pages_mem` but for dirtied pages
- `group_dirty` : if `HAVE_FINCORE` constant is define and the platform provides the relevant information, like `group_mem` but for dirtied pages

## F.48.5. DEBUG

You can debug the `ltfincore` with the following error level: `DEBUG1` and `DEBUG5`.

For example:

```
set client_min_messages TO debug1; -- debug5 is only usefull to
trace each block
```

## F.48.6. REQUIREMENTS

- `ltfincore` needs `mincore()` or `fincore()` and `POSIX_FADVISE`

## F.48.7. LIMITATIONS

- `ltfincore` has a limited mode when `POSIX_FADVISE` is not provided by the platform.

## F.49. Itree

This module implements a data type `ltree` for representing labels of data stored in a hierarchical tree-like structure. Extensive facilities for searching through label trees are provided.

This module is considered "trusted", that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.49.1. Definitions

A *label* is a sequence of alphanumeric characters and underscores (for example, in C locale the characters `A-Za-z0-9_` are allowed). Labels must be less than 256 characters long.

Examples: `42`, `Personal_Services`

A *label path* is a sequence of zero or more labels separated by dots, for example `L1.L2.L3`, representing a path from the root of a hierarchical tree to a particular node. The length of a label path cannot exceed 65535 labels.

Example: `Top.Countries.Europe.Russia`

The `ltree` module provides several data types:

- `ltree` stores a label path.
- `lquery` represents a regular-expression-like pattern for matching `ltree` values. A simple word matches that label within a path. A star symbol (`*`) matches zero or more labels. These can be joined with dots to form a pattern that must match the whole label path. For example:

```
foo           Match the exact label path foo
*.foo.*      Match any label path containing the label foo
*.foo        Match any label path whose last label is foo
```

Both star symbols and simple words can be quantified to restrict how many labels they can match:

```
*{n}         Match exactly n labels
*{n,}        Match at least n labels
*{n,m}       Match at least n but not more than m labels
*{,m}        Match at most m labels – same as *{0,m}
foo{n,m}     Match at least n but not more than m occurrences
              of foo
foo{,}       Match any number of occurrences of foo, including
              zero
```

In the absence of any explicit quantifier, the default for a star symbol is to match any number of labels (that is, { , }) while the default for a non-star item is to match exactly once (that is, {1}).

There are several modifiers that can be put at the end of a non-star lquery item to make it match more than just the exact match:

```
@           Match case-insensitively, for example a@ matches A
*           Match any label with this prefix, for example foo*
              matches foobar
%           Match initial underscore-separated words
```

The behavior of % is a bit complicated. It tries to match words rather than the entire label. For example foo\_bar% matches foo\_bar\_baz but not foo\_barbaz. If combined with \*, prefix matching applies to each word separately, for example foo\_bar%\* matches foo1\_bar2\_baz but not foo1\_br2\_baz.

Also, you can write several possibly-modified non-star items separated with | (OR) to match any of those items, and you can put ! (NOT) at the start of a non-star group to match any label that doesn't match any of the alternatives. A quantifier, if any, goes at the end of the group; it means some number of matches for the group as a whole (that is, some number of labels matching or not matching any of the alternatives).

Here's an annotated example of lquery:

```
Top.*{0,2}.sport*@.!football|tennis{1,}.Russ*|Spain
a.  b.      c.      d.      e.
```

This query will match any label path that:

- a. begins with the label Top
- b. and next has zero to two labels before
- c. a label beginning with the case-insensitive prefix sport
- d. then has one or more labels, none of which match football nor tennis
- e. and then ends with a label beginning with Russ or exactly matching Spain.

- ltxtquery represents a full-text-search-like pattern for matching ltree values. An ltxtquery value contains words, possibly with the modifiers @, \*, % at the end; the modifiers

have the same meanings as in `lquery`. Words can be combined with `&` (AND), `|` (OR), `!` (NOT), and parentheses. The key difference from `lquery` is that `ltxquery` matches words without regard to their position in the label path.

Here's an example `ltxquery`:

```
Europe & Russia*@ & !Transportation
```

This will match paths that contain the label `Europe` and any label beginning with `Russia` (case-insensitive), but not paths containing the label `Transportation`. The location of these words within the path is not important. Also, when `%` is used, the word can be matched to any underscore-separated word within a label, regardless of position.

Note: `ltxquery` allows whitespace between symbols, but `ltree` and `lquery` do not.

## F.49.2. Operators and Functions

Type `ltree` has the usual comparison operators `=`, `<>`, `<`, `>`, `<=`, `>=`. Comparison sorts in the order of a tree traversal, with the children of a node sorted by label text. In addition, the specialized operators shown in Table F.64 are available.

**Table F.64. `ltree` Operators**

Operator	Description
<code>ltree @&gt; ltree</code>	<code>boolean</code> Is left argument an ancestor of right (or equal)?
<code>ltree &lt;@ ltree</code>	<code>boolean</code> Is left argument a descendant of right (or equal)?
<code>ltree ~ lquery</code>	<code>boolean</code>
<code>lquery ~ ltree</code>	<code>boolean</code> Does <code>ltree</code> match <code>lquery</code> ?
<code>ltree ? lquery[]</code>	<code>boolean</code>
<code>lquery[] ? ltree</code>	<code>boolean</code> Does <code>ltree</code> match any <code>lquery</code> in array?
<code>ltree @ ltxquery</code>	<code>boolean</code>
<code>ltxquery @ ltree</code>	<code>boolean</code> Does <code>ltree</code> match <code>ltxquery</code> ?
<code>ltree    ltree</code>	<code>ltree</code> Concatenates <code>ltree</code> paths.
<code>ltree    text</code>	<code>ltree</code>
<code>text    ltree</code>	<code>ltree</code> Converts text to <code>ltree</code> and concatenates.
<code>ltree[] @&gt; ltree</code>	<code>boolean</code>
<code>ltree &lt;@ ltree[]</code>	<code>boolean</code> Does array contain an ancestor of <code>ltree</code> ?
<code>ltree[] &lt;@ ltree</code>	<code>boolean</code>
<code>ltree @&gt; ltree[]</code>	<code>boolean</code> Does array contain a descendant of <code>ltree</code> ?

<b>Operator</b>	<b>Description</b>
<code>ltree[] ~ lquery</code> → boolean <code>lquery ~ ltree[]</code> → boolean	Does array contain any path matching <code>lquery</code> ?
<code>ltree[] ? lquery[]</code> → boolean <code>lquery[] ? ltree[]</code> → boolean	Does <code>ltree</code> array contain any path matching any <code>lquery</code> ?
<code>ltree[] @ ltxtquery</code> → boolean <code>ltxtquery @ ltree[]</code> → boolean	Does array contain any path matching <code>ltxtquery</code> ?
<code>ltree[] ?@&gt; ltree</code> → ltree	Returns first array entry that is an ancestor of <code>ltree</code> , or NULL if none.
<code>ltree[] ?&lt;@ ltree</code> → ltree	Returns first array entry that is a descendant of <code>ltree</code> , or NULL if none.
<code>ltree[] ?~ lquery</code> → ltree	Returns first array entry that matches <code>lquery</code> , or NULL if none.
<code>ltree[] ?@ ltxtquery</code> → ltree	Returns first array entry that matches <code>ltxtquery</code> , or NULL if none.

The operators `<@`, `@>`, `@` and `~` have analogues `^<@`, `^@>`, `^@`, `^~`, which are the same except they do not use indexes. These are useful only for testing purposes.

The available functions are shown in Table F.65.

**Table F.65. ltree Functions**

<b>Function</b>	<b>Description</b> <b>Example(s)</b>
<code>subtree ( ltree, start integer, end integer )</code> → ltree	Returns subpath of <code>ltree</code> from position <code>start</code> to position <code>end-1</code> (counting from 0). <code>subtree( 'Top.Child1.Child2', 1, 2 )</code> → Child1
<code>subpath ( ltree, offset integer, len integer )</code> → ltree	Returns subpath of <code>ltree</code> starting at position <code>offset</code> , with length <code>len</code> . If <code>offset</code> is negative, subpath starts that far from the end of the path. If <code>len</code> is negative, leaves that many labels off the end of the path. <code>subpath( 'Top.Child1.Child2', 0, 2 )</code> → Top.Child1
<code>subpath ( ltree, offset integer )</code> → ltree	Returns subpath of <code>ltree</code> starting at position <code>offset</code> , extending to end of path. If <code>offset</code> is negative, subpath starts that far from the end of the path. <code>subpath( 'Top.Child1.Child2', 1 )</code> → Child1.Child2
<code>nlevel ( ltree )</code> → integer	Returns number of labels in path. <code>nlevel( 'Top.Child1.Child2' )</code> → 3
<code>index ( a ltree, b ltree )</code> → integer	Returns position of first occurrence of <code>b</code> in <code>a</code> , or -1 if not found.

Function	Description	Example(s)
		<code>index('0.1.2.3.5.4.5.6.8.5.6.8', '5.6') → 6</code>
	<code>index(a ltree, b ltree, offset integer) → integer</code> Returns position of first occurrence of <i>b</i> in <i>a</i> , or -1 if not found. The search starts at position <i>offset</i> ; negative <i>offset</i> means start <i>-offset</i> labels from the end of the path.	<code>index('0.1.2.3.5.4.5.6.8.5.6.8', '5.6', -4) → 9</code>
	<code>text2ltree(text) → ltree</code> Casts <i>text</i> to <i>ltree</i> .	
	<code>ltree2text(ltree) → text</code> Casts <i>ltree</i> to <i>text</i> .	
	<code>lca(ltree [, ltree [, ...]]) → ltree</code> Computes longest common ancestor of paths (up to 8 arguments are supported).	<code>lca('1.2.3', '1.2.3.4.5.6') → 1.2</code>
	<code>lca(ltree[]) → ltree</code> Computes longest common ancestor of paths in array.	<code>lca(array['1.2.3'::ltree, '1.2.3.4']) → 1.2</code>

## F.49.3. Indexes

*ltree* supports several types of indexes that can speed up the indicated operators:

- B-tree index over *ltree*: <, <=, =, >=, >
- GiST index over *ltree* (`gist_ltree_ops` opclass): <, <=, =, >=, >, @>, <@, @, ~, ?

`gist_ltree_ops` GiST opclass approximates a set of path labels as a bitmap signature. Its optional integer parameter `siglen` determines the signature length in bytes. The default signature length is 8 bytes. Valid values of signature length are between 1 and 2024 bytes. Longer signatures lead to a more precise search (scanning a smaller fraction of the index and fewer heap pages), at the cost of a larger index.

Example of creating such an index with the default signature length of 8 bytes:

```
CREATE INDEX path_gist_idx ON test USING GIST (path);
```

Example of creating such an index with a signature length of 100 bytes:

```
CREATE INDEX path_gist_idx ON test USING GIST (path
gist_ltree_ops(siglen=100));
```

- GiST index over *ltree[]* (`gist__ltree_ops` opclass): *ltree[]* <@ *ltree*, *ltree* @> *ltree[]*, @, ~, ?

`gist__ltree_ops` GiST opclass works similarly to `gist_ltree_ops` and also takes signature length as a parameter. The default value of `siglen` in `gist__ltree_ops` is 28 bytes.

Example of creating such an index with the default signature length of 28 bytes:

```
CREATE INDEX path_gist_idx ON test USING GIST (array_path);
```

Example of creating such an index with a signature length of 100 bytes:

```
CREATE INDEX path_gist_idx ON test USING GIST (array_path
gist__ltree_ops(siglen=100));
```

Note: This index type is lossy.

## F.49.4. Example

This example uses the following data (also available in file contrib/ltree/ltreetest.sql in the source distribution):

```
CREATE TABLE test (path ltree);
INSERT INTO test VALUES ('Top');
INSERT INTO test VALUES ('Top.Science');
INSERT INTO test VALUES ('Top.Science.Astronomy');
INSERT INTO test VALUES ('Top.Science.Astronomy.Astrophysics');
INSERT INTO test VALUES ('Top.Science.Astronomy.Cosmology');
INSERT INTO test VALUES ('Top.Hobbies');
INSERT INTO test VALUES ('Top.Hobbies.Amateurs_Astronomy');
INSERT INTO test VALUES ('Top.Collections');
INSERT INTO test VALUES ('Top.Collections.Pictures');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy');
INSERT INTO test VALUES
('Top.Collections.Pictures.Astronomy.Stars');
INSERT INTO test VALUES
('Top.Collections.Pictures.Astronomy.Galaxies');
INSERT INTO test VALUES
('Top.Collections.Pictures.Astronomy.Astronauts');
CREATE INDEX path_gist_idx ON test USING GIST (path);
CREATE INDEX path_idx ON test USING BTREE (path);
```

Now, we have a table test populated with data describing the hierarchy shown below:

```

              Top
             /  |  \
          Science Hobbies Collections
           /      |      \
        Astronomy Amateurs_Astronomy Pictures
         /  \      |
    Astrophysics Cosmology           Astronomy
                                     /  |  \
                                   Galaxies Stars Astronauts
```

We can do inheritance:

```
ltreetest=> SELECT path FROM test WHERE path <@ 'Top.Science';
           path
-----
Top.Science
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
```



(4 rows)

Here are some examples of path matching:

```
ltreetest=> SELECT path FROM test WHERE path ~ '*.Astronomy.*';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
Top.Collections.Pictures.Astronomy
Top.Collections.Pictures.Astronomy.Stars
Top.Collections.Pictures.Astronomy.Galaxies
Top.Collections.Pictures.Astronomy.Astronauts
(7 rows)
```

```
ltreetest=> SELECT path FROM test WHERE path ~ '.*!
pictures@.Astronomy.*';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
(3 rows)
```

Here are some examples of full text search:

```
ltreetest=> SELECT path FROM test WHERE path @ 'Astro*% & !
pictures@';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
Top.Hobbies.Amateurs_Astronomy
(4 rows)
```

```
ltreetest=> SELECT path FROM test WHERE path @ 'Astro* & !
pictures@';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
(3 rows)
```

Path construction using functions:

```
ltreetest=> SELECT subpath(path,0,2) || 'Space' || subpath(path,2) FROM
test WHERE path <@ 'Top.Science.Astronomy';
           ?column?
```

```
-----
Top.Science.Space.Astronomy
Top.Science.Space.Astronomy.Astrophysics
Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

We could simplify this by creating a SQL function that inserts a label at a specified position in a path:

```
CREATE FUNCTION ins_label(ltree, int, text) RETURNS ltree
AS 'select subpath($1,0,$2) || $3 || subpath($1,$2);'
LANGUAGE SQL IMMUTABLE;

ltreetest=> SELECT ins_label(path,2,'Space') FROM test WHERE path
<@ 'Top.Science.Astronomy';
           ins_label
-----
Top.Science.Space.Astronomy
Top.Science.Space.Astronomy.Astrophysics
Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

## F.49.5. Authors

All work was done by Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megeera/postgres/gist/> for additional information. Authors would like to thank Eugeny Rodichev for helpful discussions. Comments and bug reports are welcome.

## F.50. Itrowlocks

The `ltrowlocks` module provides a function to show row locking information for a specified table.

By default use is restricted to superusers, members of the `pg_stat_scan_tables` role, and users with `SELECT` permissions on the table.

### F.50.1. Overview

`pgrowlocks(text)` returns `setof record`

The parameter is the name of a table. The result is a set of records, with one row for each locked row within the table. The output columns are shown in Table F.66.

**Table F.66. `pgrowlocks` Output Columns**

Name	Type	Description
<code>locked_row</code>	<code>tid</code>	Tuple ID (TID) of locked row
<code>locker</code>	<code>xid</code>	Transaction ID of locker, or multixact ID if multitransaction
<code>multi</code>	<code>boolean</code>	True if locker is a multitransaction
<code>xids</code>	<code>xid[]</code>	Transaction IDs of lockers (more than one if multitransaction)
<code>modes</code>	<code>text[]</code>	Lock mode of lockers (more than one if multitransaction), an array of Key Share, Share, For No Key Update, No Key Update, For Update, Update.

Name	Type	Description
<code>pids</code>	<code>integer[]</code>	Process IDs of locking backends (more than one if multitransaction)

`pgrowlocks` takes `AccessShareLock` for the target table and reads each row one by one to collect the row locking information. This is not very speedy for a large table. Note that:

1. If an `ACCESS EXCLUSIVE` lock is taken on the table, `pgrowlocks` will be blocked.
2. `pgrowlocks` is not guaranteed to produce a self-consistent snapshot. It is possible that a new row lock is taken, or an old lock is freed, during its execution.

`pgrowlocks` does not show the contents of locked rows. If you want to take a look at the row contents at the same time, you could do something like this:

```
SELECT * FROM accounts AS a, pgrowlocks('accounts') AS p
WHERE p.locked_row = a.ctid;
```

Be aware however that such a query will be very inefficient.

## F.50.2. Sample Output

```
=# SELECT * FROM pgrowlocks('t1');
locked_row | locker | multi | xids | modes | pids
-----+-----+-----+-----+-----+-----
(0,1)      | 609   | f     | {609} | {"For Share"} | {3161}
(0,2)      | 609   | f     | {609} | {"For Share"} | {3161}
(0,3)      | 607   | f     | {607} | {"For Update"} | {3107}
(0,4)      | 607   | f     | {607} | {"For Update"} | {3107}
(4 rows)
```

## F.50.3. Author

Tatsuo Ishii

## F.51. Itstattuple

The `ltstattuple` module provides various functions to obtain tuple-level statistics.

Because these functions return detailed page-level information, access is restricted by default. By default, only the role `pg_stat_scan_tables` has `EXECUTE` privilege. Superusers of course bypass this restriction. After the extension has been installed, users may issue `GRANT` commands to change the privileges on the functions to allow others to execute them. However, it might be preferable to add those users to the `pg_stat_scan_tables` role instead.

### F.51.1. Functions

`pgstattuple(regclass)` returns record

`pgstattuple` returns a relation's physical length, percentage of “dead” tuples, and other info. This may help users to determine whether vacuum is necessary or not. The argument is the target relation's name (optionally schema-qualified) or OID. For example:

```
test=> SELECT * FROM pgstattuple('pg_catalog.pg_proc');
```

```

-[ RECORD 1 ]-----+-----
table_len      | 458752
tuple_count    | 1470
tuple_len      | 438896
tuple_percent  | 95.67
dead_tuple_count | 11
dead_tuple_len | 3157
dead_tuple_percent | 0.69
free_space     | 8932
free_percent   | 1.95

```

The output columns are described in Table F.67.

**Table F.67. pgstattuple Output Columns**

Column	Type	Description
table_len	bigint	Physical relation length in bytes
tuple_count	bigint	Number of live tuples
tuple_len	bigint	Total length of live tuples in bytes
tuple_percent	float8	Percentage of live tuples
dead_tuple_count	bigint	Number of dead tuples
dead_tuple_len	bigint	Total length of dead tuples in bytes
dead_tuple_percent	float8	Percentage of dead tuples
free_space	bigint	Total free space in bytes
free_percent	float8	Percentage of free space

### Note

The `table_len` will always be greater than the sum of the `tuple_len`, `dead_tuple_len` and `free_space`. The difference is accounted for by fixed page overhead, the per-page table of pointers to tuples, and padding to ensure that tuples are correctly aligned.

`pgstattuple` acquires only a read lock on the relation. So the results do not reflect an instantaneous snapshot; concurrent updates will affect them.

`pgstattuple` judges a tuple is “dead” if `HeapTupleSatisfiesDirty` returns false.

`pgstattuple(text)` returns record

This is the same as `pgstattuple(regclass)`, except that the target relation is specified as TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

`pgstatindex(regclass)` returns record

`pgstatindex` returns a record showing information about a B-tree index. For example:

```

test=> SELECT * FROM pgstatindex('pg_cast_oid_index');
-[ RECORD 1 ]-----+-----

```

```

version          | 2
tree_level      | 0
index_size      | 16384
root_block_no   | 1
internal_pages  | 0
leaf_pages      | 1
empty_pages     | 0
deleted_pages   | 0
avg_leaf_density| 54.27
leaf_fragmentation | 0
    
```

The output columns are:

Column	Type	Description
version	integer	B-tree version number
tree_level	integer	Tree level of the root page
index_size	bigint	Total index size in bytes
root_block_no	bigint	Location of root page (zero if none)
internal_pages	bigint	Number of "internal" (upper-level) pages
leaf_pages	bigint	Number of leaf pages
empty_pages	bigint	Number of empty pages
deleted_pages	bigint	Number of deleted pages
avg_leaf_density	float8	Average density of leaf pages
leaf_fragmentation	float8	Leaf page fragmentation

The reported `index_size` will normally correspond to one more page than is accounted for by `internal_pages` + `leaf_pages` + `empty_pages` + `deleted_pages`, because it also includes the index's metapage.

As with `pgstattuple`, the results are accumulated page-by-page, and should not be expected to represent an instantaneous snapshot of the whole index.

`pgstatindex(text)` returns record

This is the same as `pgstatindex(regclass)`, except that the target index is specified as TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

`pgstatginindex(regclass)` returns record

`pgstatginindex` returns a record showing information about a GIN index. For example:

```

test=> SELECT * FROM pgstatginindex('test_gin_index');
-[ RECORD 1 ]---
version          | 1
pending_pages    | 0
pending_tuples   | 0
    
```

The output columns are:

Column	Type	Description
version	integer	GIN version number

Column	Type	Description
pending_pages	integer	Number of pages in the pending list
pending_tuples	bigint	Number of tuples in the pending list

pgstathashindex(regclass) returns record

pgstathashindex returns a record showing information about a HASH index. For example:

```
test=> select * from pgstathashindex('con_hash_index');
-[ RECORD 1 ]-----+-----
version          | 4
bucket_pages    | 33081
overflow_pages  | 0
bitmap_pages    | 1
unused_pages    | 32455
live_items      | 10204006
dead_items      | 0
free_percent    | 61.8005949100872
```

The output columns are:

Column	Type	Description
version	integer	HASH version number
bucket_pages	bigint	Number of bucket pages
overflow_pages	bigint	Number of overflow pages
bitmap_pages	bigint	Number of bitmap pages
unused_pages	bigint	Number of unused pages
live_items	bigint	Number of live tuples
dead_tuples	bigint	Number of dead tuples
free_percent	float	Percentage of free space

pg\_relpages(regclass) returns bigint

pg\_relpages returns the number of pages in the relation.

pg\_relpages(text) returns bigint

This is the same as pg\_relpages(regclass), except that the target relation is specified as TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

pgstattuple\_approx(regclass) returns record

pgstattuple\_approx is a faster alternative to pgstattuple that returns approximate results. The argument is the target relation's name or OID. For example:

```
test=> SELECT * FROM
  pgstattuple_approx('pg_catalog.pg_proc'::regclass);
-[ RECORD 1 ]-----+-----
table_len          | 573440
scanned_percent    | 2
```

```

approx_tuple_count    | 2740
approx_tuple_len      | 561210
approx_tuple_percent  | 97.87
dead_tuple_count      | 0
dead_tuple_len        | 0
dead_tuple_percent    | 0
approx_free_space     | 11996
approx_free_percent   | 2.09

```

The output columns are described in Table F.68.

Whereas `pgstattuple` always performs a full-table scan and returns an exact count of live and dead tuples (and their sizes) and free space, `pgstattuple_approx` tries to avoid the full-table scan and returns exact dead tuple statistics along with an approximation of the number and size of live tuples and free space.

It does this by skipping pages that have only visible tuples according to the visibility map (if a page has the corresponding VM bit set, then it is assumed to contain no dead tuples). For such pages, it derives the free space value from the free space map, and assumes that the rest of the space on the page is taken up by live tuples.

For pages that cannot be skipped, it scans each tuple, recording its presence and size in the appropriate counters, and adding up the free space on the page. At the end, it estimates the total number of live tuples based on the number of pages and tuples scanned (in the same way that `VACUUM` estimates `pg_class.reltuples`).

**Table F.68. `pgstattuple_approx` Output Columns**

Column	Type	Description
<code>table_len</code>	<code>bigint</code>	Physical relation length in bytes (exact)
<code>scanned_percent</code>	<code>float8</code>	Percentage of table scanned
<code>approx_tuple_count</code>	<code>bigint</code>	Number of live tuples (estimated)
<code>approx_tuple_len</code>	<code>bigint</code>	Total length of live tuples in bytes (estimated)
<code>approx_tuple_percent</code>	<code>float8</code>	Percentage of live tuples
<code>dead_tuple_count</code>	<code>bigint</code>	Number of dead tuples (exact)
<code>dead_tuple_len</code>	<code>bigint</code>	Total length of dead tuples in bytes (exact)
<code>dead_tuple_percent</code>	<code>float8</code>	Percentage of dead tuples
<code>approx_free_space</code>	<code>bigint</code>	Total free space in bytes (estimated)
<code>approx_free_percent</code>	<code>float8</code>	Percentage of free space

In the above output, the free space figures may not match the `pgstattuple` output exactly, because the free space map gives us an exact figure, but is not guaranteed to be accurate to the byte.

## F.51.2. Authors

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## F.52. `It_walminer`

## F.52.1. What is It\_walminer?

Please refer to the It\_walminer reference manual<sup>6</sup>.

## F.53. myfce

myfce - Mysql's compatibility functions.

### F.53.1. Features Compatible with Mysql Databases

Features compatible with Mysql databases are provided. These features enable you to easily migrate to LightDB and reduce the costs of reconfiguring applications. The table below lists features compatible with Mysql databases.

**Table F.69. Data type**

Item	Overview
DATETIME	DATETIME is an alias for timestamp without time zone.
LONGTEXT	LONGTEXT is an alias for TEXT.
SIGNED	SIGNED is a signed integer, equivalent to bigint.

**Table F.70. Data Cast**

Item	Overview
bool->varchar	Transform bool type true to string '1' and false to string '0' for compatible with mysql
cast(expr as unsigned)	Transform expr to unsigned bigint value, but now return type is numeric.

**Table F.71. Mathematical Functions**

Item	Overview
CONV	Convert numbers between different number bases
LOG10	Return the base-10 logarithm of the argument
LOG2	Return the base-2 logarithm of the argument
RAND	Returns a random floating-point value v in the range 0 and 1.0
TRUNCATE	Truncate to specified number of decimal places

**Table F.72. String Functions**

Item	Overview
ELT	Return string at index number
FIELD	Index (position) of first argument in subsequent arguments
FIND_IN_SET	Index (position) of first argument within second argument
FROM_BASE64	Decode base64 encoded string and return result

<sup>6</sup> [https://gitee.com/zhjh256/It\\_walminer/blob/master/README.md](https://gitee.com/zhjh256/It_walminer/blob/master/README.md)



Item	Overview
INSERT	Insert substring at specified position up to specified number of characters
INSTR	Get the first occurrence position of the substring
LCASE	Synonym for LOWER()
LOCATE	Return the position of the first occurrence of substring
MID	Return a substring starting from the specified position
SPACE	Return a string of the specified number of spaces
STRCMP	Compare two strings
TO_BASE64	Return the argument converted to a base-64 string
UCASE	Synonym for UPPER()
SUBSTR	Return the substring as specified
SUBSTRING	Return the substring as specified
SUBSTRING_INDEX	Return a substring from a string before the specified number of occurrences of the delimiter

**Table F.73. Date/Time Functions**

Item	Overview
DATEDIFF	Subtract two dates
DATE_ADD	Add the specified time interval to the date
DATE_FORMAT	Return date / time data in different formats
DATE_SUB	Subtracts the specified time interval from the date
DAY	Returns the date part of the date month
DAYOFWEEK	Returns the day of the week index of the current week, starting at 1
FROM_UNIXTIME	Returns the date / datetime representation of the UNIX timestamp
SEC_TO_TIME	Converts seconds to 'hh:mm:ss' format
STR_TO_DATE	Convert string to date / time value
SYSDATE	Return the time at which the function executes
TIME_TO_SEC	Return the argument converted to seconds
TIMEDIFF	Subtract time
TIMESTAMPDIFF	Subtract an interval from a datetime expression
TO_DAYS	Return the date argument converted to days
TO_SECONDS	Return the date or datetime argument converted to seconds since Year 0
UNIX_TIMESTAMP	Returns the UNIX timestamp of an exact point in time
WEEKOFYEAR	Returns the number of weeks of the date
YEAR	Returns the year of the date
QUARTER	Returns the quarter of the year for date

Item	Overview
LAST_DAY	Return the last day of the month for the argument
CURDATE	Return the current date

**Table F.74. JSON Functions**

Item	Overview
JSON_ARRAY	Evaluates a (possibly empty) list of values and returns a JSON array containing those values.
JSON_OBJECT	Evaluates a (possibly empty) list of key-value pairs and returns a JSON object containing those pairs.
JSON_EXTRACT	Returns data from a JSON document, selected from the parts of the document matched by the path arguments.
JSON_CONTAINS	Indicates by returning true or false whether a given candidate JSON document is contained within a target JSON document.
JSON_CONTAINS_PATH	Returns true or false to indicate whether a JSON document contains data at a given path or paths.
JSON_PRETTY	Provides pretty-printing of JSON values similar to that implemented in PHP and by other languages and database systems.
JSON_REMOVE	Removes data from a JSON document and returns the result.
JSON_INSERT	Inserts data into a JSON document and returns the result.
JSON_REPLACE	Replaces existing values in a JSON document and returns the result.
JSON_SET	Inserts or updates data in a JSON document and returns the result.

**Table F.75. Conditional Expressions**

Item	Overview
IF	If/else construct

**Table F.76. Aggregate Functions**

Item	Overview
ANY_VALUE	For compatibility with MySQL mode non ONLY_FULL_GROUP_BY syntax behavior of group by in by mode
GROUP_CONCAT	Returns a concatenated, delimited list of string values.

**Table F.77. System Information Functions and Operators**

Item	Overview
DATABASE	Synonym for current_schema()

**Table F.78. Miscellaneous Functions**

Item	Overview
BIN_TO_UUID	Convert binary UUID to string
COMPRESS	Compress string and return binary data
UNCOMPRESS	Decompress the binary data compressed by compress() and restore the original string
UUID	returns a randomly generated UUID, as a string of 36 characters.
UUID_TO_BIN	Convert string UUID to binary

**Table F.79. Operators**

Item	Overview
IFNULL	The corresponding value is returned according to whether the parameter is empty
ISNULL	Test whether the argument is NULL

**Table F.80. Arithmetic Operators**

Item	Overview
/	Division operator

**Table F.81. Compare Operators**

Item	Overview
=	Equal operator, support for varchar with bool or text.
!=	Non-equal operator, support for varchar with bool or text.

**Table F.82. SQL Queries**

Item	Overview
DUAL table	Table provided by the system

## F.53.2. SQL Functions Reference

### F.53.2.1. Mathematical Functions

The following mathematical functions are supported:

- CONV
- LOG10
- LOG2
- RAND
- TRUNCATE

#### F.53.2.1.1. CONV

**Description**

Convert numbers between different number bases.

**Syntax**

```
conv( p_num text, p_from_base int4, p_to_base int4) RETURNS text
```

**General rules**

- Converts numbers between different number bases.
- Returns a string representation of the number N, converted from base from\_base to base to\_base. Returns NULL if any argument is NULL. The argument N is interpreted as an integer, but may be specified as an integer or a string.
- The minimum base is 2 and the maximum base is 36. If from\_base is a negative number, N is regarded as a signed number. Otherwise, N is treated as unsigned. CONV() works with 64-bit precision.

**Example**

In the following example, '123456' converted from base 10 to base 16 is 1E240.

```
select conv('123456', 10, 16);
conv
-----
1E240
(1 row)
```

**F.53.2.1.2. LOG10****Description**

return the base-10 logarithm of the argument.

**Syntax**

```
log10(p1 numeric) RETURNS numeric
log10(p1 double precision) RETURNS double precision
```

**General rules**

- Returns the base-10 logarithm of p1. If X is less than or equal to 0.0E0, the function returns NULL and a warning “Invalid argument for logarithm” is reported.

**Example**

In the following example, return the base-10 logarithm of the argument 2.

```
select log10(2);
log10
-----
0.3010299956639812
(1 row)
```

### F.53.2.1.3. LOG2

**Description**

Return the base-2 logarithm of the argument.

**Syntax**

```
log2(p_num numeric) RETURNS numeric
```

**General rules**

- Returns the base-2 logarithm of p\_num. If p\_num is less than or equal to 0.0E0, the function returns NULL and a warning “Invalid argument for logarithm” is reported.

**Example**

In the following example, return the base-2 logarithm of the argument 64.

```
select log2(64);
       log2
-----
6.0000000000000000
(1 row)
```

### F.53.2.1.4. RAND

**Description**

Returns a random floating-point value v in the range 0 and 1.0.

**Syntax**

```
rand(p_seed int default null) RETURNS double precision
```

**General rules**

- With a constant initializer argument, the seed is initialized once when the statement is prepared, prior to execution.
- With a nonconstant initializer argument (such as a column name), the seed is initialized with the value for each invocation of RAND().
- One implication of this behavior is that for equal argument values, RAND(N) returns the same value each time, and thus produces a repeatable sequence of column values.
- RAND() in a WHERE clause is evaluated for every row (when selecting from one table) or combination of rows (when selecting from a multiple-table join).

**Example**

In the following example, the sequence of values produced by RAND(123) is the same both places it occurs.

```
select rand(123);
```

```
          rand
-----
0.05425240159967615
(1 row)
```

### F.53.2.1.5. TRUNCATE

#### Description

Truncate to specified number of decimal places.

#### Syntax

```
TRUNCATE(SMALLINT X,INTEGER D) returns INTEGER
TRUNCATE(INTEGER X,INTEGER D) returns INTEGER
TRUNCATE(BIGINT X,INTEGER D) returns BIGINT
TRUNCATE(DOUBLE PRECISION X,INTEGER D) returns DOUBLE PRECISION
TRUNCATE(NUMERIC,INTEGER D) returns NUMERIC
```

#### General rules

- Returns the number X, truncated to D decimal places.
- If D is 0, the result has no decimal point or fractional part.
- D can be negative to cause D digits left of the decimal point of the value X to become zero.

#### Example

In the following example, the result of "1.223" truncated to 1 decimal places is returned.

```
SELECT TRUNCATE(1.223,1);
   truncate
-----
          1.2
(1 row)
```

### F.53.2.2. String Functions

The following string functions are supported:

- ELT
- FIELD
- FIND\_IN\_SET
- INSTR
- FROM\_BASE64
- INSERT
- LCASE
- LOCATE

- MID
- SPACE
- STRCMP
- TO\_BASE64
- UCASE
- SUBSTR
- SUBSTRING
- SUBSTRING\_INDEX

#### F.53.2.2.1. ELT

##### Description

Return string at index number.

##### Syntax

```
elt(str_pos int, VARIADIC strlist text[]) RETURNS text
```

##### General rules

- ELT() returns the str\_pos<sup>th</sup> element of the list of strings: str1 if str\_pos = 1, str2 if str\_pos = 2, and so on.
- Returns NULL if N is less than 1 or greater than the number of arguments.
- ELT() is the complement of FIELD().

##### Example

In the following example, Return 'Bb' at 2.

```
select elt( 2, 'Aa', 'Bb', 'Cc', 'Dd', 'Ff');
elt
-----
Bb
(1 row)
```

#### F.53.2.2.2. FIELD

##### Description

Index (position) of first argument in subsequent arguments.

##### Syntax

```
field(str text, VARIADIC strlist text[]) RETURNS bigint
field(str numeric, VARIADIC strlist numeric[]) RETURNS bigint
```

##### General rules

- Returns the index (position) of *str* in the *str1*, *str2*, *str3*, ... list. Returns 0 if *str* is not found.
- If all arguments to `FIELD()` are strings, all arguments are compared as strings. If all arguments are numbers, they are compared as numbers. Otherwise, the arguments are compared as double.
- If *str* is NULL, the return value is 0 because NULL fails equality comparison with any value. `FIELD()` is the complement of `ELT()`.

**Example**

In the following example, Index (position) of 'Bb' in 'Aa', 'Bb', 'Cc', 'Dd', 'Ff' 2 is returned.

```
select field('Bb', 'Aa', 'Bb', 'Cc', 'Dd', 'Ff');
field
-----
      2
(1 row)
```

**F.53.2.2.3. FIND\_IN\_SET**

**Description**

Index (position) of first argument within second argument.

**Syntax**

```
FIND_IN_SET(str "any",strlist TEXT) returns INTEGER
```

**General rules**

- Returns a value in the range of 1 to N if the string *str* is in the string list *strlist* consisting of N substrings. *strlist* is a string composed of substrings separated by , characters.
- Returns 0 if *str* is not in *strlist* or if *strlist* is the empty string.
- Returns NULL if either argument is NULL. This function does not work properly if the first argument contains a comma (,) character.
- If first argument is not String Types,the first parameter will be converted to string.In other words,find\_in\_set(n,strlist) is equivalent to find\_in\_set(n::text,strlist)
- The data type of the return value is integer.

**Example**

In the following example,position of 'b' within 'a,b,c,d' is returned.

```
SELECT FIND_IN_SET('b', 'a,b,c,d');
find_in_set
-----
          2
(1 row)
```

**F.53.2.2.4. FROM\_BASE64**

**Description**



Decode base64 encoded string and return result.

**Syntax**

```
from_base64(p_str text) RETURNS text
```

**General rules**

- Takes a string encoded with the base-64 encoded rules used by TO\_BASE64() and returns the decoded result as a binary string.
- The result is NULL if the argument is NULL or not a valid base-64 string.
- See the description of TO\_BASE64() for details about the encoding and decoding rules.

**Example**

In the following example, Decode base64 encoded string 'YWJj' and return result 'abc'.

```
select from_base64('YWJj');
from_base64
-----
abc
(1 row)
```

### F.53.2.2.5. INSERT

**Description**

Insert substring at specified position up to specified number of characters.

**Syntax**

```
insert(p_source text, p_pos bigint, p_len bigint, p_replacement
text) RETURNS text
```

**General rules**

- Returns the string str, with the substring beginning at position pos and len characters long replaced by the string newstr.
- Returns the original string if pos is not within the length of the string. Replaces the rest of the string from position pos if len is not within the length of the rest of the string.
- Returns NULL if any argument is NULL.

**Example**

In the following example, Insert substring 'What' at specified position 3 up to specified number 4 of characters.

```
select insert('Quadratic', 3, 4, 'What');
insert
-----
QuWhattic
```

(1 row)

### F.53.2.2.6. INSTR

#### Description

Get the first occurrence position of the substring.

#### Syntax

```
instr(str text, patt text) RETURNS int
```

#### General rules

- Get the first occurrence position of sub string patt in str, starting from 1.
- If not found, return 0.

#### Example

In the following example, the first occurrence of substring '4de' in string 'abc124deff4de' is 6.

```
select instr('abc124deff4de', '4de');
instr
-----
      6
(1 row)
```

### F.53.2.2.7. LCASE

#### Description

Synonym for LOWER().

#### Syntax

```
lcase(p_source text) RETURNS text
```

#### General rules

- LCASE() is a synonym for LOWER().
- Returns the string str with all characters changed to lowercase according to the current character set mapping. The default is utf8mb4.

#### Example

In the following example,Returns the string 'quadratic' with all characters changed to lowercase.

```
select lcase('QuadRatic');
lcase
-----
quadratic
```

(1 row)

### F.53.2.2.8. LOCATE

#### Description

Return the position of the first occurrence of substring.

#### Syntax

```
LOCATE(substr TEXT,str TEXT) returns INTEGER  
LOCATE(substr TEXT,str TEXT,POS INTEGER) returns INTEGER
```

#### General rules

- The first syntax returns the position of the first occurrence of substring *substr* in string *str*.
- The second syntax returns the position of the first occurrence of substring *substr* in string *str*, starting at position *pos*.
- Returns 0 if *substr* is not in *str*.
- Returns NULL if any argument is NULL.

#### Example

In the following example, position of 'bar' in 'foobarbar', starting at position 5. is returned.

```
SELECT LOCATE('bar', 'foobarbar', 5);  
   locate  
-----  
          7  
(1 row)
```

### F.53.2.2.9. MID

#### Description

Return a substring starting from the specified position.

#### Syntax

```
mid(p_source text, p_pos bigint, p_len bigint) RETURNS text
```

#### General rules

- The forms without a len argument return a substring from string *str* starting at position *pos*. The forms with a len argument return a substring len characters long from string *str*, starting at position *pos*.
- It is also possible to use a negative value for *pos*. In this case, the beginning of the substring is *pos* characters from the end of the string, rather than the beginning. A negative value may be used for *pos* in any of the forms of this function. A value of 0 for *pos* returns an empty string.

#### Example

In the following example, return a substring 'ongy' starting from the specified position 2.

```
select mid('Hongye', 2, 4);
mid
-----
ongy
(1 row)
```

### F.53.2.2.10. SPACE

#### Description

Return a string of the specified number of spaces.

#### Syntax

```
space(p_num int) RETURNS text
```

#### General rules

- Returns a string consisting of N space characters.

#### Example

In the following example, return a string of the specified number of spaces.

```
select concat('|', space(11), '|');
concat
-----
|           |
(1 row)
```

### F.53.2.2.11. STRCMP

#### Description

Compare two strings.

#### Syntax

```
strcmp(p1 text, p2 text) RETURNS int
```

#### General rules

- STRCMP() returns 0 if the strings are the same, -1 if the first argument is smaller than the second according to the current sort order, and 1 otherwise.

#### Example

In the following example, returns -1 the first argument is smaller than the second according to the current sort order.

```
select strcmp('text', 'text2');
strcmp
-----
      -1
(1 row)
```

### F.53.2.2.12. TO\_BASE64

#### Description

Return the argument converted to a base-64 string.

#### Syntax

```
to_base64(p_str text) RETURNS text
```

#### General rules

- Converts the string argument to base-64 encoded form and returns the result as a character string with the connection character set and collation.
- If the argument is not a string, it is converted to a string before conversion takes place. The result is NULL if the argument is NULL.
- Base-64 encoded strings can be decoded using the FROM\_BASE64() function.

#### Example

In the following example, return the argument 'abc' converted to a base-64 string 'YWJj'.

```
select to_base64('abc');
to_base64
-----
YWJj
(1 row)
```

### F.53.2.2.13. UCASE

#### Description

Synonym for UPPER().

#### Syntax

```
ucase(p_source text) RETURNS text
```

#### General rules

- Returns the string str with all characters changed to uppercase according to the current character set mapping. The default is utf8mb4.

#### Example

In the following example, returns the string 'QUADRATIC' with all characters changed to uppercase according to the current character set mapping.

```
select ucase('QuadRatic');
       ucase
-----
QUADRATIC
(1 row)
```

### F.53.2.2.14. SUBSTR

#### Description

Return the substring as specified

#### Syntax

```
substr(str text, pos int) RETURNS text
substr(str text, pos int, len int) RETURNS text
```

#### General rules

- The forms without a len argument return a substring from string str starting at position pos. The forms with a len argument return a substring len characters long from string str, starting at position pos.
- It is also possible to use a negative value for pos. In this case, the beginning of the substring is pos characters from the end of the string, rather than the beginning. A negative value may be used for pos in any of the forms of this function. A value of 0 for pos returns an empty string.
- This function is multibyte safe. It returns NULL if any of its arguments are NULL.
- If len is less than 1, the result is the empty string.
- It is also possible for both pos and len to accept numeric type, if the fractional part of a input less than 0.5, round to integer part, otherwise round to floor of input + 0.5 for a positive input, floor of input-0.5 would be applied if input is negative.

#### Example

In the following example, the result is bc

```
select substr('abc',-2,2);
       substr
-----
bc
(1 row)
```

### F.53.2.2.15. SUBSTRING

#### Description

Return the substring as specified

#### Syntax

```
substring(str text, pos int) RETURNS text
```

substring(str text, pos int, len int) RETURNS text

**General rules**

- substring is a synonym for substr

**Example**

In the following example, the result is bc

```
select substring('abc',-2,2);
  substring
-----
      bc
(1 row)
```

**F.53.2.2.16. SUBSTRING\_INDEX****Description**

Return a substring from a string before the specified number of occurrences of the delimiter

**Syntax**

```
substring_index(str varchar, delim varchar, count integer) RETURNS
varchar
```

**General rules**

- Returns the substring from string str before count occurrences of the delimiter delim.
- If count is positive, everything to the left of the final delimiter (counting from the left) is returned.
- If count is negative, everything to the right of the final delimiter (counting from the right) is returned.
- SUBSTRING\_INDEX() performs a case-sensitive match when searching for delim.
- This function is multibyte safe.
- SUBSTRING\_INDEX() returns NULL if any of its arguments are NULL.
- When delim is " return "(same with mysql).

**Example**

```
lightdb@test_m=# SELECT SUBSTRING_INDEX('www.mysql.com', '.', 2);
  substring_index
-----
  www.mysql
(1 row)

lightdb@test_m=# SELECT SUBSTRING_INDEX('www.mysql.com', '.', -2);
  substring_index
-----
  mysql.com
```

(1 row)

### F.53.2.3. Date/Time Functions

The following date/time functions are supported:

- DATEDIFF
- DATE\_ADD
- DATE\_FORMAT
- DATE\_SUB
- DAY
- DAYOFWEEK
- FROM\_UNIXTIME
- STR\_TO\_DATE
- SYSDATE
- SEC\_TO\_TIME
- TIME\_TO\_SEC
- TIMEDIFF
- TIMESTAMPDIFF
- TO\_DAYS
- TO\_SECONDS
- UNIX\_TIMESTAMP
- WEEKOFYEAR
- YEAR
- QUARTER
- LAST\_DAY
- CURDATE

#### F.53.2.3.1. DATEDIFF

##### Description

Subtract two dates.

##### Syntax

```
DATEDIFF(expr1 timestamp,expr2 timestamp) RETURN integer  
DATEDIFF(expr1 text,expr2 text) RETURN integer  
DATEDIFF(expr1 timestamptz,expr2 timestamptz) RETURN integer  
DATEDIFF(expr1 timestamptz,expr2 timestamp) RETURN integer  
DATEDIFF(expr1 timestamp,expr2 timestamptz) RETURN integer
```



```
DATEDIFF(expr1 date, expr2 date) RETURN integer
DATEDIFF(expr1 date, expr2 numeric) RETURN integer
DATEDIFF(expr1 numeric, expr2 date) RETURN integer
DATEDIFF(expr1 numeric, expr2 numeric) RETURN integer
```

**General rules**

- *expr1 - expr2* expressed as a value in days from one date to the other. *expr1* and *expr2* are date or date-and-time expressions. Only the date parts of the values are used in the calculation.
- Returns NULL if any argument is NULL.
- Parameter can't be time type(mysql can be time type).

**Example**

In the following example, 1 is returned because '2007-12-31' minus '2007-12-30' equals 1

```
SELECT DATEDIFF('2007-12-31 23:59:59', '2007-12-30');
datediff
-----
1
(1 row)
SELECT DATEDIFF(cast('2007-12-31 23:59:59' as
  datetime), cast('2007-12-30' as datetime));
datediff
-----
1
(1 row)
SELECT DATEDIFF(cast('2007-12-31 23:59:59' as
  date), cast('2007-12-30' as date));
datediff
-----
1
(1 row)
```

**F.53.2.3.2. DATE\_ADD****Description**

Date addition.

**Syntax**

```
DATE_ADD(expr1 timestampz, expr2 interval) RETURN date
DATE_ADD(expr1 text, expr2 interval) RETURN date
```

**General rules**

- Returns the date type after adding interval (year / month / day) to the *expr1* date parameter
- The second parameter *expr2* only support interval (year / month / day)

**Example**

In the following example, '2020-01-02' is returned because '20200101' add 1 day

```

select date_add('20200101', interval 1 day);
       date_add
-----
2020-01-02
(1 row)

```

### F.53.2.3.3. DATE\_FORMAT

#### Description

Date format display.

#### Syntax

```

DATE_FORMAT(expr1 timestamp, expr2 text) RETURN text
DATE_FORMAT(expr1 timestamptz, expr2 text) RETURN text
DATE_FORMAT(expr1 text, expr2 text) RETURN text

```

#### General rules

- Return expr1 time parameter, display and output in expr2 format

#### Example

In the following example, '2021/12/01 11,59,59' is returned because expr2is in '%Y/%m/%d %h,%i,%s' format

```

select date_format('20211201 11:59:59', '%Y/%m/%d %h,%i,%s');
       date_format
-----
2021/12/01 11,59,59
(1 row)

```

Table F.83 shows the template patterns available for formatting date\_format values.

**Table F.83. Template Patterns for date\_format Formatting**

Pattern	Description
%a	Abbreviated week name
%b	Abbreviated month name
%c	Month, value
%D	Day of the month with English prefix
%d	Day of month, value (00-31)
%e	Day of month, value (0-31)
%f	Microsecond
%H	Hours (00-23)
%h	Hours (01-12)
%I	Hours (01-12)
%i	Minute, value (00-59)

Pattern	Description
%j	Day of year (001-366)
%k	Hours (0-23)
%l	Hours (1-12)
%M	Month Name
%m	Month, value (00-12)
%P	AM or PM
%r	Time, 12 hours (hh: mm: ss AM or PM)
%S	Seconds (00-59)
%s	Seconds (00-59)
%T	Time, 24 hours (hh: mm: ss)
%W	Week Name
%Y	Year, 4 digits
%y	Year, 2 digits

#### F.53.2.3.4. DATE\_SUB

##### Description

Date subtraction.

##### Syntax

```
DATE_SUB(expr1 timestampz, expr2 interval) RETURN date
DATE_SUB(expr1 text, expr2 interval) RETURN date
```

##### General rules

- Returns the date type after the expr1 date parameter minus the interval (year / month / day)
- The second parameter expr2 only support interval (year / month / day)

##### Example

In the following example, '2019-12-31' is returned because '20200101' minus 1 day

```
select date_sub('20200101', interval 1 day);
   date_sub
-----
2019-12-31
(1 row)
```

#### F.53.2.3.5. DAY

##### Description

Return month date.

##### Syntax

```
DAY(expr1 text) RETURN int2
DAY(expr1 timestamptz) RETURN int4
```

**General rules**

- Returns the date part of a given expr1 date month
- Only month and day parameters are not supported, such as '0101', 0704

**Example**

In the following example, '1' is returned because 2011/12/01's date is 1

```
select day('2011/12/01');
day
-----
    1
(1 row)
```

**F.53.2.3.6. DAYOFWEEK****Description**

Return to the day of the week.

**Syntax**

```
DAYOFWEEK(expr1 text) RETURN int4
DAYOFWEEK(expr1 timestamptz) RETURN int4
```

**General rules**

- Returns the day of the week according to the expr1 date parameter. The return value is 1 ~ 7, and Sunday is 1
- At least include the complete time format, such as 20200202, 200202. Parameters less than 6 bits are not supported

**Example**

In the following example, '4' is returned because 20200101 is Wednesday

```
select dayofweek(20200101);
dayofweek
-----
          4
(1 row)
```

**F.53.2.3.7. FROM\_UNIXTIME****Description**

Return time format according to UNIX timestamp.

**Syntax**

```
FROM_UNIXTIME(expr1 text) RETURN timestamp
FROM_UNIXTIME(expr1 int8) RETURN timestamp
FROM_UNIXTIME(expr1 text, expr2 text) RETURN text
FROM_UNIXTIME(expr1 int8, expr2 text) RETURN text
```

**General rules**

- Return time format according to expr1 parameter UNIX timestamp. The date format can be specified according to the expr2 parameter

**Example**

In the following example, timestamp is returned according to UNIX timestamp 20220910

```
select from_unixtime(20220910);
      from_unixtime
-----
1970-08-23 08:55:10
(1 row)
select from_unixtime(20220910, '%Y/%m/%d %h,%i,%s');
      from_unixtime
-----
1970/08/23 08,55,10
(1 row)
```

Table F.84 shows the template patterns available for formatting from\_unixtime values.

**Table F.84. Template Patterns for from\_unixtime Formatting**

Pattern	Description
%a	Abbreviated week name
%b	Abbreviated month name
%c	Month, value
%D	Day of the month with English prefix
%d	Day of month, value (00-31)
%e	Day of month, value (0-31)
%f	Microsecond
%H	Hours (00-23)
%h	Hours (01-12)
%I	Hours (01-12)
%i	Minute, value (00-59)
%j	Day of year (001-366)
%k	Hours (0-23)
%l	Hours (1-12)
%M	Month Name
%m	Month, value (00-12)
%p	AM or PM
%r	Time, 12 hours (hh: mm: ss AM or PM)

Pattern	Description
%S	Seconds (00-59)
%s	Seconds (00-59)
%T	Time, 24 hours (hh: mm: ss)
%W	Week Name
%Y	Year, 4 digits
%y	Year, 2 digits

### F.53.2.3.8. SEC\_TO\_TIME

#### Description

Converts seconds to 'hh:mm:ss' format.

#### Syntax

```
sec_to_time(p_secs int) RETURNS interval
```

#### General rules

- Returns the seconds argument, converted to hours, minutes, and seconds, as a TIME value.
- The range of the result is constrained to that of the TIME data type. A warning occurs if the argument corresponds to a value outside that range.

#### Example

In the following example, Converts seconds 80580 to 'hh:mm:ss' format 22:23:00.

```
select mysql.sec_to_time(80580);
sec_to_time
-----
22:23:00
(1 row)
```

### F.53.2.3.9. STR\_TO\_DATE

#### Description

Convert string to time value. This is the inverse of the DATE\_FORMAT() function. It takes a string str and a format string format. STR\_TO\_DATE() returns a DATETIME value if the format string contains both date and time parts, or a DATE or TIME value if the string contains only date or time parts. If the date,time, or datetime value extracted from str is illegal, STR\_TO\_DATE() returns error.

#### Syntax

```
STR_TO_DATE(datetime_str text, datetime_format text) RETURN
  datetime
STR_TO_DATE(date_str text, date_format text) RETURN date
STR_TO_DATE(time_str text, time_format text) RETURN time
```

#### General rules

- Convert string str parameter and format format parameter to time value
- If the NO\_ZERO\_DATE SQL mode is enabled, zero dates are disallowed. In that case, STR\_TO\_DATE() returns NULL.

**Example**

In the following example, '2022-09-10 11:13:13' is returned according to timestamp '2022/09/10 11,13,13' and format '%Y/%m/%d %h,%i,%s'. It returns a DATETIME value if the format string contains both date and time parts.

```
select str_to_date('2022/09/10 11,13,13', '%Y/%m/%d %h,%i,%s');
      str_to_date
-----
2022-09-10 11:13:13
(1 row)
```

In the following example, returns a DATE value because of the format string contains only date parts.

```
select str_to_date('2022/09/10', '%Y/%m/%d');
      str_to_date
-----
2022-09-10
(1 row)
```

In the following example, returns a TIME value because of the format string contains only time parts.

```
select str_to_date('09:00:59', '%h:%i:%s');
      str_to_date
-----
09:00:59
(1 row)
```

If the NO\_ZERO\_DATE SQL mode is enabled, zero dates are disallowed. In that case, STR\_TO\_DATE() return NULL:

```
set lightdb_sql_mode = 'no_zero_date';
select str_to_date('2022/09/0', '%Y/%m/%d');
      str_to_date
-----

(1 row)
```

Table F.85 shows the template patterns available for formatting str\_to\_date values.

**Table F.85. Template Patterns for str\_to\_date Formatting**

Pattern	Description
%a	Abbreviated week name
%b	Abbreviated month name
%c	Month, value

Pattern	Description
%D	Day of the month with English prefix
%d	Day of month, value (00-31)
%e	Day of month, value (0-31)
%f	Microsecond
%H	Hours (00-23)
%h	Hours (01-12)
%I	Hours (01-12)
%i	Minute, value (00-59)
%j	Day of year (001-366)
%k	Hours (0-23)
%l	Hours (1-12)
%M	Month Name
%m	Month, value (00-12)
%P	AM or PM
%r	Time, 12 hours (hh: mm: ss AM or PM)
%S	Seconds (00-59)
%s	Seconds (00-59)
%T	Time, 24 hours (hh: mm: ss)
%W	Week Name
%Y	Year, 4 digits
%y	Year, 2 digits

### F.53.2.3.10. SYSDATE

#### Description

Return the time at which the function executes.

#### Syntax

```
sysdate() RETURNS timestamp(0)
```

#### General rules

- Returns the time at which it executes, it is nondeterministic.
- The return value affected by timezone setting.
- Available since version 23.2

#### Examples as below:

```
select sysdate;
        sysdate
-----
2023-05-06 16:06:59
(1 row)
```



### F.53.2.3.11. TIME\_TO\_SEC

**Description**

Return the argument converted to seconds.

**Syntax**

```
time_to_sec(p_time time) RETURNS int
```

**General rules**

- Returns the time argument, converted to seconds.

**Example**

In the following example, returns the time argument '22:23:00' converted to seconds 80580.

```
select time_to_sec('22:23:00');
time_to_sec
-----
          80580
(1 row)
```

### F.53.2.3.12. TIMEDIFF

**Description**

Subtract time.

**Syntax**

```
timediff(p_date1 timestamptz, p_date2 timestamptz) RETURNS interval
```

**General rules**

- TIMEDIFF() returns expr1 \_ expr2 expressed as a time value. expr1 and expr2 are time or date-and-time expressions, but both must be of the same type.
- The result returned by TIMEDIFF() is limited to the range allowed for TIME values. Alternatively, you can use either of the functions TIMESTAMPDIFF() and UNIX\_TIMESTAMP(), both of which return integers.

**Example**

In the following example, returns '2000-01-01 00:00:00' \_ '2000-01-01 00:00:00.000001' expressed as a time value.

```
select mysql.timediff('2000-01-01 00:00:00', '2000-01-01
00:00:00.000001');
timediff
-----
-00:00:00.000001
(1 row)
```

### F.53.2.3.13. TIMESTAMPDIFF

#### Description

Subtract an interval from a datetime expression.

#### Syntax

```
timestampdiff( p_unit text, p_ts1 text, p_ts2 text) RETURNS
  bigint
timestampdiff( p_unit text, p_ts1 text, p_ts2 timestampz)
  RETURNS bigint
timestampdiff( p_unit text, p_ts1 timestampz, p_ts2 text)
  RETURNS bigint
timestampdiff( p_unit text, p_ts1 timestampz, p_ts2 timestampz)
  RETURNS bigint
```

#### General rules

- Returns `datetime_expr2 - datetime_expr1`, where `datetime_expr1` and `datetime_expr2` are date or datetime expressions.
- One expression may be a date and the other a datetime; a date value is treated as a datetime having the time part '00:00:00' where necessary.
- The unit for the result (an integer) is given by the unit argument. The unit parameters support MICROSECOND, SECOND, MINUTE, HOUR, DAY, WEEK, MONTH, QUARTER and YEAR, with or without quotes.

#### Example

In the following example, Returns '1911-11-11 11:23:45.123456' - '2021-12-12 12:12:12.654321'::timestamp, the result (an integer) is given by MICROSECOND.

```
select timestampdiff ('MICROSECOND', '1911-11-11
  11:23:45.123456'::timestamp, '2021-12-12
  12:12:12.654321'::timestamp);
  timestampdiff
-----
3474060507530865
(1 row)
```

```
select timestampdiff (MICROSECOND, '1911-11-11
  11:23:45.123456'::timestamp, '2021-12-12
  12:12:12.654321'::timestamp);
  timestampdiff
-----
3474060507530865
(1 row)
```

### F.53.2.3.14. TO\_DAYS

#### Description

Return the date argument converted to days.

#### Syntax

```
to_days(p_date timestamp) RETURNS bigint
to_days(p_date timestampz) RETURNS bigint
to_days( p_date text) RETURNS bigint
to_days( p_date text, p_format text) RETURNS bigint
to_days(p_date bigint) RETURNS bigint
```

**General rules**

- Given a date `date`, returns a day number (the number of days since year 0).
- `TO_DAYS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable.

**Example**

In the following example, return the date argument '1111-11-11' converted to days 406098.

```
select to_days('1111-11-11');
to_days
-----
    406098
(1 row)
```

**F.53.2.3.15. TO\_SECONDS****Description**

Return the date or datetime argument converted to seconds since Year 0.

**Syntax**

```
to_seconds(p_date timestamp) RETURNS bigint
to_seconds(p_date timestampz) RETURNS bigint
```

**General rules**

- Given a date or datetime `expr`, returns the number of seconds since the year 0. If `expr` is not a valid date or datetime value, returns `NULL`.
- Like `TO_DAYS()`, `TO_SECONDS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable.

**Example**

In the following example, Return the date or datetime argument '2009-11-29' converted to seconds 63426672000 since Year 0.

```
select to_seconds('2009-11-29'::timestamp);
to_seconds
-----
```

```
63426672000
(1 row)
```

### F.53.2.3.16. UNIX\_TIMESTAMP

#### Description

Return UNIX timestamp according to time format.

#### Syntax

```
UNIX_TIMESTAMP() RETURN int8
UNIX_TIMESTAMP(expr1 timestamptz) RETURN int8
UNIX_TIMESTAMP(expr1 text) RETURN int8
```

#### General rules

- Returns the UNIX timestamp according to the expr1 parameter time format. If there is no parameter, returns the current UNIX timestamp
- Expr1 parameter contains at least the complete log format, such as 20200101

#### Example

In the following example, Return the unix timestamp '1577808000' corresponding parameter 20200101.

```
select unix_timestamp(20200101);
   unix_timestamp
-----
          1577808000
(1 row)
select unix_timestamp();
   unix_timestamp
-----
          1663051334
(1 row)
```

### F.53.2.3.17. WEEKOFYEAR

#### Description

According to the time, return to the week within a year.

#### Syntax

```
WEEKOFYEAR(expr1 timestamptz) RETURN int4
WEEKOFYEAR(expr1 text) RETURN int4
```

#### General rules

- According to the time expr1 parameter, return to the week within a year
- At least include the complete time format, such as 20200202, 200202. Parameters less than 6 bits are not supported

**Example**

In the following example, '36' is returned because '20220910' is the 36th week of the year

```
select weekofyear('20220910');
   weekofyear
-----
                36
(1 row)
```

**F.53.2.3.18. YEAR****Description**

Returns the year of the date.

**Syntax**

```
YEAR(expr1 timestampz) RETURN int4
YEAR(expr1 text) RETURN int4
```

**General rules**

- Returns the year according to the expr1 parameter date
- It supports complete month, day and month time parameters, such as '20200101' and '200101'. It does not support only including month and day parameters, such as '0101' and '0704'

**Example**

In the following example, '2020' is returned because the year of '20200101' is 2020

```
select year(20200101);
   year
-----
    2020
(1 row)
select year('200101');
   year
-----
    2020
(1 row)
```

**F.53.2.3.19. QUARTER****Description**

Returns the quarter of the year for date, in the range 1 to 4.

**Syntax**

```
QUARTER(timestamp) RETURN int4
```

**General rules**

- NULL if date is NULL.
- It only supports the timestamp type, and any type that can be implicitly converted to a timestamp type now (like date type).

**Example**

In the following example, '4' is returned because the quarter of '20201001' is 4

```
select quarter(cast('20201001'as date));
quarter
-----
         4
(1 row)

select quarter(cast('20201001'as datetime));
quarter
-----
         4
(1 row)

select quarter('20201001');
quarter
-----
         4
(1 row)
```

**F.53.2.3.20. LAST\_DAY****Description**

Returns the corresponding value for the last day of the month.

**Syntax**

```
LAST_DAY(date) RETURN date
LAST_DAY(text) RETURN date
```

**General rules**

- Returns NULL if the argument is NULL.
- Error if the argument is invalid.
- It only supports date and text type (also includes any data type that can be implicitly converted to either type) now.

**Example**

In the following example, last day of the month is returned if parameter is valid:

```
lightdb@test_m=# SELECT LAST_DAY('2003-02-05');
last_day
```

```
-----
2003-02-28
(1 row)

lightdb@test_m=# SELECT LAST_DAY('2004-02-05');
      last_day
-----
2004-02-29
(1 row)

lightdb@test_m=# SELECT LAST_DAY('2004-01-01 01:01:01');
      last_day
-----
2004-01-31
(1 row)

lightdb@test_m=# SELECT LAST_DAY('2003-03-32');
ERROR:  date/time field value out of range: "2003-03-32"
HINT:   Perhaps you need a different "datestyle" setting.
CONTEXT: SQL function "last_day" statement 1
lightdb@test_m=#
```

### F.53.2.3.21. CURDATE

#### Description

Returns the current date as a value in 'YYYY-MM-DD' format.

#### Syntax

```
CURDATE() RETURN date
```

#### General rules

- Cannot return YYYYMMDD format like mysql yet, therefore, multiplication and division are not supported, addition and subtraction results are different from mysqls. Mysql will Returns the current date as a value in 'YYYY-MM-DD' or YYYYMMDD format, depending on whether the function is used in string or numeric context.

#### Example

```
lightdb@test_m=# select curdate();
      curdate
-----
2023-12-06
(1 row)

lightdb@test_m=# select curdate()+1;
      ?column?
-----
2023-12-07
(1 row)

lightdb@test_m=# select curdate()/2;
ERROR:  operator does not exist: date / integer
```

```
LINE 1: select curdate()/2;
          ^
```

HINT: No operator matches the given name and argument types. You might need to add explicit type casts.

```
lightdb@test_m=# select curdate()*2;
```

ERROR: operator does not exist: date \* integer

```
LINE 1: select curdate()*2;
          ^
```

HINT: No operator matches the given name and argument types. You might need to add explicit type casts.

```
lightdb@test_m=# select curdate()-2;
?column?
```

-----

```
2023-12-04
```

```
(1 row)
```

## F.53.2.4. JSON Functions

The following json functions are supported:

- JSON\_ARRAY
- JSON\_OBJECT
- JSON\_EXTRACT
- JSON\_CONTAINS
- JSON\_CONTAINS\_PATH
- JSON\_PRETTY
- JSON\_REMOVE
- JSON\_INSERT
- JSON\_REPLACE
- JSON\_SET

### F.53.2.4.1. JSON\_ARRAY

#### Description

Evaluates a (possibly empty) list of values and returns a JSON array containing those values.

#### Syntax

```
JSON_ARRAY( VARIADIC "any" ) RETURNS jsonb
```

#### General rules

- Returns a JSON array, the data type is jsonb.

#### Example

```
SELECT JSON_ARRAY(1, 'abc', NULL, TRUE, NOW());
```



json\_array

```
-----  
[1, "abc", null, true, "2023-05-31T19:44:44.881055+08:00"]  
(1 row)
```

### F.53.2.4.2. JSON\_OBJECT

#### Description

Evaluates a (possibly empty) list of key-value pairs and returns a JSON object containing those pairs.

#### Syntax

```
JSON_OBJECT( VARIADIC "any" ) RETURNS jsonb
```

#### General rules

- Returns a JSON object, the data type is jsonb.
- An error occurs if any key name is NULL or the number of arguments is odd.

#### Example

```
SELECT JSON_OBJECT('id', 87, 'name', 'carrot');  
          json_object  
-----  
{"id": 87, "name": "carrot"}  
(1 row)  
  
SELECT JSON_OBJECT('id', 87, 'name', 'carrot', 'id', 99);  
          json_object  
-----  
{"id": 99, "name": "carrot"}  
(1 row)
```

### F.53.2.4.3. JSON\_EXTRACT

#### Description

Returns data from a JSON document, selected from the parts of the document matched by the path arguments.

#### Syntax

```
JSON_EXTRACT(json_doc jsonb, path jsonpath) RETURNS jsonb
```

#### General rules

- The return value consists of all values matched by the path arguments, the data type is jsonb. If it is possible that those arguments could return multiple values, the matched values are autowrapped as an array, in the order corresponding to the paths that produced them. Otherwise, the return value is the single matched value.
- Returns NULL if any argument is NULL or no paths locate a value in the document.

- An error occurs if the `json_doc` argument is not a valid JSON document or any path argument is not a valid path expression.

**Example**

```
SELECT JSON_EXTRACT('{"k1":11,"k2":22,"k2 2":33}','$.k1');
      json_extract
```

```
-----
      11
(1 row)
```

```
SELECT JSON_EXTRACT('{"k1":11,"k2":22,"k2 2":33}','$.k2 2');
      json_extract
```

```
-----
      33
(1 row)
```

```
SELECT JSON_EXTRACT('{"a":{"c":20, "d":{"b":{"b":30, "c":40}, "e":
{"b":50}}}, "c":{"b":60, "c":70}, "b":80}','$.a.c');
      json_extract
```

```
-----
      20
(1 row)
```

```
SELECT JSON_EXTRACT('[10,"str", null, true]','$[1]');
      json_extract
```

```
-----
      "str"
(1 row)
```

```
SELECT JSON_EXTRACT('[10,"str", null, true]','$[last]');
      json_extract
```

```
-----
      true
(1 row)
```

```
SELECT JSON_EXTRACT('[10,"str", null, true]','$[last-2]');
      json_extract
```

```
-----
      "str"
(1 row)
```

In the following example, multiple values matched, they are autowrapped as an array.

```
SELECT JSON_EXTRACT('[10,"str", null, true]','$[1 to 3]');
      json_extract
```

```
-----
["str", null, true]
(1 row)
```

```
SELECT JSON_EXTRACT('[10,"str", null, true]','$[*]');
      json_extract
```

```
-----
[10, "str", null, true]
(1 row)
```

```
SELECT JSON_EXTRACT('[10]', '$[*]');
       json_extract
-----
      [10]
(1 row)
```

```
SELECT JSON_EXTRACT('{"k1":1,"k2":"22","k2 2":[3,33]}', '$.*');
       json_extract
-----
      [1, "22", [3, 33]]
(1 row)
```

#### F.53.2.4.4. JSON\_CONTAINS

##### Description

Indicates by returning true or false whether a given candidate JSON document is contained within a target JSON document.

##### Syntax

```
JSON_CONTAINS(json_doc jsonb, json_val jsonb, path jsonpath)
RETURNS bool
```

##### General rules

- Returns NULL if any argument is NULL, or if the path argument does not identify a section of the target document.
- An error occurs if target or candidate is not a valid JSON document.
- To check only whether any data exists at the path, use JSON\_CONTAINS\_PATH() instead.

##### Example

```
SELECT JSON_CONTAINS('{"a": 111, "b": 222, "c": {"d": 4444}}',
       '111', '$.a');
       json_contains
-----
          t
(1 row)
```

```
SELECT JSON_CONTAINS('{"a": "111", "b": 222, "c": {"d": 4444}}',
       '111', '$.a');
       json_contains
-----
          f
(1 row)
```

```
SELECT JSON_CONTAINS('{"a": "111", "b": 222, "c": {"d": 4444}}', '"
111"', '$.a');
       json_contains
-----
          f
(1 row)
```

```

SELECT JSON_CONTAINS('{ "a": 111, "b": 222, "c": { "d": 4444 } }',
  '{"d" : 4444 }', '$.c');
  json_contains
-----
t
(1 row)

```

### F.53.2.4.5. JSON\_CONTAINS\_PATH

#### Description

Returns true or false to indicate whether a JSON document contains data at a given path or paths.

#### Syntax

```

JSON_CONTAINS_PATH(json_doc jsonb, one_or_all text, variadic
  jsonpath[]) RETURNS bool

```

#### General rules

- The return value is false if no specified path exists within the document. Otherwise, the return value depends on the `one_or_all` argument:
  - 'one' : true if at least one path exists within the document, false otherwise.
  - 'all' : true if all paths exist within the document, false otherwise.
- An error occurs if the `json_doc` argument is not a valid JSON document, any path argument is not a valid path expression, or `one_or_all` is not 'one' or 'all'.
- To check for a specific value at a path, use `JSON_CONTAINS()` instead.

#### Example

```

SELECT JSON_CONTAINS_PATH('{ "a": 111, "b": 222, "c": { "d": 4444 } }',
  'one', '$.a', '$.z');
  json_contains_path
-----
t
(1 row)

```

```

SELECT JSON_CONTAINS_PATH('{ "a": 111, "b": 222, "c": { "d": 4444 } }',
  'one', '$.d');
  json_contains_path
-----
f
(1 row)

```

```

SELECT JSON_CONTAINS_PATH('{ "a": 111, "b": 222, "c": { "d": 4444 } }',
  'all', '$a', '$.b', '$.c');
  json_contains_path
-----
t
(1 row)

```

```

SELECT JSON_CONTAINS_PATH('{ "a": 111, "b": 222, "c": { "d": 4444} }',
  'all', '$a', '$.b', '$.d');
  json_contains_path
-----
f
(1 row)

```

### F.53.2.4.6. JSON\_PRETTY

#### Description

Provides pretty-printing of JSON values similar to that implemented in PHP and by other languages and database systems.

#### Syntax

```
JSON_PRETTY(json_doc jsonb) RETURNS text
```

#### General rules

- The data type of return value is `text`.
- The value supplied must be a JSON value or a valid string representation of a JSON value. Extraneous whitespaces and newlines present in this value have no effect on the output.
- For a NULL value, the function returns NULL. If the value is not a JSON document, or if it cannot be parsed as one, the function fails with an error.

#### Example

```

SELECT JSON_PRETTY('{ "a": { "b": { "z": 1 } }, "c": [ 5, { "z": 2 } ], "z": 3 },
  "z": 4 }');
  json_pretty
-----
{
  "a": {
    "b": {
      "z": 1
    },
    "c": [
      5,
      {
        "z": 2
      }
    ],
    "z": 3
  },
  "z": 4
}
(1 row)

```

### F.53.2.4.7. JSON\_REMOVE

#### Description

Removes data from a JSON document and returns the result.

## Syntax

JSON\_REMOVE(jsonb, jsonpath) RETURNS jsonb

## General rules

- Removes data from a JSON document and returns the result. Returns NULL if any argument is NULL.
- An error occurs if the jsonb argument is not a valid JSON document or any path argument is not a valid path expression or is \$ or contains a \* or \*\* wildcard.
- It is not an error if the element to be removed does not exist in the document; in that case, the path does not affect the document.

## Example

```
SELECT JSON_REMOVE('{ "a": 1, "b": [1,2,3], "c": {"d": 4} }',  
 '$.c.d');
```

```
      json_remove
```

```
-----  
{ "a": 1, "b": [1, 2, 3], "c": {} }  
(1 row)
```

```
SELECT JSON_REMOVE('{ "a": 1, "b": [1,2,3], "c": {"d": 4} }',  
 '$.b[last]');
```

```
      json_remove
```

```
-----  
{ "a": 1, "b": [1, 2], "c": {"d": 4} }  
(1 row)
```

```
SELECT JSON_REMOVE('{ "a": 1, "b": [1,2,3], "c": {"d": 4} }',  
 '$.c.z');
```

```
      json_remove
```

```
-----  
{ "a": 1, "b": [1, 2, 3], "c": {"d": 4} }  
(1 row)
```

Different from MySQL, when accessing a JSON object through period ., if the object name is not enclosed in double quotes and it is a valid ECMAScript identifier name with some special characters (like \$), LightDB will prompt an error.

```
SELECT JSON_REMOVE('{ "a": 1, "b": [1,2,3], "c": {"d": 4} }', '$.  
$z');
```

## F.53.2.4.8. JSON\_INSERT

### Description

Inserts data into a JSON document and returns the result.

### Syntax

```
JSON_INSERT(jsonb, jsonpath, anyelement) RETURNS jsonb
JSON_INSERT(jsonb, jsonpath, text) RETURNS jsonb
```

**General rules**

- Inserts data into a JSON document and returns the result. Returns NULL if any argument is NULL.
- An error occurs if the jsonb argument is not a valid JSON document or any path argument is not a valid path expression or contains a \* or \*\* wildcard.
- A path-value pair for an existing path in the document is ignored and does not overwrite the existing document value. A path-value pair for a nonexisting path in the document adds the value to the document.

**Example**

```
SELECT JSON_INSERT('{ "a": 1, "b": [2, 3]}', '$.a', 10);
      json_insert
-----
{"a": 1, "b": [2, 3]}
(1 row)

SELECT JSON_INSERT('{ "a": 1, "b": [2, 3]}', '$.c', 200);
      json_insert
-----
{"a": 1, "b": [2, 3], "c": 200}
(1 row)
```

### F.53.2.4.9. JSON\_REPLACE

**Description**

Replaces existing values in a JSON document and returns the result.

**Syntax**

```
JSON_REPLACE(jsonb, jsonpath, anyelement) RETURNS jsonb
JSON_REPLACE(jsonb, jsonpath, text) RETURNS jsonb
```

**General rules**

- Replaces existing values in a JSON document and returns the result. Returns NULL if any argument is NULL.
- An error occurs if the jsonb argument is not a valid JSON document or any path argument is not a valid path expression or contains a \* or \*\* wildcard.
- A path-value pair for an existing path in the document overwrites the existing document value with the new value. A path-value pair for a nonexisting path in the document is ignored and has no effect.

**Example**

```
SELECT JSON_REPLACE('{ "a": 1, "b": [2, 3]}', '$.a', 10);
      json_replace
-----
```

```
{ "a": 10, "b": [2, 3] }
(1 row)
```

```
SELECT JSON_REPLACE('{ "a": 1, "b": [2, 3] }', '$.c', 'null');
       json_replace
```

```
-----
{ "a": 1, "b": [2, 3] }
(1 row)
```

```
SELECT JSON_REPLACE('100', '$', '{ "a": 1, "b": [2, 3] }'::jsonb);
       json_replace
```

```
-----
{ "a": 1, "b": [2, 3] }
(1 row)
```

Different from MySQL, when accessing a JSON object through period ., if the object name is not enclosed in double quotes and it is an illegal ECMAScript identifier name, LightDB will not prompt an error but return the original value.

```
SELECT JSON_REPLACE('{ "a": 1, "b": [2, 3] }', '$.b.2z', 4);
       json_replace
```

```
-----
{ "a": 1, "b": [2, 3] }
(1 row)
```

#### F.53.2.4.10. JSON\_SET

##### Description

Inserts or updates data in a JSON document and returns the result.

##### Syntax

```
JSON_SET(jsonb, jsonpath, anyelement) RETURNS jsonb
JSON_SET(jsonb, jsonpath, text) RETURNS jsonb
```

##### General rules

- Inserts or updates data in a JSON document and returns the result. Returns NULL if json\_doc or path is NULL.
- An error occurs if the jsonb argument is not a valid JSON document or any path argument is not a valid path expression or contains a \* or \*\* wildcard.
- A path-value pair for an existing path in the document overwrites the existing document value with the new value. A path-value pair for a nonexisting path in the document adds the value to the document.

##### Example

```
SELECT JSON_SET('{ "a": 1, "b": [2, 3] }', '$.a', 10);
       json_set
```

```
-----
{ "a": 10, "b": [2, 3] }
```



```
(1 row)

SELECT JSON_SET('{ "a": 1, "b": [2, 3]}', '$.c', '[true, false]');
           json_set
-----
{"a": 1, "b": [2, 3], "c": "[true, false]"}
(1 row)

SELECT JSON_SET('{ "a": 1, "b": [2, 3]}', '$.b.z', 4);
           json_set
-----
{"a": 1, "b": [2, 3]}
(1 row)
```

## F.53.2.5. Conditional Expressions

The following functions for making comparisons are supported:

- IF

### F.53.2.5.1. IF

#### Description

If expr1 is TRUE, IF() returns expr2. Otherwise, it returns expr3.

#### Syntax

```
IF(expr1, expr2, expr3)
```

#### General rules

- If only one of expr2 or expr3 is explicitly NULL, the result type of the IF() function is "text".
- If one of expr2 and expr3 is a string, the result type of the IF() function is "text", otherwise it is "numeric".
- The following data types can be used in expr2 and expr3:
  - CHAR
  - VARCHAR
  - TEXT
  - INTEGER
  - BIGINT
  - SMALLINT
  - NUMERIC
  - REAL
  - DOUBLE PRECISION
  - BOOLEAN

- TIMESTAMPTZ

**Example**

In the following example, 3 is returned because the value of  $1 > 2$  is false.

```
SELECT IF(1>2,2,3);
   if
----
   3
(1 row)
```

## F.53.2.6. Aggregate Functions

The following aggregation functions are supported:

- ANY\_VALUE
- GROUP\_CONCAT

### F.53.2.6.1. ANY\_VALUE

**Description**

For compatibility with MySQL mode non ONLY\_FULL\_GROUP\_BY syntax behavior of group by in by mode.

**Syntax**

```
ANY_VALUE(anyelement)
```

**General rules**

- This function is useful for in MySQL compatible GROUP BY queries when the ONLY\_FULL\_GROUP\_BY SQL mode is enabled, for cases when MySQL rejects a query that you know is valid for reasons that MySQL cannot determine, Default ANY\_VALUE will return the first line causing ambiguity. The function return value and type are the same as the return value and type of its argument.

Note that this behavior is only a nonstandard syntax compatible with MySQL. It is used to ensure that the execution in LightDB will not report errors, but the results cannot be guaranteed to be completely consistent with MySQL. It is not recommended to use this feature. Please use the standard syntax format.

**Example**

In the following example, if id is a nonindexed column, the following query fails:

```
select col1, co2, max(co3) from t1 group by id;
ERROR: column "t1.col1" must appear in the GROUP BY clause or be
       used in an aggregate function
LINE 1: select col1, co2, max(co3) from t1 group by id;
              ^
```

Use ANY\_VALUE() to refer to col1 and col2:

```
select any_value(col1) as col1, any_value(col2) as col2, max(col3) from
t1 group by id;
col1 | col2 | max
-----+-----+-----
  6 |    9 |   30
  4 |    5 |    5
  3 |    3 |    4
  2 |    3 |    4
(4 rows)
```

### F.53.2.6.2. GROUP\_CONCAT

#### Description

Returns a concatenated, delimited list of string values.

#### Syntax

```
GROUP_CONCAT( [DISTINCT] column_name1 [ORDER BY {unsigned_integer
| column_name2 | expr} [ASC | DESC] [SEPARATOR delimiter TEXT])
returns TEXT
```

#### General rules

- This function returns a string result with the concatenated non-NULL values from a group.
- It returns NULL if there are no non-NULL values.
- To sort values in the result, use the ORDER BY clause. To sort in reverse order, add the DESC (descending) keyword to the name of the column you are sorting by in the ORDER BY clause. The default is ascending order; this may be specified explicitly using the ASC keyword.
- To eliminate duplicate values, use the DISTINCT clause.
- The default separator between values in a group is comma (.). To specify a separator explicitly, use SEPARATOR followed by the string literal value that should be inserted between group values. To eliminate the separator altogether, specify SEPARATOR "".

#### Example

In the following example, the result with values of column col1 in table t delimited by ':' is returned.

```
select GROUP_CONCAT(col1 separator ':') from (values('BBBB',1),
('AAAA',1),('CCCC',2)) as t(col1 ,col2) group by col2;
group_concat
-----
BBBB:AAAA
CCCC
(2 rows)
```

### F.53.2.7. System Information Functions and Operators

The following System Information functions are supported:

- DATABASE

### F.53.2.7.1. DATABASE

#### Description

Synonym for `current_schema()`. The concept of schema is similar to that of database in MySQL. You can specify the current schema by setting the `search_path`.

#### Syntax

`DATABASE()` returns TEXT

#### General rules

- Returns the name of the schema that is first in the search path (or a null value if the search path is empty).
- Like mysql, This is the schema that will be used for any tables or other named objects that are created without specifying a target schema.

#### Example

In the following example, current schema is `lightdb`.

```
select database();
  database
-----
  lightdb
(1 row)
```

## F.53.2.8. Miscellaneous Functions

The following Miscellaneous Functions are supported:

- BIN\_TO\_UUID
- COMPRESS
- UNCOMPRESS
- UUID
- UUID\_TO\_BIN

### F.53.2.8.1. BIN\_TO\_UUID

#### Description

Convert binary UUID to string.

#### Syntax

`bin_to_uuid(p_uuid bytea, swap_flag int4 default 0)` RETURNS uuid

#### General rules

- `BIN_TO_UUID()` is the inverse of `UUID_TO_BIN()`. It converts a binary UUID to a string UUID and returns the result. The binary value should be a UUID as a `VARBINARY(16)` value.
- The return value is a utf8 string of five hexadecimal numbers separated by dashes. (For details about this format, see the `UUID()` function description.) If the `UUID` argument is `NULL`, the return value is `NULL`. If any argument is invalid, an error occurs.

**Example**

In the following example, Convert binary UUID '\x0768a47dd355372b4926ee668b6cb443' to string '0768a47d-d355-372b-4926-ee668b6cb443'.

```
select bin_to_uuid('\x0768a47dd355372b4926ee668b6cb443');
           bin_to_uuid
-----
0768a47d-d355-372b-4926-ee668b6cb443
(1 row)
```

**F.53.2.8.2. COMPRESS**

**Description**

Compress string and return binary data.

**Syntax**

```
COMPRESS(expr1 text) RETURN bytea
```

**General rules**

- Compress string `expr1` parameter and return binary data. The corresponding decompression function is `UNCOMPRESS`

**Example**

In the following example, compress 'abc123' into binary data '\x06000000616263313233'.

```
select compress('abc123');
           compress
-----
\x06000000616263313233
(1 row)
```

**F.53.2.8.3. UNCOMPRESS**

**Description**

Decompress the binary data compressed by `compress()` and restore the original string.

**Syntax**

```
UNCOMPRESS(expr1 bytea) RETURN text
```

**General rules**

- Decompress the binary data expr1 parameter compressed by compress() and restore the original string

**Example**

In the following example, decompress binary data '\x06000000616263313233' into bCompress 'abc123'

```
select uncompress(compress('abc123'));
       uncompress
-----
       abc123
(1 row)
```

**F.53.2.8.4. UUID****Description**

returns a randomly generated UUID, as a string of 36 characters.

**Syntax**

```
uuid() RETURNS text
```

**General rules**

- UUID() returns a value that conforms to UUID version 4 as described in RFC 4122. The value is a 128-bit number represented as a utf8 string of five hexadecimal numbers in aaaaaaa-bbbccc-cccc-eeeeeeee format.

**Example**

In the following example, generate random UUID.

```
select uuid();
              uuid
-----
f31f29e5-481f-4666-aa74-8cee3aa44545
(1 row)
```

**F.53.2.8.5. UUID\_TO\_BIN****Description**

Convert string UUID to binary.

**Syntax**

```
uuid_to_bin(p_uuid uuid, swap_flag int4 default 0) RETURNS bytea
```

**General rules**

- Converts a string UUID to a binary UUID and returns the result. (The IS\_UUID() function description lists the permitted string UUID formats.)
- The return binary UUID is a VARBINARY(16) value. If the UUID argument is NULL, the return value is NULL. If any argument is invalid, an error occurs.

**Example**

In the following example, Convert string UUID '0768a47d-d355-372b-4926-ee668b6cb443' to binary '\x0768a47dd355372b4926ee668b6cb443'.

```
select uuid_to_bin('0768a47d-d355-372b-4926-
ee668b6cb443'::uuid)::text;
      uuid_to_bin
-----
\x0768a47dd355372b4926ee668b6cb443
(1 row)
```

## F.53.2.9. Operators

The following Operators are supported:

- IFNULL
- ISNULL

### F.53.2.9.1. IFNULL

**Description**

The corresponding value is returned according to whether the parameter is empty.

**Syntax**

```
IFNULL(expr1 anycompatible, expr2 anycompatible) RETURNS
  anycompatible
IFNULL(expr1 text, expr2 text) RETURNS text
```

**General rules**

- Judge whether the first parameter is null. If it is null, the value of the second parameter will be returned. If it is not null, the value of the first parameter will be returned
- The two input parameters must belong to the same category, and the `typcategory` field of `pg_type` can be determined

**Example**

In the following example, when the first parameter is null, the second parameter 15 is returned; otherwise, the first parameter 1 is returned

```
select ifnull(1, 15);
  ifnull
-----
      1
(1 row)
```

```
select ifnull(null, 15);
   ifnull
-----
        15
(1 row)
```

### F.53.2.9.2. ISNULL

#### Description

Test whether the argument is NULL

#### Syntax

```
isnull(text) RETURNS bool
isnull(numeric) RETURNS bool
isnull(timestampz) RETURNS bool
```

#### General rules

- If expr is NULL, ISNULL() returns true, otherwise it returns false.

#### Example

In the following example, expr is not NULL, ISNULL() returns false.

```
select isnull(0)::text;
   isnull
-----
   false
(1 row)
```

## F.53.2.10. Arithmetic Operators

The following arithmetic operator are supported:

- /

### F.53.2.10.1. /

#### Description

Division operator. Division by zero produces a NULL result, reported a warning log.

#### Example

Division operator examples. Division by zero produces a NULL result, reported a warning log.

```
select 2 / 4;
   ?column?
-----
  0.50000000000000000000
(1 row)
```



```
select 1.0 / 2;
?column?
-----
0.50000000000000000000000000000000
(1 row)

select 2 / 0;
WARNING: division by zero
?column?
-----

(1 row)
```

## F.53.2.11. Compare Operators

The following compare operators are supported:

- =
- !=

### F.53.2.11.1. =

#### Description

Equal operator, support for varchar with bool or text. Got true for equality and false for non-equality.

#### Example

```
select '1'::varchar = true;
?column?
-----
t
(1 row)

select '1'::varchar = '1'::text;
?column?
-----
t
(1 row)

create table a(b varchar(5), c int);
insert into a values(true, 1);
insert into a values('true', 2);

select * from a;
 b | c
---+---
 1 | 1
true | 2
(2 rows)

select * from a where b = true;
 b | c
---+---
 1 | 1
(1 row)
```

```
select * from a where b = 'true';
  b   | c
-----+-----
 true | 2
(1 row)
```

### F.53.2.11.2. !=

#### Description

Non-equal operator, support for varchar with bool or text. Got true for non-equality and false for equality.

#### Example

```
select '1' != true;
?column?
-----
  f
(1 row)
```

```
select '1'::varchar != '1'::text;
?column?
-----
  f
(1 row)
```

```
create table a(b varchar(5), c int);
insert into a values(true, 1);
insert into a values('true', 2);
```

```
select * from a;
  b   | c
-----+-----
  1   | 1
 true | 2
(2 rows)
```

```
select * from a where b != true;
  b   | c
-----+-----
 true | 2
(1 row)
```

```
select * from a where b != 'true';
  b | c
---+---
  1 | 1
(1 row)
```

### F.53.2.12. Convert type

#### F.53.2.12.1. Convert bool type to varchar

##### Description

Previously, bool type would transform to varchar kept invariant as aspect, like true to 'true' or false to 'false'. Myfice changes the rules above, transform bool type true to string '1' and false to string '0' for compatible with mysql.

### Example

```
create table tb (a varchar(5), b int);
insert into tb values('true', 2);           -- insert text 'true' as
expected
insert into tb values(true, 1);           -- insert true of bool
type, expected to insert text '1' instead
insert into tb values(1, 3);             -- insert numeric 1,
expected to insert text '1' instead
insert into tb values('1', 4);          -- insert text '1' as
expected
insert into tb values(false, 5);         -- insert false of bool
type, expected to insert text '0'
insert into tb values('false', 6);      -- insert text 'false' as
expected
insert into tb values(0, 7);             -- insert numeric 0,
expected to insert text '0' instead
insert into tb values('0', 8);          -- insert text '0' as
expected
select * from tb;
a  | b
-----+-----
true | 2
1   | 1
1   | 3
1   | 4
0   | 5
false | 6
0   | 7
0   | 8
(8 rows)
```

### F.53.2.12.2. cast(expr as unsigned)

#### Description

transform expr to unsigned bigint value.

#### General rules

- Return type is numeric type. It is different from mysql, mysql is unsigned bigint type.
- Expr of Date/Time types is not supported to cast yet. See examples for details.
- Floating-point number in character types is not truncated when cast like mysql#'1.9' truncate to 1#. See examples for details.
- Negative floating-point constant is not truncated when cast like mysql8.0, but mysql5.7 truncate it (floating-point number in col is not truncated). See examples for details.
- Negative constant is truncated to 9223372036854775808 when overflowed like mysql8.0(mysql5.7 is 0). See examples for details.
- Support casting strings in scientific notation format to unsigned, like '2e2' to 200(it is different from mysql, mysql is 2 after cast). See examples for details.

**Example**

```
lightdb@test_m=# select cast(123 as unsigned) as unsigned;
      unsigned
-----
          123
(1 row)

lightdb@test_m=# select cast(-123 as unsigned) as unsigned;
      unsigned
-----
18446744073709551493
(1 row)

lightdb@test_m=# select cast(18446744073709551615 as unsigned) as
      unsigned;
-----
18446744073709551615
(1 row)

lightdb@test_m=# select cast(18446744073709551616 as unsigned) as
      unsigned;
-----
18446744073709551615
(1 row)

lightdb@test_m=# select cast(18446744073709551616 as unsigned) as
      unsigned;
WARNING: unsigned bigint out of range, Truncated
      unsigned
-----
18446744073709551615
(1 row)

lightdb@test_m=# select cast(-9223372036854775808 as unsigned) as
      unsigned;
-----
9223372036854775808
(1 row)

-- mysql5.7# 0 #mysql8.0: 9223372036854775808
lightdb@test_m=# select cast(-9223372036854775809 as unsigned) as
      unsigned;
WARNING: unsigned bigint out of range, Truncated
      unsigned
-----
9223372036854775808
(1 row)

lightdb@test_m=# select cast(1.4 as unsigned) as unsigned;
      unsigned
-----
          1
(1 row)

lightdb@test_m=# select cast(1.5 as unsigned) as unsigned;
      unsigned
-----
          2
(1 row)
```

```
lightdb@test_m=# select cast(1.9 as unsigned) as unsigned;
unsigned
-----
          2
(1 row)

-- mysql5.7: 0      mysql8.0: 18446744073709551614
lightdb@test_m=# select cast(-1.9 as unsigned) as unsigned;
unsigned
-----
18446744073709551614
(1 row)

-- mysql5.7: 0      mysql8.0: 18446744073709551614
lightdb@test_m=# select cast(-1.5 as unsigned) as unsigned;
unsigned
-----
18446744073709551614
(1 row)

-- mysql5.7: 0      mysql8.0: 18446744073709551615
lightdb@test_m=# select cast(-1.4 as unsigned) as unsigned;
unsigned
-----
18446744073709551615
(1 row)

-- mysql: 1
lightdb@test_m=# select cast('1.4' as unsigned) as unsigned;
unsigned
-----
          1
(1 row)

-- mysql: 1
lightdb@test_m=# select cast('1.5' as unsigned) as unsigned;
unsigned
-----
          2
(1 row)

-- mysql: 1
lightdb@test_m=# select cast('1.9' as unsigned) as unsigned;
unsigned
-----
          2
(1 row)

-- mysql: 18446744073709551615
lightdb@test_m=# select cast('-1.4' as unsigned) as unsigned;
unsigned
-----
18446744073709551615
(1 row)

-- mysql: 18446744073709551615
lightdb@test_m=# select cast('-1.5' as unsigned) as unsigned;
unsigned
```

```

-----
18446744073709551614
(1 row)

-- mysql: 18446744073709551615
lightdb@test_m=# select cast('-1.9' as unsigned) as unsigned;
      unsigned
-----
18446744073709551614
(1 row)

lightdb@test_m=# select cast(2e2 as unsigned) as unsigned;
      unsigned
-----
          200
(1 row)

lightdb@test_m=# select cast('2e2' as unsigned) as unsigned;
      unsigned
-----
          200
(1 row)

lightdb@test_m=# create table test_c(key1 float4);
CREATE TABLE
lightdb@test_m=# insert into test_c values('-1.6');
INSERT 0 1
lightdb@test_m=# insert into test_c values('-1.4');
INSERT 0 1
lightdb@test_m=# insert into test_c values('-1.5');
INSERT 0 1
lightdb@test_m=# select cast(key1 as unsigned) , key1 from test_c;
 numeric2unsigned | key1
-----+-----
18446744073709551614 | -1.6
18446744073709551615 | -1.4
18446744073709551614 | -1.5
(3 rows)

lightdb@test_m=# select cast(cast('20121212' as date) as unsigned);
ERROR:  cannot cast type date to numeric
LINE 1: select cast(cast('20121212' as date) as unsigned);
                   ^
lightdb@test_m=#

```

### F.53.2.13. AES encryption and decryption

The following AES encryption and decryption and hexadecimal conversion operators are supported:

- hex
- unhex
- aes\_encrypt
- aes\_decrypt

#### F.53.2.13.1. hex

**Description**

The hex function converts bytea data to text.

**Syntax**

hex(data bytea) returns text

**Example**

```
select hex('\x0123456789abcdef');
       hex
-----
0123456789abcdef
(1 row)
```

**F.53.2.13.2. unhex****Description**

The unhex function converts varchar data to bytea.

**Syntax**

unhex(data varchar) returns bytea

**Example**

```
select unhex('0123456789abcdef');
       unhex
-----
\x0123456789abcdef
(1 row)
```

**F.53.2.13.3. aes\_encrypt****Description**

AES encryption function.

**Syntax**

aes\_encrypt(data bytea, key bytea) returns bytea  
aes\_encrypt(data varchar, key varchar) returns bytea

**Example**

```
select aes_encrypt('world', '123456');
       aes_encrypt
-----
\x85400d3bbeeb51259f497fcb4bee03e
(1 row)
```

#### F.53.2.13.4. aes\_decrypt

##### Description

AES decryption function.

##### Syntax

```
aes_decrypt(data bytea, key bytea) returns bytea
aes_decrypt(data varchar, key varchar) returns bytea
aes_decrypt(data bytea, key varchar) returns bytea
```

##### Example

```
select aes_decrypt(aes_encrypt('world', '123456'), '123456');
 aes_decrypt
-----
 \x776f726c64
(1 row)
```

### F.53.3. Queries

The following queries are supported:

- DUAL Table

DUAL table is a virtual table provided by the system. Use when executing SQL where access to a base table is not required, such as when performing tests to get result expressions such as functions and operators.

##### Example

In the following example, the current system date is returned.

```
SELECT CURRENT_DATE "date" FROM DUAL;
   date
-----
2023-05-13
(1 row)
```

## F.54. mysql\_fdw

This LightDB extension implements a Foreign Data Wrapper (FDW) for MySQL<sup>7</sup>.

### F.54.1. Installation

To compile the MySQL<sup>8</sup> foreign data wrapper, MySQL's C client library is needed, and the default version is 8.0.26. This library can be downloaded from the official MySQL website<sup>9</sup>.

The `mysql_config` must also be in the library path, it resides in the MySQL lib directory.

---

<sup>7</sup> <https://www.mysql.com/>

<sup>8</sup> <https://www.mysql.com/>

<sup>9</sup> <https://dev.mysql.com/downloads/mysql/>



```
$ export LD_LIBRARY_PATH=/usr/lib64/mysql/:
$LD_LIBRARY_PATH
```

## F.54.2. Enhancements

The following enhancements are added to the latest version of `mysql_fdw`:

### F.54.2.1. Write-able FDW

The previous version was only read-only, the latest version provides the write capability. The user can now issue an insert, update, and delete statements for the foreign tables using the `mysql_fdw`. It uses the LightDB type casting mechanism to provide opposite type casting between MySQL and LightDB data types.

### F.54.2.2. Connection Pooling

The latest version comes with a connection pooler that utilises the same MySQL database connection for all the queries in the same session. The previous version would open a new MySQL database connection for every query. This is a performance enhancement.

### F.54.2.3. WHERE clause push-down

The latest version will push-down the foreign table where clause to the foreign server. The where condition on the foreign table will be executed on the foreign server hence there will be fewer rows to bring across to LightDB. This is a performance feature.

### F.54.2.4. Column push-down

The previous version was fetching all the columns from the target foreign table. The latest version does the column push-down and only brings back the columns that are part of the select target list. This is a performance feature.

### F.54.2.5. Prepared Statement

(Refactoring for `select` queries to use prepared statement)

The `select` queries are now using prepared statements instead of simple query protocol.

### F.54.2.6. JOIN push-down

`mysql_fdw` now also supports join push-down. The joins between two foreign tables from the same remote MySQL server are pushed to a remote server, instead of fetching all the rows for both the tables and performing a join locally, thereby enhancing the performance. Currently, joins involving only relational and arithmetic operators in join-clauses are pushed down to avoid any potential join failure. Also, only the INNER and LEFT/RIGHT OUTER joins are supported, and not the FULL OUTER, SEMI, and ANTI join. This is a performance feature.

## F.54.3. Usage

The following parameters can be set on a MySQL foreign server object:

- `host`: Address or hostname of the MySQL server. Defaults to `127.0.0.1`
- `port`: Port number of the MySQL server. Defaults to `3306`
- `secure_auth`: Enable or disable secure authentication. Default is `true`

- `init_command`: SQL statement to execute when connecting to the MySQL server.
- `use_remote_estimate`: Controls whether `mysql_fdw` issues remote EXPLAIN commands to obtain cost estimates. Default is `false`
- `reconnect`: Enable or disable automatic reconnection to the MySQL server if the existing connection is found to have been lost. Default is `false`.
- `ssl_key`: The path name of the client private key file.
- `ssl_cert`: The path name of the client public key certificate file.
- `ssl_ca`: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server.
- `ssl_cacpath`: The path name of the directory that contains trusted SSL CA certificate files.
- `ssl_cipher`: The list of permissible ciphers for SSL encryption.
- `fetch_size`: This option specifies the number of rows `mysql_fdw` should get in each fetch operation. It can be specified for a foreign table or a foreign server. The option specified on a table overrides an option specified for the server. The default is 100.

The following parameters can be set on a MySQL foreign table object:

- `dbname`: Name of the MySQL database to query. This is a mandatory option.
- `table_name`: Name of the MySQL table, default is the same as foreign table.
- `max_blob_size`: Max blob size to read without truncation.
- `fetch_size`: Same as `fetch_size` parameter for foreign server.

The following parameters need to supplied while creating user mapping.

- `username`: Username to use when connecting to MySQL.
- `password`: Password to authenticate to the MySQL server with.

## F.54.4. Examples

```
-- load extension first time after install
CREATE EXTENSION mysql_fdw;

-- create server object
CREATE SERVER mysql_server
  FOREIGN DATA WRAPPER mysql_fdw
  OPTIONS (host '127.0.0.1', port '3306');

-- create user mapping
CREATE USER MAPPING FOR LightDB
  SERVER mysql_server
  OPTIONS (username 'foo', password 'bar');

-- create foreign table
CREATE FOREIGN TABLE warehouse
(
  warehouse_id int,
  warehouse_name text,
  warehouse_created timestamp
```

```

)
SERVER mysql_server
OPTIONS (dbname 'db', table_name 'warehouse');

-- insert new rows in table
INSERT INTO warehouse values (1, 'UPS', current_date);
INSERT INTO warehouse values (2, 'TV', current_date);
INSERT INTO warehouse values (3, 'Table',
current_date);

-- select from table
SELECT * FROM warehouse ORDER BY 1;

warehouse_id | warehouse_name | warehouse_created
-----+-----+-----
          1 | UPS             | 10-JUL-20 00:00:00
          2 | TV              | 10-JUL-20 00:00:00
          3 | Table           | 10-JUL-20 00:00:00

-- delete row from table
DELETE FROM warehouse where warehouse_id = 3;

-- update a row of table
UPDATE warehouse set warehouse_name = 'UPS_NEW' where
warehouse_id = 1;

-- explain a table with verbose option
EXPLAIN VERBOSE SELECT warehouse_id, warehouse_name
FROM warehouse WHERE warehouse_name LIKE 'TV' limit 1;

                                QUERY PLAN

-----
Limit (cost=10.00..11.00 rows=1 width=36)
  Output: warehouse_id, warehouse_name
  -> Foreign Scan on public.warehouse
(cost=10.00..1010.00 rows=1000 width=36)
  Output: warehouse_id, warehouse_name
  Local server startup cost: 10
  Remote query: SELECT `warehouse_id`, `warehouse_name`
FROM `db`.`warehouse` WHERE ((`warehouse_name` LIKE BINARY 'TV'))

```

## F.55. oracle\_fdw

oracle\_fdw is a LightDB extension that provides a Foreign Data Wrapper for easy and efficient access to Oracle databases, including pushdown of WHERE conditions and required columns as well as comprehensive EXPLAIN support.

oracle\_fdw was written by Laurenz Albe, with notable contributions from Vincent Mora of Oslandia and Tatsuro Yamada of the NTT OSS Center.

Special thanks to Christian Ullrich for ongoing help with Windows.

### F.55.1. Cookbook

This is a simple example how to use oracle\_fdw.

More detailed information will be provided in the sections Options and Usage. You should also read the LightDB documentation on foreign data and the commands referenced there.

For the sake of this example, let's assume you can connect as operating system user `lightdb` (or whoever starts the LightDB server) with the following command:

```
sqlplus orauser/orapwd@//dbserver.mydomain.com:1521/
ORADB
```

That means that the Oracle client and the environment is set up correctly.

We want to access a table defined like this:

```
SQL> DESCRIBE oratab
Name                               Null?    Type
-----
ID                                  NOT NULL NUMBER(5)
TEXT                                VARCHA2(30)
FLOATING                            NOT NULL NUMBER(7,2)
```

Then configure `oracle_fdw` as LightDB superuser like this:

```
ltdb=# CREATE EXTENSION oracle_fdw;
ltdb=# CREATE SERVER oradb FOREIGN DATA WRAPPER
oracle_fdw
        OPTIONS (dbserver '//
dbserver.mydomain.com:1521/ORADB');
```

(You can use other naming methods or local connections, see the description of the option `dbserver` below.)

It is a good idea to use a superuser only where really necessary, so let's allow a normal user to use the foreign server (this is not required for the example to work, but I recommend it):

```
ltdb=# GRANT USAGE ON FOREIGN SERVER oradb TO pguser;
```

Then you can connect to LightDB as `pguser` and define:

```
ltdb=> CREATE USER MAPPING FOR pguser SERVER oradb
        OPTIONS (user 'orauser', password 'orapwd');
```

(You can use external authentication to avoid storing Oracle passwords; see below.)

```
ltdb=> CREATE FOREIGN TABLE oratab (
        id          integer          OPTIONS (key
'true') NOT NULL,
        text        character varying(30),
        floating    double precision NOT NULL
        ) SERVER oradb OPTIONS (schema 'ORAUSER', table
'ORATAB');
```

(Remember that table and schema name -- the latter is optional -- must normally be in uppercase.)

Now you can use the table like a regular LightDB table.

## F.55.2. Objects created by the extension

```
FUNCTION oracle_fdw_handler() RETURNS fdw_handler
FUNCTION oracle_fdw_validator(text[], oid) RETURNS void
```

These functions are the handler and the validator function necessary to create a foreign data wrapper.

```
FOREIGN DATA WRAPPER oracle_fdw
HANDLER oracle_fdw_handler
VALIDATOR oracle_fdw_validator
```

The extension automatically creates a foreign data wrapper named `oracle_fdw`.

Normally that's all you need, and you can proceed to define foreign servers. You can create additional Oracle foreign data wrappers, for example if you need to set the `nls_lang` option (you can alter the existing `oracle_fdw` wrapper, but all modifications will be lost after a dump/restore).

```
FUNCTION oracle_close_connections() RETURNS void
```

This function can be used to close all open Oracle connections in this session. See the Usage section for further description.

```
FUNCTION oracle_diag(name DEFAULT NULL) RETURNS text
```

This function is useful for diagnostic purposes only.

It will return the versions of `oracle_fdw`, LightDB server and Oracle client. If called with no argument or `NULL`, it will additionally return the values of some environment variables used for establishing Oracle connections.

```
FUNCTION oracle_execute(server name, stmt text) RETURNS
void
```

This function can be used to execute arbitrary SQL statements on the remote Oracle server. That will only work with statements that do not return results (typically DDL statements).

Be careful when using this function, since it might disturb the transaction management of `oracle_fdw`. Remember that running a DDL statement in Oracle will issue an implicit `COMMIT`. You are best advised to use this function outside of multi-statement transactions.

## F.55.3. Options

### F.55.3.1. Foreign data wrapper options

(Caution: If you modify the default foreign data wrapper `oracle_fdw`, any changes will be lost upon dump/restore. Create a new foreign data wrapper if you want the options to be persistent. The

SQL script shipped with the software contains a CREATE FOREIGN DATA WRAPPER statement you can use.)

- `nls_lang` (optional)

Sets the NLS\_LANG environment variable for Oracle to this value.

NLS\_LANG is in the form "language\_territory.charset" (for example AMERICAN\_AMERICA.AL32UTF8). This must match your database encoding. When this value is not set, oracle\_fdw will automatically do the right thing if it can and issue a warning if it cannot. Set this only if you know what you are doing. See the Problems section.

### F.55.3.2. Foreign server options

- `dbserver` (required)

The Oracle database connection string for the remote database.

This can be in any of the forms that Oracle supports as long as your Oracle client is configured accordingly.

Set this to an empty string for local ("BEQUEATH") connections.

- `isolation_level` (optional, defaults to `serializable`)

The transaction isolation level to use at the Oracle database.

The value can be `serializable`, `read_committed` or `read_only`.

Note that the Oracle table can be queried more than once during a single LightDB statement (for example, during a nested loop join). To make sure that no inconsistencies caused by race conditions with concurrent transactions can occur, the transaction isolation level must guarantee read stability.

This is only guaranteed with Oracle's SERIALIZABLE or READ ONLY isolation levels.

Unfortunately Oracle's implementation of SERIALIZABLE is rather bad and causes serialization errors (ORA-08177) in unexpected situations, like inserts into the table.

Using READ COMMITTED transactions works around this problem, but there is a risk of inconsistencies. If you want to use it, check your execution plans if the foreign scan could be executed more than once.

- `nchar` (boolean, optional, defaults to off)

Setting this option to on chooses a more expensive character conversion on the Oracle side. This is required if you are using a single-byte Oracle database character set, but have NCHAR or NVARCHAR2 columns containing characters that cannot be represented in the database character set.

Setting `nchar` to on has a noticeable performance impact, and it causes ORA-01461 errors with UPDATE statements that set strings over 2000 bytes (or 16383 if you have MAX\_STRING\_SIZE = EXTENDED). This error seems to be an Oracle bug.

### F.55.3.3. User mapping options

- `user` (required)

The Oracle user name for the session.

Set this to an empty string for external authentication if you don't want to store Oracle credentials in the LightDB database (one simple way is to use an external password store).

- `password` (required)

The password for the Oracle user.

### F.55.3.4. Foreign table options

- `table` (required)

The Oracle table name. This name must be written exactly as it occurs in Oracle's system catalog, so normally consist of uppercase letters only.

To define a foreign table based on an arbitrary Oracle query, set this option to the query enclosed in parentheses, e.g.

```
OPTIONS (table '(SELECT col FROM tab
WHERE val = ''string''))
```

Do not set the `schema` option in this case.

INSERT, UPDATE and DELETE will work on foreign tables defined on simple queries; if you want to avoid that (or confusing Oracle error messages for more complicated queries), use the table option `readonly`.

- `dblink` (optional)

The Oracle database link through which the table is accessed. This name must be written exactly as it occurs in Oracle's system catalog, so normally consist of uppercase letters only.

- `schema` (optional)

The table's schema (or owner). Useful to access tables that do not belong to the connecting Oracle user. This name must be written exactly as it occurs in Oracle's system catalog, so normally consist of uppercase letters only.

- `max_long` (optional, defaults to "32767")

The maximal length of any LONG, LONG RAW and XMLTYPE columns in the Oracle table. Possible values are integers between 1 and 1073741823 (the maximal size of a bytea in LightDB). This amount of memory will be allocated at least twice, so large values will consume a lot of memory.

If `max_long` is less than the length of the longest value retrieved, you will receive the error message `ORA-01406: fetched column value was truncated`.

- `readonly` (optional, defaults to "false")

INSERT, UPDATE and DELETE is only allowed on tables where this option is not set to `yes/on/true`.

- `sample_percent` (optional, defaults to "100")

This option only influences ANALYZE processing and can be useful to ANALYZE very large tables in a reasonable time.

The value must be between 0.000001 and 100 and defines the percentage of Oracle table blocks that will be randomly selected to calculate LightDB table statistics. This is accomplished using the `SAMPLE BLOCK (x)` clause in Oracle.

ANALYZE will fail with `ORA-00933` for tables defined with Oracle queries and may fail with `ORA-01446` for tables defined with complex Oracle views.

- `prefetch` (optional, defaults to "200")

Sets the number of rows that will be fetched with a single round-trip between LightDB and Oracle during a foreign table scan. This is implemented using Oracle row prefetching. The value must be between 0 and 10240, where a value of zero disables prefetching.

Higher values can speed up performance, but will use more memory on the LightDB server.

## F.55.4. Usage

### F.55.4.1. Oracle permissions

The Oracle user will obviously need `CREATE SESSION` privilege and the right to select from the table or view in question.

For `EXPLAIN VERBOSE` the user will also need `SELECT` privileges on `V$SQL` and `V$SQL_PLAN`.

### F.55.4.2. Connections

`oracle_fdw` caches Oracle connections because it is expensive to create an Oracle session for each individual query. All connections are automatically closed when the LightDB session ends.

The function `oracle_close_connections()` can be used to close all cached Oracle connections. This can be useful for long-running sessions that don't access foreign tables all the time and want to avoid blocking the resources needed by an open Oracle connection.

You cannot call this function inside a transaction that modifies Oracle data.

### F.55.4.3. Columns

When you define a foreign table, the columns of the Oracle table are mapped to the LightDB columns in the order of their definition.

`oracle_fdw` will only include those columns in the Oracle query that are actually needed by the LightDB query.

The LightDB table can have more or less columns than the Oracle table. If it has more columns, and these columns are used, you will receive a warning and `NULL` values will be returned.

If you want to `UPDATE` or `DELETE`, make sure that the `key` option is set on all columns that belong to the table's primary key. Failure to do so will result in errors.

### F.55.4.4. Oracle permissions

You must define the LightDB columns with data types that `oracle_fdw` can translate (see the conversion table below). This restriction is only enforced if the column actually gets used, so you can define "dummy" columns for untranslatable data types as long as you don't access them (this trick only works with `SELECT`, not when modifying foreign data). If an Oracle value exceeds the size of the LightDB column (e.g., the length of a `varchar` column or the maximal integer value), you will receive a runtime error.

These conversions are automatically handled by `oracle_fdw`:

Oracle type	Possible LightDB types
CHAR	char, varchar, text



	NCHAR	char, varchar, text
	VARCHAR	char, varchar, text
	VARCHAR2	char, varchar, text,
json		
	NVARCHAR2	char, varchar, text
	CLOB	char, varchar, text,
json		
	LONG	char, varchar, text
	RAW	uuid, bytea
	BLOB	bytea
	BFILE	bytea (read-only)
	LONG RAW	bytea
	NUMBER	numeric, float4, float8,
char, varchar, text		
	NUMBER(n,m)	numeric, float4, float8, int2,
int4, int8,		
		boolean, char,
varchar, text		
	FLOAT	numeric, float4, float8,
char, varchar, text		
	BINARY_FLOAT	numeric, float4, float8,
char, varchar, text		
	BINARY_DOUBLE	numeric, float4, float8,
char, varchar, text		
	DATE	date, timestamp,
timestampz, char, varchar, text		
	TIMESTAMP	date, timestamp,
timestampz, char, varchar, text		
	TIMESTAMP WITH TIME ZONE	date, timestamp,
timestampz, char, varchar, text		
	TIMESTAMP WITH	date, timestamp,
timestampz, char, varchar, text		
	LOCAL TIME ZONE	
	INTERVAL YEAR TO MONTH	interval, char, varchar,
text		
	INTERVAL DAY TO SECOND	interval, char, varchar,
text		
	XMLTYPE	xml, char, varchar, text
	MDSYS.SDO_GEOMETRY	geometry (see "PostGIS
support" below)		

If a NUMBER is converted to a boolean, 0 means false, everything else true

Inserting or updating XMLTYPE only works with values that do not exceed the maximum length of the VARCHAR2 data type (4000 or 32767, depending on the MAX\_STRING\_SIZE parameter).

NCLOB is currently not supported because Oracle cannot automatically convert it to the client encoding.

If you need conversions exceeding the above, define an appropriate view in Oracle or LightDB.

## F.55.4.5. WHERE conditions and ORDER BY clauses

LightDB will use all applicable parts of the WHERE clause as a filter for the scan. The Oracle query that oracle\_fdw constructs will contain a WHERE clause corresponding to these filter criteria whenever such a condition can safely be translated to Oracle SQL. This feature, also known as push-down of WHERE clauses, can greatly reduce the number of rows retrieved from Oracle and may enable Oracle's optimizer to choose a good plan for accessing the required tables.

Similarly, ORDER BY clauses will be pushed down to Oracle wherever possible. Note that no ORDER BY condition that sorts by a character string will be pushed down as the sort orders in LightDB and Oracle cannot be guaranteed to be the same.

To make use of that, try to use simple conditions for the foreign table. Choose LightDB column data types that correspond to Oracle's types, because otherwise conditions cannot be translated.

The expressions `now()`, `transaction_timestamp()`, `current_timestamp`, `current_date` and `localtimestamp` will be translated correctly.

The output of EXPLAIN will show the Oracle query used, so you can see which conditions were translated to Oracle and how.

### F.55.4.6. Joins between foreign tables

`oracle_fdw` can push down joins to the Oracle server, that is, a join between two foreign tables will lead to a single Oracle query that performs the join on the Oracle side.

There are some restrictions when this can happen:

- Both tables must be defined on the same foreign server.
- Joins between three or more tables won't be pushed down.
- The join must be in a SELECT statement.
- `oracle_fdw` must be able to push down all join conditions and WHERE clauses.
- Cross joins without join conditions are not pushed down.
- If a join is pushed down, ORDER BY clauses will not be pushed down

It is important that table statistics for both foreign tables have been collected with ANALYZE for LightDB to determine the best join strategy.

### F.55.4.7. Modifying foreign data

`oracle_fdw` supports INSERT, UPDATE and DELETE on foreign tables. This is allowed by default (also in databases upgraded from an earlier LightDB release) and can be disabled by setting the `readonly` table option.

For UPDATE and DELETE to work, the columns corresponding to the primary key columns of the Oracle table must have the `key` column option set. These columns are used to identify a foreign table row, so make sure that the option is set on all columns that belong to the primary key.

If you omit a foreign table column during INSERT, that column is set to the value defined in the DEFAULT clause on the LightDB foreign table (or NULL if there is no DEFAULT clause). DEFAULT clauses on the corresponding Oracle columns are not used. If the LightDB foreign table does not include all columns of the Oracle table, the Oracle DEFAULT clauses will be used for the columns not included in the foreign table definition.

The RETURNING clause on INSERT, UPDATE and DELETE is supported except for columns with Oracle data types LONG and LONG RAW (Oracle doesn't support these data types in the RETURNING clause).

Triggers on foreign tables are supported. Triggers defined with AFTER and FOR EACH ROW require that the foreign table has no columns with Oracle data type LONG or LONG RAW. This is because such triggers make use of the RETURNING clause mentioned above.

While modifying foreign data works, the performance is not particularly good, specifically when many rows are affected, because (owing to the way foreign data wrappers work) each row has to be treated individually.

Transactions are forwarded to Oracle, so BEGIN, COMMIT, ROLLBACK and SAVEPOINT work as expected. Prepared statements involving Oracle are not supported. See the Internals section for details.

Since oracle\_fdw uses serialized transactions by default, it is possible that data modifying statements lead to a serialization failure:

```
ORA-08177: can't serialize access for this
transaction
```

This can happen if concurrent transactions modify the table and gets more likely in long running transactions. Such errors can be identified by their SQLSTATE (40001). An application using oracle\_fdw should retry transactions that fail with this error.

It is possible to use a different transaction isolation level, see Foreign server options for a discussion.

### F.55.4.8. EXPLAIN

LightDB's EXPLAIN will show the query that is actually issued to Oracle. EXPLAIN VERBOSE will show Oracle's execution plan (that will not work with Oracle server 9i or older, see Problems).

### F.55.4.9. ANALYZE

You can use ANALYZE to gather statistics on a foreign table. This is supported by oracle\_fdw.

Without statistics, LightDB has no way to estimate the row count for queries on a foreign table, which can cause bad execution plans to be chosen.

LightDB will not automatically gather statistics for foreign tables with the autovacuum daemon like it does for normal tables, so it is particularly important to run ANALYZE on foreign tables after creation and whenever the remote table has changed significantly.

Keep in mind that analyzing an Oracle foreign table will result in a full sequential table scan. You can use the table option `sample_percent` to speed this up by using only a sample of the Oracle table.

### F.55.4.10. PostGIS support

The data type `geometry` is only available when PostGIS is installed.

The only supported geometry types are POINT, LINE, POLYGON, MULTIPOINT, MULTILINE and MULTIPOLYGON in two and three dimensions. Empty PostGIS geometries are not supported because they have no equivalent in Oracle Spatial.

NULL values for Oracle SRID will be converted to 0 and vice versa. For other conversions between Oracle SRID and PostGIS SRID, create a file `srid.map` in the LightDB share directory. Each line of this file shall contain an Oracle SRID and the corresponding PostGIS SRID, separated by whitespace. Keep the file small for good performance.

### F.55.4.11. Support for IMPORT FOREIGN SCHEMA

IMPORT FOREIGN SCHEMA is supported to bulk import table definitions for all tables in an Oracle schema.

In addition to the documentation of IMPORT FOREIGN SCHEMA, consider the following:

- IMPORT FOREIGN SCHEMA will create foreign tables for all objects found in ALL\_TAB\_COLUMNS. That includes tables, views and materialized views, but not synonyms.
- These are the supported options for IMPORT FOREIGN SCHEMA:

- `case`: controls case folding for table and column names during import

The possible values are:

- `keep`: leave the names as they are in Oracle, usually in upper case.
- `lower`: translate all table and column names to lower case.
- `smart`: only translate names that are all upper case in Oracle (this is the default).
- `collation`: the collation used for case folding for the `lower` and `smart` options of `case`

The default value is `default` which is the database's default collation. Only collations in the `pg_catalog` schema are supported. See the `collname` values in the `pg_collation` catalog for a list of possible values.

- `dblink`: the Oracle database link through which the schema is accessed

This name must be written exactly as it occurs in Oracle's system catalog, so normally consist of uppercase letters only.

- `readonly`: sets the `readonly` option on all imported tables

See the Options section for details.

- `max_long`: sets the `max_long` option on all imported tables

See the Options section for details.

- `sample_percent`: sets the `sample_percent` option on all imported tables

See the Options section for details.

- `prefetch`: sets the `prefetch` option on all imported tables

See the Options section for details.

- The Oracle schema name must be written exactly as it is in Oracle, so normally in upper case. Since LightDB translates names to lower case before processing, you must protect the schema name with double quotes (for example "SCOTT").
- Table names in the `LIMIT TO` or `EXCEPT` clause must be written as they will appear in LightDB after the case folding described above.

Note that `IMPORT FOREIGN SCHEMA` does not work with Oracle server 8i; see the Problems section for details.

## F.55.5. Internals

`oracle_fdw` sets the `MODULE` of the Oracle session to `LightDB` and the `ACTION` to the backend process number. This can help identifying the Oracle session and allows you to trace it with `DBMS_MONITOR.SERV_MOD_ACT_TRACE_ENABLE`.

`oracle_fdw` uses Oracle's result prefetching to avoid unnecessary client-server round-trips. The `prefetch` row count can be configured with the `prefetch` table option and is set to 200 by default.

Rather than using a `PLAN_TABLE` to explain an Oracle query (which would require such a table to be created in the Oracle database), `oracle_fdw` uses execution plans stored in the library cache. For that, an Oracle query is explicitly described, which forces Oracle to parse the query. The hard part is to find the `SQL_ID` and `CHILD_NUMBER` of the statement in `V$SQL` because the `SQL_TEXT` column contains only the first 1000 bytes of the query. Therefore, `oracle_fdw` adds a comment to the query

that contains an MD5 hash of the query text. This is used to search in V\$SQL. The actual execution plan or cost information is retrieved from V\$SQL\_PLAN.

oracle\_fdw uses transaction isolation level SERIALIZABLE on the Oracle side, which corresponds to LightDB's REPEATABLE READ. This is necessary because a single LightDB statement can lead to multiple Oracle queries (e.g. during a nested loop join) and the results need to be consistent.

Unfortunately the Oracle implementation of SERIALIZABLE has certain quirks; see the Problems section for more.

The Oracle transaction is committed immediately before the local transaction commits, so that a completed LightDB transaction guarantees that the Oracle transaction has completed. However, there is a small chance that the LightDB transaction cannot complete even though the Oracle transaction is committed. This cannot be avoided without using two-phase transactions and a transaction manager, which is beyond what a foreign data wrapper can reasonably provide.

Prepared statements involving Oracle are not supported for the same reason.

## F.55.6. Problems

### F.55.6.1. Encoding

Characters stored in an Oracle database that cannot be converted to the LightDB database encoding will silently be replaced by `replacement_characters`, typically a normal or inverted question mark, by Oracle. You will get no warning or error messages.

If you use a LightDB database encoding that Oracle does not know (currently, these are EUC\_CN, EUC\_KR, LATIN10, MULE\_INTERNAL, WIN874 and SQL\_ASCII), non-ASCII characters cannot be translated correctly. You will get a warning in this case, and the characters will be replaced by replacement characters as described above.

You can set the `nls_lang` option of the foreign data wrapper to force a certain Oracle encoding, but the resulting characters will most likely be incorrect and lead to LightDB error messages. This is probably only useful for SQL\_ASCII encoding if you know what you are doing. See the Options section.

### F.55.6.2. Limited functionality in old Oracle versions

- The definition of the Oracle system catalogs V\$SQL and V\$SQL\_PLAN has changed with Oracle 10.1. Using EXPLAIN VERBOSE with older Oracle server versions will result in errors like:

```
ERROR: error describing query:
OCIStmtExecute failed to execute
      remote query for sql_id
DETAIL:  ORA-00904: "LAST_ACTIVE_TIME":
invalid identifier
```

There is no plan to fix this, since Oracle 9i has been out of Extended Support since 2010 and the functionality is not essential.

- IMPORT FOREIGN SCHEMA throws the following error with Oracle server 8i:

```
ERROR: error importing foreign schema:
OCIStmtExecute failed to execute
      column query
DETAIL:  ORA-00904: invalid column name
```

This is because the view `ALL_TAB_COLUMNS` lacks the column `CHAR_LENGTH`, which was added in Oracle 9i.

### F.55.6.3. Serialization errors

In Oracle 11.2 or above, inserting the first row into a newly created Oracle table with `oracle_fdw` will lead to a serialization error.

This is because of an Oracle feature called `deferred segment creation` which defers allocation of storage space for a new table until the first row is inserted. This causes a serialization failure with serializable transactions (see document 1285464.1 in Oracle's knowledge base).

This is no serious problem; you can work around it by either ignoring that first error or creating the table with `SEGMENT CREATION IMMEDIATE`.

A much nastier problem is that concurrent inserts can sometimes cause serialization errors when an index page is split concurrently with a modifying serializable transaction (see Oracle document 160593.1).

Oracle claims that this is not a bug, and the suggested solution is to retry the transaction that got a serialization error.

### F.55.6.4. Oracle bugs

This is a list of Oracle bugs that have affected `oracle_fdw` in the past.

Bug 2728408 can cause `ORA-8177 cannot serialize access for this transaction` even if no modification of remote data is attempted.

It can occur with Oracle server 8.1.7.4 (install one-off patch 2728408) or Oracle server 9.2 (install Patch Set 9.2.0.4 or better).

## F.56. orafce

`orafce` - Oracle's compatibility functions and packages.

### F.56.1. Features Compatible with Oracle Databases

Features compatible with Oracle databases are provided. These features enable you to easily migrate to LightDB and reduce the costs of reconfiguring applications. The table below lists features compatible with Oracle databases.

**Table F.86. Data type**

Item	Overview
<code>VARCHAR2</code>	Variable-length character data type
<code>NVARCHAR2</code>	Variable-length national character data type
<code>DATE</code>	Data type that stores date and time
<code>NUMBER</code>	<code>NUMBER</code> is an alias for <code>NUMERIC</code>
<code>CLOB</code>	stores single-byte and multibyte character data and has mostly same functionality with <code>text</code> data type.
<code>BLOB</code>	stores unstructured binary large objects and has mostly same functionality with <code>'bytea'</code> data type.

Item	Overview
RAW	Variable-length hex data type .
PLS_INTEGER	A PL/SQL data type used for storing signed integers.
BINARY_FLOAT	32-bit floating point number. This data type requires 4 bytes.
BINARY_DOUBLE	64-bit floating point number. This data type requires 8 bytes.
XMLType	Variable-length xml data type .

varchar2 and nvarchar2 is config in priority between varchar and char, after create orafce extensin, the priority is :

numeric > double precision > real > bigint > integer > smallint > text > varchar > varchar2 > nvarchar2 > char

**Table F.87. SQL Queries**

Item	Overview
DUAL table	Table provided by the system

**Table F.88. Mathematical Functions**

Item	Overview	Parallel attribute
BIN_TO_NUM	Converts a bit vector to its equivalent number	Safe
BITAND	Performs a bitwise AND operation	Safe
BITOR	Performs a bitwise OR operation	Safe
BITXOR	Performs a bitwise XOR operation	Safe
COSH	Calculates the hyperbolic cosine of a number	Safe
MOD	Returns the remainder (modulus) of argument 1 divided by argument 2.	Safe
REMAINDER	Returns the remainder of n2 divided by n1	Safe
ROUND_TIES_TO_EVEN	Returns n rounded to integer places	Safe
SINH	Calculates the hyperbolic sine of a number	Safe
TANH	Calculates the hyperbolic tangent of a number	Safe
CEIL	Returns the smallest integer(type interval will extract the days to number first) that is greater than or equal to a number	Safe

**Table F.89. String Functions**

<b>Item</b>	<b>Overview</b>	<b>Parallel attribute</b>
INSTR	Returns the position of a substring in a string	Safe
INSTRB	Returns the position in the string that is the first byte of a specified occurrence of the substring	Safe
LENGTH	Returns the length of a string in number of characters	Safe
LENGTHB	Returns the length of a string in number of bytes	Safe
LPAD	Left-pads a string to a specified length with a sequence of characters	Safe
LTRIM	Removes the specified characters from the beginning of a string	Safe
NLSSORT	Returns a byte string used to sort strings in linguistic sort sequence based on locale	Safe
REGEXP_COUNT	searches a string for a regular expression, and returns a count of the matches	Safe
REGEXP_INSTR	returns the beginning or ending position within the string where the match for a pattern was located	Safe
REGEXP_LIKE	condition in the WHERE clause of a query, causing the query to return rows that match the given pattern	Safe
REGEXP_SUBSTR	returns the string that matches the pattern specified in the call to the function	Safe
REGEXP_REPLACE	returns the string that matches the pattern specified in the call to the function	Safe
REPLACE	REPLACE returns string with every occurrence of search_string replaced with replacement_string	Safe
RPAD	Right-pads a string to a specified length with a sequence of characters	Safe
RTRIM	Removes the specified characters from the end of a string	Safe
SOUNDEX	Returns a character string containing the phonetic representation of char.	Safe



Item	Overview	Parallel attribute
SUBSTR	Extracts part of a string using characters to specify position and length	Safe
SUBSTRB	Extracts part of a string using bytes to specify position and length	Safe
GUID	Return UUID	Safe
CONCAT	concatenate two strings	Safe
UPPER	make all letters uppercase	Safe

**Table F.90. Date/Time Functions**

Item	Overview	Parallel attribute
ADD_MONTHS	Adds months to a date	Safe
DBTIMEZONE	Returns the value of the database time zone	Safe
LENGTHB	Returns the length of a string in number of bytes	Safe
LAST_DAY	Returns the last day of the month in which the specified date falls	Safe
LTRIM	Removes the specified characters from the beginning of a string	Safe
MONTHS_BETWEEN	Returns the number of months between two dates	Safe
NEXT_DAY	Returns the date of the first instance of a particular day of the week that follows the specified date	Safe
ROUND	Rounds a date	Safe
SESSIONTIMEZONE	Returns the time zone of the session	Safe
SYSDATE	Returns the system date	Safe
TRUNC	Truncates a date	Safe
TZ_OFFSET	Returns the time zone offset	Safe

**Table F.91. Data Type Formatting Functions**

Item	Overview	Parallel attribute
CONVERT	Converts a character string from one character set to another.	Safe
NUMTOYMINTERVAL	Converts number to an INTERVAL YEAR TO MONTH literal	Safe
TO_BLOB(raw)	Converts RAW values to BLOB values.	Safe
TO_CHAR	Converts a value to a string	Safe

Item	Overview	Parallel attribute
TO_DATE	Converts a string to a date in accordance with the specified format	Safe
TO_MULTI_BYTE	Converts a single-byte string to a multibyte string	Safe
TO_NUMBER	Converts a value to a number in accordance with the specified format	Safe
TO_SINGLE_BYTE	Converts a multibyte string to a single-byte string	Safe
TO_CLOB	Converts a string or a number to clob	

**Table F.92. Conditional Expressions**

Item	Overview	Parallel attribute
DECODE	Compares values, and if they match, returns a corresponding value	Safe
LNNVL	Evaluates if a value is false or unknown	Safe
NANVL	Returns a substitute value when a value is not a number (NaN)	Safe
NVL	Returns a substitute value when a value is NULL	Safe
NVL2	Returns a substitute value based on whether a value is NULL or not NULL	Safe

**Table F.93. Aggregate Functions**

Item	Overview	Parallel attribute
ANY_VALUE	Returns a single non-deterministic value of expr.	Unsafe
BIT_AND_AGG	Returns the result of a bitwise AND operation	Unsafe
BIT_OR_AGG	Returns the result of a bitwise OR operation	Unsafe
BIT_XOR_AGG	Returns the result of a bitwise XOR operation	Unsafe
KURTOSIS_POP	Used to determine the characteristics of outliers in a given distribution	Unsafe
KURTOSIS_SAMP	Used to determine the characteristics of outliers in a given distribution	Unsafe
LISTAGG	Returns a concatenated, delimited list of string values	Unsafe
MEDIAN	Calculates the median of a set of values	Unsafe

Item	Overview	Parallel attribute
SKEWNESS_POP	Used to determine symmetry in a given distribution	Unsafe
SKEWNESS_SAMP	Used to determine symmetry in a given distribution	Unsafe

**Table F.94. Functions that return internal information**

Item	Overview	Parallel attribute
DUMP	Returns internal information of a value	Safe
NLS_CHARSET_ID	Returns the character set ID number corresponding to character set name string.	Safe
NLS_CHARSET_NAME	Returns the name of the character set corresponding to ID number number.	Safe
SYS_CONTEXT	Returns the value of parameter associated with the context namespace at the current instant	Safe
USERENV	Returns the value of parameter associated with the context 'USERENV' at the current session	Safe

**Table F.95. SQL Operators**

Item	Overview
Datetime operator	Datetime operator for the DATE type

**Table F.96. Other functions**

Item	Overview	Parallel attribute
EMPTY_CLOB	Return an empty CLOB	Safe
EMPTY_BLOB	Return an empty BLOB	Safe
ORA_HASH	ORA_HASH is a function that computes a hash value for a given expression	Safe
VSIZE	Returns the number of bytes in the internal representation of expr	Safe
DEPS_SAVE_AND_DROP_DEPENDENCIES	Save and drop dependencies for table	Unsafe
DEPS_RESTORE_DEPENDENCIES	Restore dependencies for table	Unsafe
PLVSTR.IS_PREFIX	Return true if a is the prefix of b.	Safe
plvdate.isleapyear	Return true if the date is a leap year.	

**Table F.97. Packages**

<b>Item</b>	<b>Overview</b>
DBMS_ALERT	Sends alerts to multiple sessions
DBMS_ASSERT	Validates the properties of an input value
DBMS_LOB	Some functions compatible with DBMS_LOB package.
DBMS_OUTPUT	Sends messages to clients
DBMS_PIPE	Creates a pipe for inter-session communication
DBMS_RANDOM	Generates random numbers
DBMS_UTILITY	Provides various utilities
DBMS_JOB	Schedules and manages jobs in the It_cron
DBMS_LOCK	Provides an interface to Lock Management services
DBMS_METADATA	Provides a way for you to retrieve metadata from the database dictionary
DBMS_OBFUSCATION_TOOLKIT	Enables an application to encrypt data using either the Data Encryption Standard (DES) or the Triple DES algorithms
DBMS_SNAPSHOT	Enables you to refresh snapshots(MVIEW)
UTL_FILE	Enables text file operations
UTL_RAW	Provides SQL functions for manipulating RAW datatypes
UTL_URL	Has two functions that provide escape and unescape mechanisms for URL characters
UTL_ENCODE	Provides functions that encode RAW data into a standard encoded format

**Table F.98. System View**

<b>Item</b>	<b>Overview</b>
DBA_SEQUENCES ALL_SEQUENCES USER_SEQUENCES	Describes sequences
DBA_SYNONYMS ALL_SYNONYMS USER_SYNONYMS	Describes the synonyms, empty now
DBA_TAB_COLS ALL_TAB_COLS USER_TAB_COLS COLS DBA_TAB_COLUMNS ALL_TAB_COLUMNS	Describes the columns of tables, views

Item	Overview
USER_TAB_COLUMNS	
DBA_TAB_COL_STATISTICS ALL_TAB_COL_STATISTICS USER_TAB_COL_STATISTICS	Contains column statistics and histogram information extracted from "[DBA/ALL/USER]_TAB_COLUMNS"
DBA_OBJECTS ALL_OBJECTS USER_OBJECTS OBJ	Describes objects
DBA_CATALOG ALL_CATALOG USER_CATALOG	Lists tables, views, and sequences
DICTIONARY DICT	Contains descriptions of data dictionary tables and views.
DBA_DEPENDENCIES ALL_DEPENDENCIES USER_DEPENDENCIES	Describes dependencies between objects
DBA_SOURCE ALL_SOURCE USER_SOURCE	Describes the text source of stored objects
DBA_PROCEDURES ALL_PROCEDURES USER_PROCEDURES	Lists functions and procedures
DBA_TRIGGERS ALL_TRIGGERS USER_TRIGGERS	Describes triggers
DBA_TRIGGER_COLS ALL_TRIGGER_COLS USER_TRIGGER_COLS	Describes the use of columns in triggers
DBA_TYPES ALL_TYPES USER_TYPES	Describes object types
DBA_CONSTRAINTS ALL_CONSTRAINTS USER_CONSTRAINTS	Describes constraint definitions

<b>Item</b>	<b>Overview</b>
DBA_CONS_COLUMNS ALL_CONS_COLUMNS USER_CONS_COLUMNS	Describes columns that are specified in constraints
DBA_VIEWS ALL_VIEWS USER_VIEWS	Describes views
DBA_TABLES ALL_TABLES USER_TABLES TABS DBA_ALL_TABLES ALL_ALL_TABLES USER_ALL_TABLES TAB	Describes object tables and relational tables
DBA_TAB_STATISTICS ALL_TAB_STATISTICS USER_TAB_STATISTICS	Displays optimizer statistics for tables
DBA_TAB_COMMENTS ALL_TAB_COMMENTS USER_TAB_COMMENTS	Displays comments on tables and views
DBA_COL_COMMENTS ALL_COL_COMMENTS USER_COL_COMMENTS	Displays comments on the columns of tables and views
DBA_TAB_MODIFICATIONS ALL_TAB_MODIFICATIONS USER_TAB_MODIFICATIONS	Describes modifications to all tables
DBA_INDEXES ALL_INDEXES USER_INDEXES IND	Describes indexes
DBA_INDEX_USAGE ALL_INDEX_USAGE USER_INDEX_USAGE	Displays cumulative statistics for each index.

<b>Item</b>	<b>Overview</b>
DBA_IND_COLUMNS ALL_IND_COLUMNS USER_IND_COLUMNS	Describes the columns of indexes on tables
DBA_IND_EXPRESSIONS ALL_IND_EXPRESSIONS USER_IND_EXPRESSIONS	Describes the expressions of function-based indexes
DBA_IND_STATISTICS ALL_IND_STATISTICS USER_IND_STATISTICS	Displays optimizer statistics for indexes
DBA_USERS ALL_USERS USER_USERS	Describes users
DBA_ROLES	Describes all roles in the database
DBA_ROLE_PRIVS USER_ROLE_PRIVS	Describes the roles granted to users and roles
PRODUCT_COMPONENT_VERSION	Contains version and status information for component products
PLAN_TABLE	PLAN_TABLE is automatically created as a global temporary table to hold the output of an EXPLAIN PLAN statement for all users, empty now
DBA_DATA_FILES	Describes database files
DBA_JOBS ALL_JOBS USER_JOBS	Describes jobs
DBA_JOBS_RUNNING	Lists all jobs that are currently running in the instance
DBA_MVIEWS ALL_MVIEWS USER_MVIEWS	Describes materialized views
DBA_MVIEW_LOGS ALL_MVIEW_LOGS USER_MVIEW_LOGS	Describes all materialized view logs now it is empty
DBA_MVIEW_COMMENTS ALL_MVIEW_COMMENTS USER_MVIEW_COMMENTS	Displays comments on the materialized views
DBA_TABLESPACES	Describes tablespaces

Item	Overview
USER_TABLESPACES	
NLS_DATABASE_PARAMETERS NLS_INSTANCE_PARAMETERS NLS_SESSION_PARAMETERS	Lists NLS parameters
DBA_SEGMENTS USER_SEGMENTS	Describes the storage allocated for segments
DBA_PART_TABLES ALL_PART_TABLES USER_PART_TABLES	Displays the object-level partitioning information for the partitioned tables
DBA_TAB_PARTITIONS ALL_TAB_PARTITIONS USER_TAB_PARTITIONS	Displays partition-level partitioning information, partition storage parameters, and partition statistics
DBA_TAB_SUBPARTITIONS ALL_TAB_SUBPARTITIONS USER_TAB_SUBPARTITIONS	Displays information for all subpartitions
DBA_PART_KEY_COLUMNS ALL_PART_KEY_COLUMNS USER_PART_KEY_COLUMNS	Describes the partitioning key columns for the partitioned objects
DBA_SUBPART_KEY_COLUMNS ALL_SUBPART_KEY_COLUMNS USER_SUBPART_KEY_COLUMNS	Displays subpartitioning key columns for composite-partitioned tables (and local indexes on composite-partitioned tables)
DBA_IND_PARTITIONS ALL_IND_PARTITIONS USER_IND_PARTITIONS	Describes index partitions
DBA_PART_INDEXES ALL_PART_INDEXES USER_PART_INDEXES	Displays the object-level partitioning information for the partitioned indexes
COL	Describes the columns of tables, views

Views starting with DBA show something in the database. Views starting with ALL is currently the same as Views starting with DBA, and no permission verification is done like oracle. now. Views starting with USER show something owned by the current user (actually is current schema. in oracle, User and schema are one-to-one correspondence).

#### Numeric implicit cast with Boolean

oracle supports type NUMERIC implicit cast to BOOL , and vice versa.

#### Example



```
CREATE TABLE test(v1 BOOLEAN, v2 NUMERIC);

-- numeric implicit cast to boolean
-- boolean implicit cast to numeric
INSERT INTO test(v1, v2) VALUES(1.1, true);
SELECT * FROM test WHERE v2 = true;
```

## F.56.2. Notes on Using orafce

Orafce is defined as user-defined functions in the "public" schema created by default when database clusters are created, so they can be available for all users without the need for special settings. For this reason, ensure that "public" (without the double quotation marks) is included in the list of schema search paths specified in the search\_path parameter.

The following features provided by orafce are implemented in LightDB and orafce using different external specifications. In the default configuration of LightDB, the standard features of LightDB take precedence.

**Table F.99. Data type**

Item	Standard feature of LightDB	Compatibility feature added by orafce
DATE	Stores date only.	Stores date and time.

**Table F.100. Function**

Item	Standard feature of LightDB	Compatibility feature added by orafce
LENGTH	If the string is CHAR type, trailing spaces are not included in the length.	If the string is CHAR type, trailing spaces are included in the length.
SUBSTR	If 0 or a negative value is specified for the start position, simply subtracting 1 from the start position, the position will be shifted to the left, from where extraction will start.	- If 0 is specified for the start position, extraction will start from the beginning of the string.  - If a negative value is specified for the start position, extraction will start from the position counted from the end of the string.
LPAD RPAD	- If the string is CHAR type, trailing spaces are removed and then the value is padded.  - The result length is handled as a number of characters.	- If the string is CHAR type, the value is padded without removing trailing spaces.  - The result length is based on the width of the displayed string. Therefore, fullwidth characters are handled using a width of 2, and halfwidth characters are handled using a width of 1.
LTRIM RTRIM	If the string is CHAR type, trailing spaces are removed and then the value is removed.	If the string is CHAR type, the value is removed without removing trailing spaces.

Item	Standard feature of LightDB	Compatibility feature added by orafce
BTRIM (*1)		
TO_DATE	The data type of the return value is DATE.	The data type of the return value is TIMESTAMP.

\*1: BTRIM does not exist for Oracle databases, however, an external specification different to LightDB is implemented in orafce to align with the behavior of the TRIM functions.

Also, the following features cannot be used in the default configuration of LightDB.

### Table F.101. Function

Feature
SYSDATE
DBTIMEZONE
SESSIONTIMEZONE
TO_CHAR (date/time value)

### Table F.102. Operator

Feature
Datetime operator

To use these features, set "oracle" and "pg\_catalog" in the "search\_path" parameter of lightdb.conf. You must specify "oracle" before "pg\_catalog" when doing this.

```
search_path = '$user', public, oracle, pg_catalog'
```

### Information

- The search\_path parameter specifies the order in which schemas are searched. Each feature compatible with Oracle databases is defined in the oracle schema.
- It is recommended to set search\_path in lightdb.conf. In this case, it will be effective for each instance.
- The configuration of search\_path can be done at the user level or at the database level. Setting examples are shown below.
- If the standard features of LightDB take precedence, and features that cannot be used with the default configuration of LightDB are not required, it is not necessary to change the settings of search\_path.
- Example of setting at the user level. This can be set by executing an SQL command. In this example, user1 is used as the username.

```
ALTER USER user1 SET search_path =
'$user', public, oracle, pg_catalog;
```

- Example of setting at the database level. This can be set by executing an SQL command. In this example, db1 is used as the database name. You must specify "oracle" before "pg\_catalog".

```
ALTER DATABASE db1 SET search_path =
"$user",public,oracle,pg_catalog;
```

See

- Refer to "Server Administration" > "Client Connection Defaults" > "Statement Behavior" in the LightDB Documentation for information on search\_path.
- Refer to "Reference" > "SQL Commands" in the LightDB Documentation for information on ALTER USER and ALTER DATABASE.

## F.56.3. Data Types

The following data types are supported:

- VARCHAR2
- NVARCHAR2
- DATE
- RAW
- PLS\_INTEGER
- BINARY\_FLOAT
- BINARY\_DOUBLE
- XMLType

### F.56.3.1. VARCHAR2

**Syntax**

Specify the VARCHAR2 type as follows.

**Table F.103. VARCHAR2 Syntax**

Data type syntax	Explanation
VARCHAR2( <i>len</i> [ <i>byte char</i> ])	String with a variable length up to <i>len</i> characters. For <i>len</i> , specify an integer greater than 0. If <i>len</i> is omitted, the string can be any length. Since 23.1, LightDB implements this syntax-sugar for compatibility with oracle varchar2 types. The keyword <i>byte</i> or <i>char</i> after <i>len</i> is optional, it is only compatible for oracle syntax, internal implementation is the same as only <i>len</i> without <i>byte</i> or <i>char</i> keyword.

**General rules**

- VARCHAR2 is a character data type. Specify the number of characters for the length.
- Strings are of variable length. The specified value will be stored as is. The upper limit for this data type is approximately one gigabyte.

**Note**

The VARCHAR2 type does not support collating sequences. Therefore, the following error occurs when a collating sequence like that of an ORDER BY clause is required. At this time, the following HINT will prompt to use a COLLATE clause, however, because collating sequences are not supported, it is not possible to use this clause.

```

ERROR:   could not determine which collation to use for string
comparison
HINT:    Use the COLLATE clause to set the collation explicitly.
    
```

If the error shown above is displayed, explicitly cast the column to VARCHAR or TEXT type.

**Example**

```

lightdb@postgres=# create table t1(name varchar2(10));
CREATE TABLE
lightdb@postgres=#
lightdb@postgres=# \d+ t1
                                Table "public.t1"
Column |      Type      | Collation | Nullable | Default | Storage |
Stats target | Description
-----+-----+-----+-----+-----+-----+
name    | varchar2(10)   |           |          |         | plain   |
        |                |           |          |         |         |
Access method: heap
    
```

```

lightdb@postgres=#
lightdb@postgres=# create table t2(name varchar2(10 byte));
CREATE TABLE
lightdb@postgres=#
lightdb@postgres=# \d+ t2
                                Table "public.t2"
Column |      Type      | Collation | Nullable | Default | Storage |
Stats target | Description
-----+-----+-----+-----+-----+
name    | varchar2(10)   |           |          |         | plain   |
        |                |           |          |         |         |
Access method: heap
    
```

```

lightdb@postgres=#
lightdb@postgres=# create table t3(name varchar2(10 char));
CREATE TABLE
lightdb@postgres=#
lightdb@postgres=# \d+ t3
                                Table "public.t3"
Column |      Type      | Collation | Nullable | Default | Storage |
Stats target | Description
-----+-----+-----+-----+-----+
name    | varchar2(10)   |           |          |         | plain   |
        |                |           |          |         |         |
Access method: heap

lightdb@postgres=#
    
```

## F.56.3.2. NVARCHAR2

### Syntax

Specify the NVARCHAR2 type as follows.

**Table F.104. NVARCHAR2 Syntax**

Data type syntax	Explanation
NVARCHAR2( <i>len</i> )	National character string with a variable length up to <i>len</i> characters. For <i>len</i> , specify an integer greater than 0. If <i>len</i> is omitted, the string can be any length.

### General rules

- NVARCHAR2 is a national character data type. Specify the number of characters for the length.
- Strings are of variable length. The specified value will be stored as is. The upper limit for this data type is approximately one gigabyte.

### Note

The NVARCHAR2 type does not support collating sequences. Therefore, the following error occurs when a collating sequence like that of an ORDER BY clause is required. At this time, the following HINT will prompt to use a COLLATE clause, however, because collating sequences are not supported, it is not possible to use this clause.

```

ERROR:   could not determine which collation to use for string
comparison
HINT:    Use the COLLATE clause to set the collation explicitly.

```

If the error shown above is displayed, explicitly cast the column to NCHAR VARYING or TEXT type.

## F.56.3.3. DATE

### Syntax

Specify the DATE type as follows.

**Table F.105. DATE Syntax**

Data type syntax	Explanation
DATE	Stores date and time

### General rules

- DATE is a date/time data type.
- Date and time are stored in DATE. The time zone is not stored.

### Note

If the DATE type of orafce is used in DDL statements such as table definitions, always set search\_path before executing a DDL statement. Even if search\_path is changed after definition, the data type will be the DATE type of LightDB.

### Information

The DATE type of orafce is equivalent to the TIMESTAMP type of LightDB. Therefore, of the existing functions of LightDB, functions for which the data type of the argument is TIMESTAMP can be used.

### F.56.3.4. RAW

#### Syntax

Specify the RAW type as follows.

**Table F.106. RAW Syntax**

RAW type syntax	Explanation
RAW(len)	Store variable-length Binary data. External representation is hexadecimal. The len is only used to be compatible with oracle, it has no effect. the binary data can be any length.

#### General rules

- RAW is a variable-length hex data type.
- Hex strings are of variable length. The specified value will be stored as binary data. The upper limit for this data type is approximately one gigabyte.

### F.56.3.5. PLS\_INTEGER

#### Syntax

Specify the PLS\_INTEGER type as follows.

**Table F.107. PLS\_INTEGER Syntax**

PLS_INTEGER type syntax	Explanation
PLS_INTEGER	The PLS_INTEGER data type stores signed integers in the range -2,147,483,648 through 2,147,483,647, represented in 32 bits.

#### General rules

- PLS\_INTEGER behaves like int4.

### F.56.3.6. BINARY\_FLOAT

#### Syntax

Specify the BINARY\_FLOAT type as follows.

**Table F.108. BINARY\_FLOAT Syntax**

BINARY_FLOAT type syntax	Explanation
BINARY_FLOAT	BINARY_FLOAT is a 32-bit, single-precision floating-point number data type. Each BINARY_FLOAT value requires 4 bytes.

#### General rules

- BINARY\_FLOAT behaves like float4 in lightdb.
- The same as oracle, it follows the IEEE754 standard.

#### Example

```
lightdb@test_o=# create table t1(key1 binary_float);
CREATE TABLE
lightdb@test_o=# \d+ t1

                                Table "public.t1"
 Column |      Type      | Collation | Nullable | Default | Storage
 | Sta
ts target | Description
-----+-----+-----+-----+-----+-----
+----
-----+-----
 key1   | binary_float |           |          |         | plain  |
      |
Access method: heap
lightdb@test_o=# insert into t1
 values(123456789012345678901234567890123456789);
INSERT 0 1
lightdb@test_o=# insert into t1 values('infinity');
INSERT 0 1
lightdb@test_o=# insert into t1 values('NaN');
INSERT 0 1
lightdb@test_o=# select * from t1;
 key1
-----
 1.2345679e+38
      Infinity
      NaN
(3 rows)
```

### F.56.3.7. BINARY\_DOUBLE

#### Syntax

Specify the BINARY\_DOUBLE type as follows.

**Table F.109. BINARY\_DOUBLE Syntax**

BINARY_DOUBLE type syntax	Explanation
BINARY_DOUBLE	BINARY_DOUBLE is a 64-bit, double-precision floating-point number data type. Each BINARY_DOUBLE value requires 8 bytes.

#### General rules

- BINARY\_DOUBLE behaves like float8 in lightdb.
- The same as oracle, it follows the IEEE754 standard.

#### Example

```
lightdb@test_o=# create table t1(key1 binary_double);
CREATE TABLE
lightdb@test_o=# \d+ t1

                                Table "public.t1"
 Column |      Type      | Collation | Nullable | Default | Storage
 | Sta
ts target | Description
-----+-----+-----+-----+-----+-----
+----
-----+-----
 key1   | binary_double |           |          |         | plain  |
      |
Access method: heap
lightdb@test_o=# insert into t1
 values(123456789012345678901234567890123456789);
INSERT 0 1
lightdb@test_o=# insert into t1 values('infinity');
INSERT 0 1
lightdb@test_o=# insert into t1 values('NaN');
INSERT 0 1
lightdb@test_o=# select * from t1;
 key1
-----
 1.2345679e+38
      Infinity
      NaN
(3 rows)
```

```

ts target | Description
-----+-----+-----+-----+-----
+----
-----+-----
key1      | binary_double |           |           | plain
|
|
Access method: heap
lightdb@test_o=# insert into t1
  values(123456789012345678901234567890123456789);
INSERT 0 1
lightdb@test_o=# insert into t1 values('infinity');
INSERT 0 1
lightdb@test_o=# insert into t1 values('NaN');
INSERT 0 1
lightdb@test_o=# select * from t1;
           key1
-----
1.2345678901234568e+38
                    Infinity
                    NaN
(3 rows)

```

### F.56.3.8. XMLType

#### Syntax

Specify the XMLType type as follows.

**Table F.110. XMLType Syntax**

XMLType syntax	Explanation
XMLType	XMLType is an object type, that can be used to store XML data.

#### General rules

- XMLType is xml data type.
- Implicit conversions between oracle.XMLType and pg\_catalog.xml are supported.

#### member function

- function getClobVal() return CLOB  
returns XML as text

#### Example

```

lightdb@postgres=# create database test_oracle
lightdb_syntax_compatible_type oracle;
CREATE DATABASE

lightdb@postgres=# \c test_oracle
You are now connected to database "test_oracle" as user
"lightdb".

```



```

compatible type: oracle

lightdb@test_oracle=# select dbms_output.serveroutput(true);
serveroutput
-----

(1 row)

lightdb@test_oracle=# CREATE TABLE xml_table (id NUMBER,
xml_column XMLType );
CREATE TABLE

lightdb@test_oracle=# INSERT INTO xml_table (id, xml_column)
VALUES (1, XMLType('<root><name>John</name></root>'));
INSERT 0 1

lightdb@test_oracle=# DECLARE
lightdb@test_oracle$$  v_clob CLOB;
lightdb@test_oracle$$ BEGIN
lightdb@test_oracle$$  SELECT XMLType.getClobVal(xml_column)
lightdb@test_oracle$$  INTO v_clob
lightdb@test_oracle$$  FROM xml_table
lightdb@test_oracle$$  WHERE id = 1;
lightdb@test_oracle$$  DBMS_OUTPUT.PUT_LINE('CLOB value: ' ||
v_clob);
lightdb@test_oracle$$ END;
lightdb@test_oracle$$ /
CLOB value: <root><name>John</name></root>
DO

lightdb@test_oracle=# DECLARE
lightdb@test_oracle$$  xml_data XMLType;
lightdb@test_oracle$$  clob_data CLOB;
lightdb@test_oracle$$ BEGIN
lightdb@test_oracle$$  xml_data := XMLType('<root><name>John
Doe</name></root>');
lightdb@test_oracle$$  clob_data := xml_data.getClobVal();
lightdb@test_oracle$$  DBMS_OUTPUT.PUT_LINE(clob_data);
lightdb@test_oracle$$ END;
lightdb@test_oracle$$ /
<root><name>John Doe</name></root>
DO

lightdb@test_oracle=# SELECT XMLType.getClobVal(xml_column)
from xml_table;
getclobval
-----
<root><name>John</name></root>
(1 row)

```

## F.56.4. Queries

The following queries are supported:

- DUAL Table

DUAL table is a virtual table provided by the system. Use when executing SQL where access to a base table is not required, such as when performing tests to get result expressions such as functions and operators.

**Example**

In the following example, the current system date is returned.

```
SELECT CURRENT_DATE "date" FROM DUAL;
      date
-----
2013-05-14
(1 row)
```

## F.56.5. SQL Functions Reference

### F.56.5.1. Mathematical Functions

The following mathematical functions are supported:

- BIN\_TO\_NUM
- BITAND
- BITOR
- BITXOR
- COSH
- MOD
- REMAINDER
- ROUND\_TIES\_TO\_EVEN
- SINH
- TANH

#### F.56.5.1.1. BIN\_TO\_NUM

**Description**

BIN\_TO\_NUM converts a bit vector to its equivalent number.

**Syntax**

```
BIN_TO_NUM(VARIADIC integer []) returns int
```

**General rules**

- Each argument to this function represents a bit in the bit vector.
- This function takes as arguments any integer data type, or any noninteger data type that can be implicitly converted to integer.

- BIN\_TO\_NUM is useful in data warehousing applications for selecting groups of interest from a materialized view using grouping sets.

**Note**

- If using BIN\_TO\_NUM for converting, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oracle" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT BIN_TO_NUM(1,0,1,0) FROM DUAL;
   bin_to_num
-----
           10
(1 row)
```

### F.56.5.1.2. BITAND

**Description**

Performs a bitwise AND operation.

**Syntax**

```
BITAND(int1 integers, int2 integers) returns bigint
```

**General rules**

- BITAND performs an AND operation on each bit of two integers, and returns the result.
- Specify integer type values.
- The data type of the return value is BIGINT.

**Example**

In the following example, the result of the AND operation on numeric literals 5 and 3 is returned.

```
SELECT BITAND(5,3) FROM DUAL;
   bitand
-----
           1
(1 row)
```

### F.56.5.1.3. BITOR

**Description**

Performs a bitwise OR operation.

**Syntax**

```
BITOR(int1 bigint, int2 bigint) returns bigint
```

**General rules**

- BITOR performs an OR operation on each bit of two bigint, and returns the result.
- Specify bigint type values.
- The data type of the return value is BIGINT.

**Note**

- If using BITOR, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

In the following example, the result of the OR operation on numeric literals 5 and 3 is returned.

```
SELECT BITOR(5,3) FROM DUAL;  
bitor  
-----  
       7  
(1 row)
```

**F.56.5.1.4. BITXOR****Description**

Performs a bitwise XOR operation.

**Syntax**

```
BITXOR(int1 bigint, int2 bigint) returns bigint
```

**General rules**

- BITXOR performs an XOR operation on each bit of two integers, and returns the result.
- Specify bigint type values.
- The data type of the return value is BIGINT.

**Note**

- If using BITXOR, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraofce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

In the following example, the result of the XOR operation on numeric literals 5 and 3 is returned.

```
SELECT BITXOR(5,3) FROM DUAL;
  bitxor
-----
         6
(1 row)
```

**F.56.5.1.5. COSH**

**Description**

Calculates the hyperbolic cosine of a number.

**Syntax**

```
COSH(num numeric) returns double precision
```

**General rules**

- COSH returns the hyperbolic cosine of the specified number.
- The number must be a numeric data type.
- The data type of the return value is DOUBLE PRECISION.

**Example**

In the following example, the hyperbolic cosine of the numeric literal 2.236 is returned.

```
SELECT COSH(2.236) FROM DUAL;
      cosh
-----
4.7313591000247
(1 row)
```

**F.56.5.1.6. MOD**

**Description**

MOD returns the remainder of n2 divided by n1. Returns n2 if n1 is 0.

**Syntax**

```
MOD(n2 bigint, n1 bigint) returns bigint
MOD(n2 integer, n1 integer) returns integer
MOD(n2 numeric, n1 numeric) returns numeric
MOD(n2 smallint, n1 smallint) returns smallint
```

**General rules**

- This function takes as arguments any numeric datatype.

**Note**

- It is not supported yet if one of the arguments is decimal number in string form and the other is an integer.

**Example**

```
SELECT mod(5,2) FROM DUAL;
mod
-----
1
```

**F.56.5.1.7. REMAINDER****Description**

Returns the remainder of n2 divided by n1.

**Syntax**

```
REMAINDER(n2 numeric, n1 numeric) returns numeric
```

**General rules**

- This function takes as arguments any numeric data type or any nonnumeric data type that can be implicitly converted to a numeric data type.
- The MOD function is similar to REMAINDER except that it uses FLOOR in its formula, whereas REMAINDER uses ROUND.
- If  $n1 \neq 0$ , then the remainder is  $n2 - (n1 * N)$  where N is the integer nearest  $n2/n1$ . If  $n2/n1$  equals  $x.5$ , then N is the nearest even integer.

**Note**

- If using REMAINDER, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT REMAINDER(5.5,2) FROM DUAL;
remainder
-----
-0.5
(1 row)
```

### F.56.5.1.8. ROUND\_TIES\_TO\_EVEN

**Description**

The function returns n rounded to integer places.

**Syntax**

```
ROUND_TIES_TO_EVEN(n NUMERIC, integer int4 DEFAULT 0) returns  
numeric
```

**General rules**

- If integer is positive, n is rounded to integer places to the right of the decimal point.
- If integer is not specified, then n is rounded to 0 places.
- If integer is negative, then n is rounded to integer places to the left of the decimal point.

**Note**

- If using ROUND\_TIES\_TO\_EVEN, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

The following example rounds a number to one decimal point to the right:

```
SELECT ROUND_TIES_TO_EVEN(45.177,1) "ROUND_EVEN" FROM DUAL;  
ROUND_EVEN  
-----  
         45.2  
(1 row)
```

The following example rounds a number to one decimal point to the left:

```
SELECT ROUND_TIES_TO_EVEN(45.177,-1) "ROUND_EVEN" FROM DUAL;  
ROUND_EVEN  
-----  
         50  
(1 row)
```

### F.56.5.1.9. SINH

**Description**

Calculates the hyperbolic sine of a number.

**Syntax**

`SINH(num numeric)` returns double precision

**General rules**

- `SINH` returns the hyperbolic sine of the specified number.
- The number must be a numeric data type.
- The data type of the return value is `DOUBLE PRECISION`.

**Example**

In the following example, the hyperbolic sine of the numeric literal 1.414 is returned.

```
SELECT SINH(1.414) FROM DUAL;
      sinh
-----
1.93460168824956
(1 row)
```

**F.56.5.1.10. TANH****Description**

Calculates the hyperbolic tangent of a number.

**Syntax**

`TANH(num numeric)` returns double precision

**General rules**

- `TANH` returns the hyperbolic tangent of the specified number.
- The number must be a numeric data type.
- The data type of the return value is `DOUBLE PRECISION`.

**Example**

In the following example, the hyperbolic tangent of the numeric literal 3 is returned.

```
SELECT TANH(3) FROM DUAL;
      tanh
-----
0.995054753686731
(1 row)
```

**F.56.5.1.11. CEIL****Description**

Returns the smallest integer(type interval will extract the days to number first) that is greater than or equal to a number.



**Syntax**

```
CEIL(i interval) returns number
CEIL(n numeric) returns numeric
CEIL(d double precision) returns numeric
```

**General rules**

- CEIL returns the smallest integer that is greater than or equal to a number.
- The number may be an interval type or numeric data type or double precision type.
- The data type of the return value is number or numeric.

**Example**

In the following example, returns the smallest integer that is greater than or equal to that number. If the argument is of type interval, extract days from an interval first which is of type numeric, and then returns the smallest integer that is greater than or equal to that number

```
select ceil(sysdate - '2023-01-01'::date) FROM dual ;
  ceil
-----
    335
(1 row)

select ceil(sysdate - to_date('2023-11-27','yyyy-mm-dd')) FROM
dual;
  ceil
-----
     5
(1 row)

select ceil(sysdate - to_date('2023-01-01','yyyy-mm-dd')) FROM
dual;
  ceil
-----
    335
(1 row)
```

**F.56.5.2. String Functions**

The following string functions are supported:

- BTRIM
- INSTR
- INSTRB
- LENGTH
- LENGTHB
- LPAD
- LTRIM

- NLSSORT
- REGEXP\_COUNT
- REGEXP\_INSTR
- REGEXP\_LIKE
- REGEXP\_SUBSTR
- REGEXP\_REPLACE
- REPLACE
- RPAD
- RTRIM
- SOUNDEX
- SUBSTR
- SUBSTRB
- CONCAT
- UPPER

#### **F.56.5.2.1. BTRIM**

##### **Description**

Removes the specified characters from the beginning and end of a string.

##### **Syntax**

```
BTRIM(str text) returns text
BTRIM(str text, trimChars text) returns text
BTRIM(str clob) returns clob
BTRIM(str clob, trimChars clob) returns clob
```

##### **General rules**

- BTRIM returns a string with *trimChars* removed from the beginning and end of string *str*.
- If multiple trim characters are specified, all characters matching the trim characters are removed. If *trimChars* is omitted, all leading and trailing halfwidth spaces are removed.
- The data type of the return value is TEXT if the first parameter is of `text` data type, CLOB if the first parameter is of `clob` data type.

##### **Note**

- BTRIM does not exist for Oracle databases.
- The CHAR type specification for BTRIM uses orafce for its behavior, which is different to that of BTRIM of LightDB. The `search_path` parameter must be modified for it to behave the same as the specification described above.

##### **Information**

The general rule for BTRIM of LightDB is as follows:

- If the string is CHAR type, trailing spaces are removed and then the trim characters are removed.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on BTRIM.

**Example**

In the following example, a string that has had "a" removed from both ends of "aabcaba" is returned.

```
SELECT BTRIM('aabcaba', 'a') FROM DUAL;
 btrim
-----
  bcab
(1 row)
```

### F.56.5.2.2. INSTR

**Description**

Returns the position of a substring in a string.

**Syntax**

```
INSTR(str1 text, str2 text) returns integer
INSTR(str1 text, str2 text, startPos integer) returns integer
INSTR(str1 text, str2 text, startPos integer, occurrences
integer) returns integer
```

**General rules**

- INSTR searches for substring *str2* in string *str1* and returns the position (in characters) in *str1* of the first character of the occurrence.
- The search starts from the specified start position *startPos* in *str1*.
- When *startPos* is 0 or negative, the start position will be the specified number of characters from the left of the end of *str1*, and INSTR will search backward from that point.
- If the start position is not specified, the search will be performed from the beginning of *str1*.
- If *occurrences* is specified, the position in *str1* of the nth occurrence of *str2* is returned. Only positive numbers can be specified.
- If *occurrences* is not specified, the start position of the first occurrence that is found is returned.
- If *str2* is not found in *str1*, 0 is returned.
- For *startPos* and *occurrences*, specify a SMALLINT or INTEGER type.
- The data type of the return value is INTEGER.

**Example**

In the following example, characters "BC" are found in string "ABCACBCAAC", and the position of those characters is returned.

```
SELECT INSTR('ABCACBCAAC', 'BC') FROM DUAL;
instr
-----
      2
(1 row)

SELECT INSTR('ABCACBCAAC', 'BC', -1, 2) FROM DUAL;
instr
-----
      2
(1 row)
```

### F.56.5.2.3. INSTRB

#### Description

The INSTRB function searches a string for a substring using bytes and returns the position in the string that is the first byte of a specified occurrence of the substring.

#### Syntax

```
INSTRB( p_source text, p_search text, p_position int4 default
1, p_occurrence int4 default 1) RETURNS integer
```

#### General rules

- INSTRB searches for substring *p\_search* in string *p\_source* and returns the position (in bytes) in *p\_source* of the first byte of the occurrence.
- The search starts from the specified start position *p\_position* in *p\_source*.
- When *p\_position* is 0 or negative, it will raise an error. It is different from ORACLE, in oracle , *p\_position* will be the specified number of bytes from the left of the end of *p\_source*, and INSTRB will search backward from that point.
- If the start position is not specified, the search will be performed from the beginning of *p\_source*.
- If *p\_occurrence* is specified, the position in *p\_source* of the nth occurrence of *p\_search* is returned. Only positive numbers can be specified.
- If *occurrences* is not specified, the start position of the first occurrence that is found is returned.
- If *p\_search* is not found in *p\_source*, 0 is returned.
- The data type of the return value is integer.

#### Note

- If using INSTRB, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

In the following example, characters "on" are found in string "hhh##onhx", and the position of those bytes is returned.

```
SELECT INSTRB('hhh##onhx', 'on') FROM DUAL;
```

```
instrb
-----
      10
(1 row)
```

```
SELECT INSTRB('hhh##onhx on xxxx', 'on', 7, 2) FROM DUAL;
```

```
instrb
-----
      15
(1 row)
```

#### F.56.5.2.4. LENGTH

##### Description

Returns the length of a string in number of characters.

##### Syntax

```
LENGTH(str text) returns integer
```

##### General rules

- LENGTH returns the number of characters in string *str*.
- If the string is CHAR type, trailing spaces are included in the length.
- The data type of the return value is INTEGER.

##### Note

The LENGTH specification above uses orafce for its behavior, which is different to that of LENGTH of LightDB. The search\_path parameter must be modified for it to behave according to the orafce specification.

##### Information

The general rule for LENGTH of LightDB is as follows:

- If the string is CHAR type, trailing spaces are not included in the length.

##### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on LENGTH.

##### Example

In the following example, the number of characters in column col2 (defined using CHAR(10)) in table t1 is returned.

```

SELECT col2,LENGTH(col2) FROM t1 WHERE col1 = '1001';
   col2      | length
-----+-----
AAAAA       |      10
(1 row)

```

### F.56.5.2.5. LENGTHB

#### Description

Returns the length of a string in number of bytes.

#### Syntax

`LENGTHB(str text)` returns integer

#### General rules

- `LENGTHB` returns the number of bytes in string *str*.
- If the string is `CHAR` type, trailing spaces are included in the length.
- The data type of the return value is `INTEGER`.

#### Example

In the following example, the number of bytes in column `col2` (defined using `CHAR(10)`) in table `t1` is returned. Note that, in the second `SELECT` statement, each character in "\*" has a length of 3 bytes, for a total of 9 bytes, and 7 bytes are added for the 7 trailing spaces. This gives a result of 16 bytes.

```

SELECT col2,LENGTHB(col2) FROM t1 WHERE col1 = '1001';
   col2      | lengthb
-----+-----
AAAAA       |      10
(1 row)

SELECT col2,LENGTHB(col2) FROM t1 WHERE col1 = '1004';
   col2      | lengthb
-----+-----
***         |      16
(1 row)

```

### F.56.5.2.6. LPAD

#### Description

Left-pads a string to a specified length with a sequence of characters.

#### Syntax

```

LPAD(str text, len integer) returns text
LPAD(str text, len integer, paddingStr text) returns text
LPAD(str CLOB, len integer, str text) returns clob

```

**General rules**

- LPAD returns the result after repeatedly padding the beginning of string *str* with padding characters *paddingStr* until the string reaches length *len*.
- If the string is CHAR type, the padding characters are added to the string without removing trailing spaces.
- In the resultant string, fullwidth characters are recognized as having a length of 2, and halfwidth characters having a length of 1. If a fullwidth character cannot be included in the resultant string because there is only space available for one halfwidth character, the string is padded with a single-byte space.
- The data type of the return value is TEXT if the first parameter is of `text` data type, CLOB if the first parameter is of `clob` data type.

**Note**

The LPAD specification above uses orafce for its behavior, which is different to that of LPAD of LightDB. The search\_path parameter must be modified for it to behave according to the orafce specification.

**Information**

The general rules for LPAD of LightDB are as follows:

- If the string is CHAR type, trailing spaces are removed and then the padding characters are added to the string.
- The result length is the number of characters.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on LPAD.

**Example**

In the following example, a 10-character string that has been formed by left-padding the string "abc" with "a" is returned.

```
SELECT LPAD('abc',10,'a') FROM DUAL;
      lpad
-----
aaaaaaaabc
(1 row)
```

**F.56.5.2.7. LTRIM****Description**

Removes the specified characters from the beginning of a string.

**Syntax**

```
LTRIM(str text) returns text
LTRIM(str text, trimChars text) returns text
```

```
LTRIM(str clob) returns clob
LTRIM(str clob, trimChars clob) returns clob
```

### General rules

- LTRIM returns a string with *trimChars* removed from the beginning of string *str*.
- If multiple trim characters are specified, all characters matching the trim characters are removed. If *trimChars* is omitted, all leading halfwidth spaces are removed.
- The data type of the return value is TEXT if the first parameter is of `text` data type, CLOB if the first parameter is of `clob` data type.

### Note

The LTRIM specification above uses orafce for its behavior, which is different to that of LTRIM of LightDB. The `search_path` parameter must be modified for it to behave according to the orafce specification.

### Information

The general rules for LTRIM of LightDB are as follows:

- If the string is CHAR type, trailing spaces are removed and then the trim characters are removed.

### See

- Refer to "Notes on Using orafce" for information on how to edit `search_path`.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on LTRIM.

### Example

In the following example, a string that has had "ab" removed from the beginning of "aabcab" is returned.

```
SELECT LTRIM('aabcab','ab') FROM DUAL;
 ltrim
-----
  cab
(1 row)
```

## F.56.5.2.8. NLSSORT

### Description

Returns a byte string that denotes the lexical order of the locale (COLLATE).

### Syntax

```
NLSSORT(str text) returns bytea
NLSSORT(str text, locale text) returns bytea
```

### General rules

- NLSSORT is used for comparing and sorting in the collating sequence of a locale (COLLATE) that differs from the default locale.



- Values that can be specified for the locale differ according to the operating system of the database server.
- If the locale is omitted, it is necessary to use `set_nls_sort` to set the locale in advance. To set the locale using `set_nls_sort`, execute a `SELECT` statement.
- The data type of the return value is `BYTEA`.

**Example of setting `set_nls_sort` using a `SELECT` statement**

```
SELECT set_nls_sort('en_US.UTF8');
```

**Note**

If specifying locale encoding, ensure it matches the database encoding.

**See**

Refer to "Server Administration" > "Localization" > "Locale Support" in the LightDB Documentation for information on the locales that can be specified.

**Example**

**Table F.111. Composition of table (t3)**

col1	col2
1001	aabcababc
2001	abcdef
3001	aacbaab

In the following example, the result of sorting column `col2` in table `t3` by "`da_DK.UTF8`" is returned.

```
SELECT col1,col2 FROM t3 ORDER BY NLSSORT(col2,'da_DK.UTF8');
col1 | col2
-----+-----
2001 | abcdef
1001 | aabcababc
3001 | aacbaab
(3 row)
```

**F.56.5.2.9. REGEXP\_COUNT**

**Description**

Searches a string for a regular expression, and returns a count of the matches.

**Syntax**

```
REGEXP_COUNT(string text, pattern text) returns integer
REGEXP_COUNT(string text, pattern text, startPos integer)
returns integer
REGEXP_COUNT(string text, pattern text, startPos integer,
flags text) returns integer
```

**General rules**

- REGEXP\_COUNT returns the number of times *pattern* occurs in a source *string*. It returns an integer indicating the number of occurrences of *pattern*. If no match is found, then the function returns 0. Returns NULL if one of the parameters is NULL, but the 'flags' parameter could be NULL.
- The search starts from the specified start position *startPos* in *string*, default starts from the beginning of *string*.
- *startPos* is a positive integer, negative values to search from the end of *string* are not allowed.
- *flags* is a character expression that lets you change the default matching behavior of the function.

**The value of *flags* can include one or more of the following characters:**

- 'i': case-insensitive matching.
- 'c': case-sensitive and accent-sensitive matching.
- 'n': the period (.) match the newline character. By default the period does not match the newline character.
- 'm': treats the source string as multiple lines.
- 'x': ignores whitespace characters. By default, whitespace characters match themselves.

**If you omit *flags* then:**

- The default is case and accent sensitivity.
- A period (.) does not match the newline character.
- The source string is treated as a single line.

**Note**

If using the REGEXP\_COUNT function, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using Oracle" for information on how to edit search\_path.

**Example**

```
SELECT REGEXP_COUNT('a' || CHR(10) || 'd', 'a.d') FROM DUAL;
  regexp_count
-----
              0
(1 row)

SELECT REGEXP_COUNT('a' || CHR(10) || 'd', 'a.d', 1, 'm') FROM
DUAL;
  regexp_count
-----
              0
(1 row)

SELECT REGEXP_COUNT('a' || CHR(10) || 'd', 'a.d', 1, 'n') FROM
DUAL;
  regexp_count
```

```

-----
              1
(1 row)

SELECT REGEXP_COUNT('a'||CHR(10)||'d', '^d$', 1, 'm') FROM
DUAL;
  regexp_count
-----
              1
(1 row)

```

### F.56.5.2.10. REGEXP\_INSTR

#### Description

Returns the beginning or ending position within the string where the match for a pattern was located.

#### Syntax

```

REGEXP_INSTR(string text, pattern text) returns integer
REGEXP_INSTR(string text, pattern text, startPos integer)
returns integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer) returns integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer) returns integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer, return_opt integer) returns integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer, return_opt integer, flags text) returns
integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer, return_opt integer, flags text) returns
integer
REGEXP_INSTR(string text, pattern text, startPos integer,
occurrence integer, return_opt integer, flags text, group integer)
returns integer

```

#### General rules

- REGEXP\_INSTR returns an integer indicating the beginning or ending position of the matched substring, depending on the value of the *return\_opt* argument. If no match is found, then the function returns 0.
- The search starts from the specified start position *startPos* in *string*, default starts from the beginning of *string*.
- *startPos* is a positive integer, negative values to search from the end of *string* are not allowed.
- *occurrence* is a positive integer indicating which occurrence of *pattern* in *string* should be search for. The default is 1, meaning the first occurrence of *pattern* in *string*.
- *return\_opt* lets you specify what should be returned in relation to the occurrence:
  - return\_opt = 0, the position of the first character of the occurrence is returned. This is the default.
  - return\_opt = 1, the position of the character following the occurrence is returned.

- *flags* is a character expression that lets you change the default matching behavior of the function. See REGEXP\_COUNT for detailed information.
- For a *pattern* with capture group, *group* is a positive integer indicating which capture group in *pattern* shall be returned by the function. Capture groups can be nested, they are numbered in order in which their left parentheses appear in *pattern*. If *group* is zero, then the position of the entire substring that matches the pattern is returned. If *group* value exceed the number of capture groups in *pattern*, the function returns zero. A null *group* value returns *NULL*. The default value for *group* is zero.

**Note**

If using the REGEXP\_INSTR function, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using oracle" for information on how to edit search\_path.

**Example**

```

SELECT REGEXP_INSTR('1234567890', '(123)(4(56)(78))') FROM
DUAL;
  regexp_instr
  -----
          1
(1 row)

SELECT REGEXP_INSTR('1234567890', '(4(56)(78))', 3) FROM DUAL;
  regexp_instr
  -----
          4
(1 row)

SELECT REGEXP_INSTR('123 123456 1234567, 1234567 1234567 12',
'^ ]+', 1, 6) FROM DUAL;
  regexp_instr
  -----
          37
(1 row)

SELECT REGEXP_INSTR('199 Oretax Prayers, Riffles Stream, CA',
'[S|R|P][[:alpha:]]{6}', 3, 2, 1) FROM DUAL;
  regexp_instr
  -----
          28
(1 row)

```

**F.56.5.2.11. REGEXP\_LIKE**

**Description**

Condition in the WHERE clause of a query, causing the query to return rows that match the given pattern.

**Syntax**

REGEXP\_LIKE(string text, pattern text) returns boolean  
 REGEXP\_LIKE(string text, pattern text, flags text) returns boolean

**General rules**

- REGEXP\_LIKE is similar to the LIKE condition, except it performs regular expression matching instead of the simple pattern matching performed by LIKE.
- Returns a boolean, *true* when *pattern* match in *string*, *false* otherwise. Returns NULL if one of the parameters is NULL, but the 'flags' parameter could be NULL.
- *flags* is a character expression that lets you change the default matching behavior of the function. See REGEXP\_COUNT for detailed information.

**Note**

If using the REGEXP\_LIKE function, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using Oracle" for information on how to edit search\_path.

**Example**

```
SELECT REGEXP_LIKE('a' || CHR(10) || 'd', 'a.d', 'm') FROM DUAL;
regexp_like
-----
f
(1 row)

SELECT REGEXP_LIKE('a' || CHR(10) || 'd', 'a.d', 'n') FROM DUAL;
regexp_like
-----
t
(1 row)
```

**F.56.5.2.12. REGEXP\_SUBSTR**

**Description**

Returns the string that matches the pattern specified in the call to the function.

**Syntax**

REGEXP\_SUBSTR(string text, pattern text) returns text  
 REGEXP\_SUBSTR(string text, pattern text, startPos integer) returns text  
 REGEXP\_SUBSTR(string text, pattern text, startPos integer, occurrence integer) returns text  
 REGEXP\_SUBSTR(string text, pattern text, startPos integer, occurrence integer, flags text) returns text  
 REGEXP\_SUBSTR(string text, pattern text, startPos integer, occurrence integer, flags text, group int) returns text  
 REGEXP\_SUBSTR(string CLOB, pattern text) returns clob

**General rules**

- REGEXP\_SUBSTR returns the matched substring resulting from matching a POSIX regular expression pattern to a string. If no match is found, then the function returns *NULL*. Returns *NULL* if one of the parameters is *NULL*, but the 'flags' parameter could be *NULL*. The function returns the string as TEXT or CLOB data in the same character set as the first argument.
- The search starts from the specified start position *startPos* in *string*, default starts from the beginning of *string*.
- *startPos* is a positive integer, negative values to search from the end of *string* are not allowed.
- *occurrence* is a positive integer indicating which occurrence of *pattern* in *string* should be search for. The default is 1, meaning the first occurrence of *pattern* in *string*.
- *flags* is a character expression that lets you change the default matching behavior of the function. See REGEXP\_COUNT for detailed information.
- For a *pattern* with capture group, *\*group\** is a positive integer indicating which capture group in *pattern* shall be returned by the function. Capture groups can be nested, they are numbered in order in which their left parentheses appear in *pattern*. If *group* is zero, then the position of the entire substring that matches the pattern is returned. If *group* value exceed the number of capture groups in *pattern*, the function returns *NULL*. A null *group* value returns *NULL*. The default value for *group* is zero.

**Note**

If using the REGEXP\_SUBSTR function, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using orafce" for information on how to edit search\_path.

**Example**

```

SELECT REGEXP_SUBSTR('number of your street, zipcode town, FR',
',[^,]+' ) FROM DUAL;
   regexp_substr
-----
, zipcode town
(1 row)

SELECT regexp_substr('number of your street, zipcode town, FR',
',[^,]+', 24) FROM DUAL;
   regexp_substr
-----
, FR
(1 row)

SELECT regexp_substr('number of your street, zipcode town, FR',
',[^,]+', 1, 2) FROM DUAL;
   regexp_substr
-----
, FR
(1 row)

SELECT regexp_substr('1234567890 1234567890', '(123)(4(56)
(78))', 1, 1, 'i', 0) FROM DUAL;

```

```

    regexp_substr
    -----
    12345678
    (1 row)

```

### F.56.5.2.13. REGEXP\_REPLACE

#### Description

Returns the string that matches the pattern specified in the call to the function.

#### Syntax

```

    REGEXP_REPLACE(string text, pattern text, replace_string text,
startPos integer,
    occurrence integer, flags text) returns text
    REGEXP_REPLACE(string clob, pattern text, replace_string text)
returns clob

```

#### General rules

- REGEXP\_REPLACE returns a modified version of the source string where occurrences of a POSIX regular expression pattern found in the source string are replaced with the specified replacement string. If no match is found or the occurrence queried exceed the number of match, then the source string untouched is returned. The function returns TEXT if the first parameter is not a CLOB and returns CLOB if the first parameter is a CLOB.
- The search and replacement starts from the specified start position *startPos* in *string*, default starts from the beginning of *string*.
- *startPos* is a positive integer, negative values to search from the end of *string* are not allowed.
- *occurrence* is a positive integer indicating which occurrence of *pattern* in *string* should be search for and replaced. The default is 0, meaning all occurrences of *pattern* in *string*.
- *flags* is a character expression that lets you change the default matching behavior of the function. See REGEXP\_COUNT for detailed information.

#### Note

If using the REGEXP\_REPLACE function, it is necessary to specify "oracle" for search\_path in advance.

#### See

Refer to "Notes on Using orafce" for information on how to edit search\_path.

#### Example

```

    SELECT regexp_replace('512.123.4567 612.123.4567',
'([[:digit:]]{3})\.[[:digit:]]{3})\.[[:digit:]]{4}'), '(\1) \2-
\3') FROM DUAL;
    regexp_replace
    -----
    (512) 123-4567 (612) 123-4567
    (1 row)

```

```

SELECT oracle.REGEXP_REPLACE('number    your    street,
zipcode town, FR', '( ){2,}', ' ', 9);
           regexp_replace
-----
number    your street, zipcode town, FR
(1 row)

SELECT oracle.REGEXP_REPLACE('number    your    street,
zipcode town, FR', '( ){2,}', ' ', 9, 2);
           regexp_replace
-----
number    your    street, zipcode town, FR
(1 row)

```

### F.56.5.2.14. REPLACE

#### Description

Returns string with every occurrence of search\_string replaced with replacement\_string.

#### Syntax

```

REPLACE(string text, pattern text) returns text
REPLACE(string text, pattern text, replace_string text)
returns text
REPLACE(string uuid, pattern text, replace_string text)
returns text
REPLACE(string CLOB, pattern text) returns CLOB
REPLACE(string CLOB, pattern text, replace_string text)
returns CLOB

```

#### General rules

- If replace\_string is omitted or null, then all occurrences of search\_string are removed. If search\_string is null, then string is returned.
- The function returns TEXT if the first argument is not a CLOB and returns CLOB if the first argument is a CLOB.

#### Note

The above REPLACE specification uses orafce for its behavior, which is different to that of REPLACE of LightDB. The search\_path parameter must be modified for it to behave according to the orafce specification.

#### Information

The general rules for REPLACE of LightDB are as follows:

- If replace\_string or search\_string is null, then null is returned.

#### See

Refer to "Notes on Using orafce" for information on how to edit search\_path.

#### Example



```
SELECT REPLACE('abcdAbcdasd', 'a') FROM DUAL;
      replace
-----
bcdAbcdsd
(1 row)
```

```
SELECT REPLACE('abcdAbcdasd', 'a','c') FROM DUAL;
      replace
-----
cbcdAbcdcsd
(1 row)
```

```
SELECT REPLACE('abcdAbcdasd', NULL,'c') FROM DUAL;
      replace
-----
abcdAbcdasd
(1 row)
```

```
SELECT REPLACE('abcdAbcdasd', 'a',NULL) FROM DUAL;
      replace
-----
bcdAbcdsd
(1 row)
```

### F.56.5.2.15. RPAD

#### Description

Right-pads a string to a specified length with a sequence of characters.

#### Syntax

```
RPAD(str text, len integer) returns text
RPAD(str text, len integer, paddingStr text) returns text
RPAD(str CLOB, len integer, paddingStr text) returns CLOB
```

#### General rules

- RPAD returns the result after repeatedly padding the end of string *str* with padding characters *paddingStr* until the string reaches length *len*.
- If the string is CHAR type, the padding characters are added to the string without removing trailing spaces.
- In the resultant string, fullwidth characters are recognized as having a length of 2, and halfwidth characters having a length of 1. If a fullwidth character cannot be included in the resultant string because there is only space available for one halfwidth character, the string is padded with a single-byte space.
- The string returned is of TEXT data type if the first parameter is a character data type, and a CLOB if the first parameter is a CLOB data type.

#### Note

The RPAD specification above uses `orafce` for its behavior, which is different to that of RPAD of `LightDB`. The `search_path` parameter must be modified for it to behave according to the `orafce` specification.

**Information**

The general rules for RPAD of LightDB are as follows:

- If the string is CHAR type, trailing spaces are removed and then the padding characters are added to the string.
- The result length is the number of characters.

**See**

- Refer to "Notes on Using oraAce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on RPAD.

**Example**

In the following example, a 10-character string that has been formed by right-padding the string "abc" with "a" is returned.

```
SELECT RPAD( 'abc' ,10 , 'a' ) FROM DUAL;
      rpad
-----
abcaaaaaaa
(1 row)
```

**F.56.5.2.16. RTRIM****Description**

Removes the specified characters from the end of a string.

**Syntax**

```
RTRIM(str text) returns text
RTRIM(str text, trimChars text) returns text
RTRIM(str clob) returns clob
RTRIM(str clob, trimChars text) returns clob
```

**General rules**

- RTRIM returns a string with *trimChars* removed from the end of string *str*.
- If multiple trim characters are specified, all characters matching the trim characters are removed. If *trimChars* is omitted, all trailing halfwidth spaces are removed.
- The string returned is of TEXT data type if the first parameter is a character data type, and a CLOB if the first parameter is a CLOB data type.

**Note**

The RTRIM specification above uses oraAce for its behavior, which is different to that of RTRIM of LightDB. The search\_path parameter must be modified for it to behave the same as the oraAce specification.

**Information**

The general rules for RTRIM of LightDB are as follows:

- If the string is CHAR type, trailing spaces are removed and then the trim characters are removed.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on RTRIM.

**Example**

In the following example, a string that has had "ab" removed from the end of "aabcab" is returned.

```
SELECT RTRIM('aabcab', 'ab') FROM DUAL;
 rtrim
-----
 aabc
(1 row)
```

### F.56.5.2.17. SOUNDEX

**Description**

SOUNDEX returns a character string containing the phonetic representation of char. This function lets you compare words that are spelled differently, but sound alike in English.

**Syntax**

```
SOUNDEX(str text) returns text
```

**General rules**

- The phonetic representation is defined in The Art of Computer Programming, Volume 3: Sorting and Searching, by Donald E. Knuth.
- Retain the first letter of the string and remove all other occurrences of the following letters: a, e, h, i, o, u, w, y.
- Assign numbers to the remaining letters as follows:

```
b, f, p, v = 1
c, g, j, k, q, s, x, z = 2
d, t = 3
l = 4
m, n = 5
r = 6
```

- If two or more letters with the same number were adjacent in the original name (before step 1), or adjacent except for any intervening h and w, then retain the first letter and omit rest of all the adjacent letters with same number.
- Return the first four bytes padded with 0.

**Note**

If using the SOUNDEX function, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using oraofce" for information on how to edit search\_path.

**Example**

In the following example, a string that has had "ab" removed from the end of "aabcab" is returned.

```
SELECT SOUNDEX('SMYTHE')=SOUNDEX('Smith') as same FROM DUAL;
same
-----
t
(1 row)
```

**F.56.5.2.18. SUBSTR****Description**

Extracts part of a string using characters to specify position and length.

**Syntax**

```
SUBSTR(str text, startPos integer) returns text
SUBSTR(str text, startPos numeric) returns text
SUBSTR(str text, startPos integer, len integer) returns text
SUBSTR(str text, startPos numeric, len numeric) returns text
SUBSTR(str CLOB, startPos number) returns CLOB
SUBSTR(str CLOB, startPos number, len number) returns CLOB
```

**General rules**

- SUBSTR extracts and returns a substring of string *str*, beginning at position *startPos*, for number of characters *len*.
- When *startPos* is positive, it will be the number of characters from the beginning of the string.
- When *startPos* is 0, it will be treated as 1.
- When *startPos* is negative, it will be the number of characters from the end of the string.
- When *len* is not specified, all characters to the end of the string are returned. NULL is returned when *len* is less than 1.
- For *startPos* and *len*, specify an integer or NUMERIC type. If numbers including decimal places are specified, they are truncated to integers.
- The string returned is of TEXT data type if the first parameter is a character data type, and a CLOB if the first parameter is a CLOB data type.

**Note**

- There are two types of SUBSTR. One that behaves as described above and one that behaves the same as SUBSTRING. The search\_path parameter must be modified for it to behave the same as the specification described above.
- If the change has not been implemented, SUBSTR is the same as SUBSTRING.

**Information**

The general rules for SUBSTRING of LightDB are as follows:

- The start position will be from the beginning of the string, whether the start position is positive, 0, or negative.
- When *len* is not specified, all characters to the end of the string are returned.
- An empty string is returned if no string is extracted or *len* is less than 1.

**See**

- Refer to "The SQL Language" > "Functions and Operators" > "String Functions and Operators" in the LightDB Documentation for information on SUBSTRING.

**Example**

In the following example, part of the string "ABCDEFGH" is extracted.

```
SELECT SUBSTR('ABCDEFGH',3,4) "Substring" FROM DUAL;
Substring
-----
CDEF
(1 row)
```

```
SELECT SUBSTR('ABCDEFGH',-5,4) "Substring" FROM DUAL;
Substring
-----
CDEF
(1 row)
```

### F.56.5.2.19. SUBSTRB

**Description**

Extracts part of a string using bytes to specify position and length.

**Syntax**

```
SUBSTRB(str text, startPos integer) returns varchar2
SUBSTRB(str text, startPos integer, len integer) returns
varchar2
```

**General rules**

- SUBSTR extracts and returns a substring of string *str*, beginning at byte position *startPos*, for number of byte *len*.
- When *startPos* is 0 or negative, extraction starts at the position found by subtracting 1 from the start position and shifting by that number of positions to the left.
- When *len* is not specified, all bytes to the end of the string are returned.
- An empty string is returned if no string is extracted or *len* is less than 1.
- For *startPos* and *len*, specify a SMALLINT or INTEGER type.
- The data type of the return value is VARCHAR2.

**Note**

The external specification of SUBSTRB is different to that of SUBSTR added by oraace, conforming with SUBSTRING of LightDB.

**Example**

In the following example, part of the string "aaabbbccc" is extracted.

```
SELECT SUBSTRB('aaabbbccc',4,3) FROM DUAL;
 substrb
-----
    bbb
(1 row)

SELECT SUBSTRB('aaabbbccc',-2,6) FROM DUAL;
 substrb
-----
    aaa
(1 row)
```

**F.56.5.2.20. CONCAT****Description**

concatenate two strings

**Syntax**

```
CONCAT(str1 TEXT, str2 TEXT) returns TEXT
CONCAST(str1 CLOB, str2 CLOB) returns CLOB
```

**General rules**

- In concatenations of two different data types, the function returns the data type that results in a lossless conversion.
- This function is equivalent to the concatenation operator (||).
- The string returned is of TEXT data type if the first parameter is a character data type, and a CLOB if the first parameter is a CLOB data type.

**Example**

```
SELECT concat('a', 'b') FROM DUAL;
 concat
-----
    ab
(1 row)

SELECT concat(to_clob('a'), 'b') FROM DUAL;
 concat
-----
    ab
(1 row)
```

### F.56.5.2.21. UPPER

#### Description

UPPER returns string with all letters uppercase.

#### Syntax

```
UPPER(string TEXT) returns TEXT
UPPER(string CLOB) returns CLOB
```

#### General rules

- The string returned is of TEXT data type if the first parameter is a character data type, and a CLOB if the first parameter is a CLOB data type.

#### Example

```
SELECT UPPER('hello world') FROM DUAL;
      upper
-----
HELLO WORLD
(1 row)

SELECT UPPER(to_clob('hello world')) FROM DUAL;
      upper
-----
HELLO WORLD
(1 row)
```

### F.56.5.3. Date/Time Functions

The following date/time functions are supported:

- ADD\_MONTHS
- DBTIMEZONE
- LAST\_DAY
- MONTHS\_BETWEEN
- NEXT\_DAY
- ROUND
- SESSIONTIMEZONE
- SYSDATE
- TRUNC
- TZ\_OFFSET

#### Note

If the DATE type only is shown in the date/time functions, these functions can be used in both Oracle and LightDB.

### F.56.5.3.1. ADD\_MONTHS

#### Description

Adds months to a date.

#### Syntax

```
ADD_MONTHS(date DATE, months INTEGER) returns DATE
ADD_MONTHS(date TIMESTAMP WITH TIME ZONE, months INTEGER)
returns TIMESTAMP
```

#### General rules

- ADD\_MONTHS returns *date plus months*.
- For *date*, specify a DATE or TIMESTAMP WITH TIME ZONE type.
- For *months*, specify a SMALLINT or INTEGER type.
- If a negative value is specified for *months*, the number of months is subtracted from the date.
- The data type of the return value is DATE or TIMESTAMP.

#### Note

If using the DATE type of ora<sub>fc</sub>e, it is necessary to specify "oracle" for search\_path in advance.

#### See

Refer to "Notes on Using ora<sub>fc</sub>e" for information on how to edit search\_path.

#### Example

The example below shows the result of adding 3 months to the date May 1, 2016.

```
SELECT ADD_MONTHS( DATE '2016/05/01', 3 ) FROM DUAL;
      add_months
-----
2016-08-01 00:00:00
(1 row)
```

### F.56.5.3.2. DBTIMEZONE

#### Description

Returns the value of the database time zone.

#### Syntax

```
DBTIMEZONE() returns text
```

#### General rules

- DBTIMEZONE returns the time zone value of the database.
- The data type of the return value is TEXT.



**Note**

- If using DBTIMEZONE, it is necessary to specify "oracle" for search\_path in advance.
- The time zone of the database is set to "GMT" by default. To change the time zone, change the "orafce.timezone" parameter. An example using the SET statement is shown below.

```
SET orafce.timezone = 'Japan';
```

- The orafce.timezone settings can be set using any of the methods for setting server parameters.
- If the SQL statement is executed with orafce.timezone set, the following message may be displayed, however, the parameter settings are enabled, so you can ignore this.

```
WARNING: unrecognized configuration parameter
"orafce.timezone"
```

- The time zones that can be set in "orafce.timezone" are the same as for the "TimeZone" server parameter.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Data Types" > "Date/Time Types" in the LightDB Documentation for information on the time zone.

**Example**

In the following example, the DBTIMEZONE result is returned.

```
SELECT DBTIMEZONE() FROM DUAL;
dbtimezone
-----
GMT
(1 row)
```

**F.56.5.3.3. LAST\_DAY****Description**

Returns the last day of the month in which the specified date falls.

**Syntax**

```
LAST_DAY(date DATE) returns DATE
LAST_DAY(date TIMESTAMPTZ) returns TIMESTAMPTZ
```

**General rules**

- LAST\_DAY returns the last day of the month in which the specified date falls.
- For *date*, specify a DATE or TIMESTAMPTZ type.

- The data type of the return value is DATE or TIMESTAMPTZ.

**Note**

If using the DATE type of ora<sub>fc</sub>e, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using ora<sub>fc</sub>e" for information on how to edit search\_path.

**Example**

In the example below, the last date of "February 01, 2016" is returned.

```
SELECT LAST_DAY( DATE '2016/02/01' ) FROM DUAL;
      last_day
-----
2016-02-29 00:00:00
(1 row)
```

### F.56.5.3.4. MONTHS\_BETWEEN

**Description**

Returns the number of months between two dates.

**Syntax**

```
MONTHS_BETWEEN(date1 DATE, date2 DATE) returns NUMERIC
MONTHS_BETWEEN(date1 TIMESTAMP WITH TIME ZONE, date2 TIMESTAMP
WITH TIME ZONE) returns NUMERIC
```

**General rules**

- MONTHS\_BETWEEN returns the difference in the number of months between *date1* and *date2*.
- For *date1* and *date2*, specify a DATE or TIMESTAMPTZ type.
- If *date2* is earlier than *date1*, the return value will be negative.
- If two dates fall on the same day, or each of the two dates are the last day of the month to which they belong, an integer is returned. If the days are different, one month is considered to be 31 days, and a value with the difference in the number of days divided by 31 added is returned.
- The data type of the return value is DATE or NUMERIC.

**Note**

If using the DATE type of ora<sub>fc</sub>e, it is necessary to specify "oracle" for search\_path in advance.

**See**

Refer to "Notes on Using ora<sub>fc</sub>e" for information on how to edit search\_path.

**Example**

In the following example, the difference between the months of March 15, 2016 and November 15, 2015 is returned.

```

SELECT MONTHS_BETWEEN(DATE '2016/03/15', DATE '2015/11/15') FROM
DUAL;
      months_between
      -----
              4
(1 row)

```

### F.56.5.3.5. NEXT\_DAY

#### Description

Returns the date of the first instance of a particular day of the week that follows the specified date.

#### Syntax

```

NEXT_DAY(date DATE, dayOfWk TEXT) returns DATE
NEXT_DAY(date DATE, dayOfWk INTEGER) returns DATE
NEXT_DAY(date TIMESTAMP WITH TIME ZONE, dayOfWk TEXT) returns
TIMESTAMP
NEXT_DAY(date TIMESTAMP WITH TIME ZONE, dayOfWk INTEGER)
returns TIMESTAMP

```

#### General rules

- NEXT\_DAY returns the date matching the first instance of *dayOfWk* that follows *date*.
- For *date*, specify a DATE or TIMESTAMPTZ WITH TIME ZONE type.
- Specify a numeric value or string indicating the day of the week.

#### Values that can be specified for the day

**Table F.112. Setting dayOfWk for NEXT\_DAY Function**

Setting example	Overview
1	1 (Sunday) to 7 (Saturday) can be specified
'Sun', or 'Sunday'	English display of the day
'*'	Japanese display of the day

- The data type of the return value is DATE or TIMESTAMP.

#### Note

- If using the DATE type of ora<sub>fc</sub>e, it is necessary to specify "oracle" for search\_path in advance.
- The ability to use Japanese for entering days is provided by the ora<sub>fc</sub>e proprietary specification. Japanese cannot be used for entering days when using date/time functions other than NEXT\_DAY (such as TO\_DATE).

#### See

Refer to "Notes on Using ora<sub>fc</sub>e" for information on how to edit search\_path.

#### Example

In the example below, the date of the first Friday on or after "May 1, 2016" is returned.

```

SELECT NEXT_DAY(DATE'2016/05/01', 'Friday') FROM DUAL;
      next_day
-----
2016-05-06 00:00:00
(1 row)

```

### F.56.5.3.6. ROUND

#### Description

Rounds a date.

#### Syntax

```

ROUND(date DATE) returns DATE
ROUND(date DATE, fmt TEXT) returns DATE
ROUND(date TIMESTAMP WITH TIME ZONE) returns TIMESTAMP WITH
TIME ZONE
ROUND(date TIMESTAMP WITH TIME ZONE, fmt TEXT) returns
TIMESTAMP WITH TIME ZONE
ROUND(date TIMESTAMP WITHOUT TIME ZONE) returns TIMESTAMP
WITHOUT TIME ZONE
ROUND(date TIMESTAMP WITHOUT TIME ZONE, fmt TEXT) returns
TIMESTAMP WITHOUT TIME ZONE

```

#### General rules

- ROUND returns a date rounded to the unit specified by format model *fmt*.
- For *date*, specify a DATE or TIMESTAMPTZ type.
- Specify the format model as a string.

#### Values that can be specified for the format model

**Table F.113. Setting Format Model for ROUND Function**

Format model	Rounding unit
Y,YY,YYY,YYYY, SYYYY, YEAR,SYEAR	Year
I,IY,IYY,IYYY	Year (values including calendar weeks, in compliance with the ISO standard)
Q	Quarter
WW	Week (first day of the year)
IW	Week (Monday of that week)
W	Week (first weekday on which the first day of the month falls)
DAY,DY,D	Week (Sunday of that week)
MONTH,MON,MM,RM	Month
CC,SCC	Century
DDD,DD,J	Day

Format model	Rounding unit
HH,HH12,HH24	Hour
MI	Minute

- If decimal places are rounded: for year, the boundary for rounding is July 1; for month, the day is 16; and for week, the weekday is Thursday.
- If *fmt* is omitted, the date is rounded by day.
- If the DATE type of LightDB is specified for the date, that DATE type will be the data type of the return value. If the TIMESTAMP type is specified for the date, the data type will be TIMESTAMP WITH TIME ZONE, irrespective of whether a time zone is used.

**Example**

In the example below, the result of "June 20, 2016 18:00:00" rounded by Sunday of the week is returned.

```
SELECT ROUND(TIMESTAMP '2016/06/20 18:00:00', 'DAY') FROM DUAL;
           round
-----
2016-06-19 00:00:00+09
(1 row)
```

**F.56.5.3.7. SESSIONTIMEZONE**

**Description**

Returns the time zone of the session.

**Syntax**

```
SESSIONTIMEZONE() returns text
```

**General rules**

- SESSIONTIMEZONE returns the time zone value between sessions.
- The data type of the return value is TEXT.

**Note**

- If using SESSIONTIMEZONE, it is necessary to specify "oracle" for search\_path in advance.
- The value returned by SESSIONTIMEZONE becomes the value set in the "TimeZone" server parameter.

**See**

Refer to "Notes on Using orafce" for information on how to edit search\_path.

**Example**

In the following example, the time zone of the session is returned.

```
SELECT SESSIONTIMEZONE() FROM DUAL;
```

```
sessiontimezone
-----
Japan
(1 row)
```

### F.56.5.3.8. SYSDATE

#### Description

Returns the system date.

#### Syntax

```
SYSDATE() returns oracle.date
```

#### General rules

- SYSDATE returns the system date.
- The data type of the return value is the DATE type of orafce.

#### Note

- If using SYSDATE, it is necessary to specify "oracle" for search\_path in advance.
- The date returned by SYSDATE depends on the time zone value of the orafce database.

#### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "DBTIMEZONE" for information on the time zone values of the database.
- Refer to "The SQL Language" > "Data Types" > "Date/Time Types" in the LightDB Documentation for information on the time zone.

#### Example

In the following example, the system date is returned.

```
SELECT SYSDATE() FROM DUAL;
        sysdate
-----
2016-06-22 08:06:51
(1 row)
```

### F.56.5.3.9. TRUNC

#### Description

Truncates a date.

#### Syntax

```
TRUNC(date DATE) returns DATE
TRUNC(date DATE, fmt TEXT) returns DATE
```

TRUNC(date TIMESTAMP WITH TIME ZONE) returns TIMESTAMP WITH TIME ZONE

TRUNC(date TIMESTAMP WITH TIME ZONE, fmt TEXT) returns TIMESTAMP WITH TIME ZONE

TRUNC(date TIMESTAMP WITHOUT TIME ZONE) returns TIMESTAMP WITHOUT TIME ZONE

TRUNC(date TIMESTAMP WITHOUT TIME ZONE, fmt TEXT) returns TIMESTAMP WITHOUT TIME ZONE

### General rules

- TRUNC returns a date truncated to the unit specified by format model *fmt*.
- For *date*, specify a DATE or TIMESTAMP type.
- Specify the format model as a string. The values that can be specified are the same as for ROUND.
- If *fmt* is omitted, the date is truncated by day.
- If the DATE type of LightDB is specified for the date, that DATE type will be the data type of the return value. If the TIMESTAMP type is specified for the date, the data type will be TIMESTAMP WITH TIME ZONE, irrespective of whether a time zone is used.

### See

Refer to "ROUND" for information on the values that can be specified for the format model.

### Example

In the example below, the result of "August 10, 2016 15:30:00" truncated by the day is returned.

```
SELECT TRUNC(TIMESTAMP '2016/08/10 15:30:00', 'DDD') FROM DUAL;
          trunc
-----
2016-08-10 00:00:00+09
(1 row)
```

## F.56.5.3.10. TZ\_OFFSET

### Description

Returns the time zone offset.

### Syntax

TZ\_OFFSET(text) returns text

### General rules

- You can enter a valid time zone region name, a time zone offset from UTC (which simply returns itself).
- For a listing of valid values for time\_zone\_name, query the name column of the pg\_timezone\_names.

### Note

- If using TZ\_OFFSET, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraace" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT TZ_OFFSET('Asia/Shanghai') FROM DUAL;
tz_offset
-----
08:00:00
(1 row)
      (1 row)
```

## F.56.5.4. Data Type Formatting Functions

The following data type formatting functions are supported:

- CONVERT
- NUMTOYMINTERVAL
- TO\_BLOB(raw)
- TO\_CHAR
- TO\_DATE
- TO\_MULTI\_BYTE
- TO\_NUMBER
- TO\_SINGLE\_BYTE
- ASCIISTR
- ASCII
- SQLCODE\_TO\_SQLSTATE
- TO\_CLOB
- RAWTOHEX
- ROWIDTOCHAR

### F.56.5.4.1. CONVERT

**Description**

CONVERT converts a character string from one character set to another.

**Syntax**

```
CONVERT(str TEXT, dest_char_set TEXT, source_char_set TEXT
DEFAULT 'utf8') returns TEXT
```



**General rules**

- The `str` argument is the value to be converted.
- The `dest_char_set` argument is the name of the character set to which `str` is converted.
- The `source_char_set` argument is the name of the character set in which `str` is stored in the database. The default value is the database character set.
- Both the destination and source character set arguments can be either literals or columns containing the name of the character set.
- For complete correspondence in character conversion, it is essential that the destination character set contains a representation of all the characters defined in the source character set. Where a character does not exist in the destination character set, a replacement character appears. Replacement characters can be defined as part of a character set definition.

**Note**

- If using `CONVERT` for converting string, it is necessary to specify "oracle" for `search_path` in advance.

**See**

- Refer to "Notes on Using Oracle" for information on how to edit `search_path`.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT CONVERT('###', 'gbk', 'utf8') from dual; FROM DUAL;
convert
-----
##
(1 row)
```

**F.56.5.4.2. NUMTOYMINTERVAL****Description**

`NUMTOYMINTERVAL` converts number to an `INTERVAL YEAR TO MONTH` literal.

**Syntax**

```
NUMTOYMINTERVAL(n numeric, interval_unit text) returns
interval
```

**General rules**

- The value for `interval_unit` specifies the unit of `n` and must resolve to one of the following string values: 'YEAR', 'MONTH'.
- `interval_unit` is case insensitive.

**Note**

- If using NUMTOYMINTERVAL for specifying date/time values, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraace" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT NUMTOYMINTERVAL(1, 'YEAR') FROM DUAL;
 numtoyminterval
-----
1 year
(1 row)
```

**F.56.5.4.3. TO\_BLOB(raw)**

**Description**

TO\_BLOB(raw) converts RAW values to BLOB values.

**Syntax**

TO\_BLOB(raw) returns blob

**Note**

- If using the TO\_BLOB(raw) function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraace" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT TO_BLOB(UTL_RAW.CAST_TO_RAW('##')) FROM DUAL;
 to_blob
-----
\xe6b58be8af95
(1 row)
```

**F.56.5.4.4. TO\_CHAR**

**Description**

Converts a value to a string.

**Syntax**

TO\_CHAR(num SMALLINT) returns TEXT

```
TO_CHAR(num INTEGER) returns TEXT
TO_CHAR(num BIGINT) returns TEXT
TO_CHAR(num REAL) returns TEXT
TO_CHAR(num DOUBLE PRECISION) returns TEXT
TO_CHAR(num NUMERIC) returns TEXT
TO_CHAR(date TIMESTAMP) returns TEXT
TO_CHAR(TEXT) returns TEXT

TO_CHAR(date TIMESTAMP, fmt TEXT) returns TEXT
TO_CHAR(date TIMESTAMP WITH TIME ZONE, fmt TEXT) returns TEXT

TO_CHAR(date TIMESTAMP, fmt TEXT, nls_date_language TEXT)
returns TEXT
TO_CHAR(date TIMESTAMP WITH TIME ZONE, fmt TEXT,
nls_date_language TEXT) returns TEXT
```

### General rules

- TO\_CHAR converts the specified number or date/time value to a string.
- For *num*, specify a numeric data type.
- For *date*, please specify the DATE or TIMESTAMP type. Additionally, you can set the date/time format for the *nls\_date\_format* variable in advance, so you don't need to specify it when calling TO\_CHAR. Here is an example of how to set it using the SET statement.

```
SET nls_date_format = 'YYYY/MM/DD HH24:MI:SS';
```

Whether it is specified at display time or at call time, the format specifier works the same regardless of case.

- For *fmt*, it is used to set the data format. When the first argument is a numeric type, see numeric value formatting functions. When the first argument is a date type, see date value formatting functions.
- For *nls\_date\_language*, it is used to set the display language environment for dates.
- The data type of the return value is TEXT.

### Note

- If using TO\_CHAR for specifying date/time values, it is necessary to specify "oracle" for *search\_path* in advance.
- The *nls\_date\_format* settings can be set using any of the methods for setting server parameters.
- If *nls\_date\_format* is set, the following message may be displayed when an SQL statement is executed, however, the parameter settings are enabled, so you can ignore this.

```
WARNING: unrecognized configuration parameter
"nls_date_format"
```

### See

- Refer to "Notes on Using orafce" for information on how to edit *search\_path*.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

### Example

In the following example, the numeric value "123.45" is returned as a string.

```
SELECT TO_CHAR(123.45) FROM DUAL;
to_char
-----
123.45
(1 row)

SELECT to_char (sysdate, 'YYYY-MM-DD',
'NLS_DATE_LANGUAGE='SIMPLIFIED CHINESE' ');
to_char
-----
2023-12-04
(1 row)
```

### F.56.5.4.5. TO\_DATE

#### Description

Converts a string to a date in accordance with the specified format.

#### Syntax

```
TO_DATE(str TEXT) returns TIMESTAMP
TO_DATE(str TEXT, fmt TEXT) returns TIMESTAMP
```

#### General rules

- TO\_DATE converts string *str* to a date in accordance with the specified format *fmt*.
- Specify a string indicating the date/time.
- Specify the required date/time format. If omitted, the format specified in the `nls_date_format` variable is used. If the `nls_date_format` variable has not been set, the existing date/time input interpretation is used. A setting example using the SET statement is shown below.

```
SET nls_date_format = 'YYYY/MM/DD HH24:MI:SS';
```

- The data type of the return value is `TIMESTAMP`.

#### Note

- The above TO\_DATE specification uses `orafce` for its behavior, which is different to that of TO\_DATE of `LightDB`. The `search_path` parameter must be modified for it to behave according to the `orafce` specification.
- The `nls_date_format` settings can be set using any of the methods for setting server parameters.
- If `nls_date_format` is set, the following message may be displayed when an SQL statement is executed, however, the parameter settings are enabled, so you can ignore this.

```
WARNING: unrecognized configuration parameter
"nls_date_format"
```

**Information**

The general rule for TO\_DATE for specifying the data type format of LightDB is as follows:

- The data type of the return value is the DATE type of LightDB.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "The SQL Language" > "Functions and Operators" > "Data Type Formatting Functions" in the LightDB Documentation for information on TO\_DATE of LightDB.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.
- Refer to "Date/Time Support" > "Date/Time Input Interpretation" in the LightDB Documentation for information on the interpretation of existing date/time input.

**Example**

In the following example, the string "2016/12/31" is converted to a date and returned.

```
SELECT TO_DATE('2016/12/31','YYYY/MM/DD') FROM DUAL;
      to_date
-----
2016-12-31 00:00:00
(1 row)
```

**F.56.5.4.6. TO\_MULTI\_BYTE****Description**

Converts a single-byte string to a multibyte string.

**Syntax**

```
TO_MULTI_BYTE(str TEXT) returns TEXT
```

**General rules**

- TO\_MULTI\_BYTE converts halfwidth characters in string *str* to fullwidth characters, and returns the converted string.
- Specify a string indicating the date/time.
- Specify the required date/time format. If omitted, the format specified in the nls\_date\_format variable is used. If the nls\_date\_format variable has not been set, the existing date/time input interpretation is used. A setting example using the SET statement is shown below.

```
Only halfwidth alphanumeric characters, spaces and symbols
can be converted.
```

- The data type of the return value is TEXT.

**Example**

In the following example, "abc123" is converted to fullwidth characters and returned.

```
SELECT TO_MULTI_BYTE('abc123') FROM DUAL;
to_multi_byte
-----
*****
(1 row)
```

"\*\*\*\*\*" is multibyte "abc123".

#### F.56.5.4.7. TO\_NUMBER

##### Description

Converts a value to a number in accordance with the specified format.

##### Syntax

```
TO_NUMBER(str TEXT) returns NUMERIC
TO_NUMBER(num NUMERIC) returns NUMERIC
TO_NUMBER(num NUMERIC, fmt NUMERIC) returns NUMERIC
```

##### General rules

- TO\_NUMBER converts the specified value to a numeric value in accordance with the specified format *fmt*.
- For *num*, specify a numeric data type.
- For *str*, specify a string indicating the numeric value. Numeric values must comprise only of convertible characters.
- Specify the required numeric data format. The specified numeric value is handled as is as a data type expression.
- The data type of the return value is NUMERIC.

##### See

Refer to "The SQL Language" > "Functions and Operators" > "Data Type Formatting Functions" in the LightDB Documentation for information on numeric value formats.

##### Example

In the following example, the numeric literal "-130.5" is converted to a numeric value and returned.

```
SELECT TO_NUMBER(-130.5) FROM DUAL;
to_number
-----
-130.5
(1 row)
```

#### F.56.5.4.8. TO\_SINGLE\_BYTE

##### Description

Converts a multibyte string to a single-byte string.

**Syntax**

```
TO_SINGLE_BYTE(str TEXT) returns TEXT
```

**General rules**

- TO\_SINGLE\_BYTE converts fullwidth characters in string *str* to halfwidth characters, and returns the converted string.
- Only fullwidth alphanumeric characters, spaces and symbols that can be displayed in halfwidth can be converted.
- The data type of the return value is TEXT.

**Example**

In the following example, "\*\*\*\*\*" is converted to halfwidth characters and returned. "\*\*\*\*\*" is multibyte "xyz999".

```
SELECT TO_SINGLE_BYTE('*****') FROM DUAL;
to_single_byte
-----
xyz999
(1 row)
```

### F.56.5.4.9. ASCIISTR

**Description**

ASCIISTR takes as its argument a string, or an expression that resolves to a string, in any character set and returns an ASCII version of the string in the database character set.

**Syntax**

```
ASCIISTR(str TEXT) returns TEXT
```

**General rules**

- Non-ASCII characters are converted to the form \xxxx, where xxxx represents a UTF-16 code unit.
- The data type of the return value is TEXT.

**Example**

In the following example, "Ä" is converted to "\00C4".

```
SELECT ASCIISTR('ABÄCDE') FROM DUAL;
asciistr
-----
AB\00C4CDE
(1 row)
```

### F.56.5.4.10. ASCII

#### Description

ASCII takes as its argument a string, or an expression that resolves to a string, in any character set and returns an value in the database character set of the first character.

#### Syntax

```
ASCIISTR(str TEXT) returns BIGINT
```

#### General rules

- If your database character set is 7-bit ASCII, then this function returns an ASCII value. If your database character set is UTF-8 Code, then this function returns an UTF-8 value.
- The data type of the return value is BIGINT.

#### Example

In the following example, "Ä" is converted to "50052" in UTF-8.

```
SELECT ORACLE.ASCII('Ä') FROM DUAL;
  ascii
-----
 50052
(1 row)
```

### F.56.5.4.11. SQLCODE\_TO\_SQLSTATE

#### Description

Convert integer error codes to string error codes of length 5.

#### Syntax

```
SQLCODE_TO_SQLSTATE(code INTEGER) returns TEXT
```

#### General rules

- Can only convert integer error codes between 0 and 715827882.
- The data type of the return value is TEXT.

#### Example

In the following example, Conversion error code 2.

```
select SQLCODE_TO_SQLSTATE(2);
  sqlcode_to_sqlstate
-----
 20000
(1 row)
```



### F.56.5.4.12. TO\_CLOB

#### Description

Converts a string or a number to clob.

#### Syntax

```
TO_CLOB(str TEXT) returns CLOB
```

#### General rules

- TO\_CLOB converts the specified value to a clob.

#### Example

```
CREATE TABLE testorafce_to_clob (  
    col_char CHAR(10),  
    col_varchar2 VARCHAR2(20),  
    col_varchar VARCHAR(20),  
    col_nchar NCHAR(10),  
    col_nvarchar2 NVARCHAR2(20),  
    col_smallint smallint,  
    col_integer integer,  
    col_bigint bigint,  
    col_decimal decimal,  
    col_numeric numeric,  
    col_real real,  
    col_double double precision,  
    col_clob CLOB,  
    col_raw raw(10)  
);  
  
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint, col_integer,  
    col_bigint, col_decimal, col_numeric, col_real, col_double,  
    col_clob, col_raw)  
VALUES ('ABC1', 'Hello', 'World', 'hello', 'world', 1, 2, 3, 4, 5,  
    6, 7, 'This is a CLOB', 'AB');
```

```
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint, col_integer,  
    col_bigint, col_decimal, col_numeric, col_real, col_double,  
    col_clob, col_raw)  
VALUES ('ABC2', 'Hello', 'World', 'hello', 'world', 1, 2, 3, 4, 5,  
    6, 7, 'This is a CLOB', '1');
```

```
INSERT INTO testorafce_to_clob (col_char, col_varchar2,  
    col_varchar, col_nchar, col_nvarchar2, col_smallint, col_integer,  
    col_bigint, col_decimal, col_numeric, col_real, col_double,  
    col_clob, col_raw)  
VALUES ('ABC3', 'Hello', 'World', 'hello', 'world', 1, 2, 3, 4, 5,  
    6, 7, to_clob('This is a CLOB'), '1AB456789');
```

```
SELECT to_clob(col_char) AS clob_char,  
    to_clob(col_varchar2) AS clob_varchar2,
```

```

to_clob(col_varchar) AS col_varchar,
to_clob(col_nchar) AS clob_nchar,
to_clob(col_nvarchar2) AS clob_nvarchar2,
to_clob(col_clob) AS clob_clob,
to_clob(col_smallint) AS col_smallint,
to_clob(col_integer) AS col_integer,
to_clob(col_bigint) AS col_bigint,
to_clob(col_decimal) AS col_decimal,
to_clob(col_numeric) AS col_numeric,
to_clob(col_real) AS col_real,
to_clob(col_double) AS col_double,
to_clob(col_raw) AS clob_nclob
FROM testorafce_to_clob order by col_char asc;

```

```

clob_char | clob_varchar2 | col_varchar | clob_nchar |
clob_nvarchar2 | clob_clob | col_smallint | col_integer |
col_bigint | col_decimal | col_numeric | col_real | col_double |
clob_nclob
-----+-----+-----+-----
+-----+-----+-----+-----
+-----+-----+-----+-----
+-----
ABC1      | Hello      | world      | hello      | world      |
| This is a CLOB | 1          | 2          | 3          | 4          |
| 5          | 6          | 7          | AB         |            |
ABC2      | Hello      | world      | hello      | world      |
| This is a CLOB | 1          | 2          | 3          | 4          |
| 5          | 6          | 7          | 01         |            |
ABC3      | Hello      | world      | hello      | world      |
| This is a CLOB | 1          | 2          | 3          | 4          |
| 5          | 6          | 7          | 01AB456789 |            |
(3 rows)

```

### F.56.5.4.13. RAWTOHEX

#### Description

RAWTOHEX CONVERTS THE INCOMING VALUE TO A CHARACTER VALUE THAT CONTAINS ITS HEXADECIMAL REPRESENTATION.

#### Syntax

```

RAWTOHEX(test_raw RAW) returns TEXT
RAWTOHEX(test_text TEXT) returns TEXT
RAWTOHEX(test_uuid UUID) returns VARCHAR2

```

#### General rules

- This function returns a value that has a hexadecimal representation of the bytes that make up the incoming value. Each byte is represented by two hexadecimal numbers.

#### Example

```

select rawtohex(sys_guid());
       rawtohex

```

```
-----  
6466c654a5dc4755902b70d0e6ea6eb6  
(1 row)
```

#### F.56.5.4.14. ROWIDTOCHAR

##### Description

ROWIDTOCHAR CONVERTS THE INCOMING VALUE ROWID of tid type TO a varchar2 type#

##### Syntax

```
ROWIDTOCHAR(test_rowid TID) returns VARCHAR2
```

##### General rules

- This function returns a value that has a varchar2 type,the max length is 18.

##### Example

```
drop TABLE if EXISTS rowidtochar_t1;  
create table rowidtochar_t1  
(  
    id int not null  
);  
insert into rowidtochar_t1 values(1);  
select rowidtochar(rowid) from rowidtochar_t1;  
rowidtochar  
-----  
(0,1)  
(1 row)
```

#### F.56.5.5. Conditional Expressions

The following functions for making comparisons are supported:

- DECODE
- LNNVL
- NANVL
- NVL
- NVL2

##### F.56.5.5.1. DECODE

##### Description

Compares values and if they match, returns a corresponding value.

##### Syntax

```
DECODE(expr, srch, result)
```

```
DECODE(expr, srch, result, default)
DECODE(expr, srch1, result1, srch2, result2)
DECODE(expr, srch1, result1, srch2, result2, default)
DECODE(expr, srch1, result1, srch2, result2, srch3, result3)
DECODE(expr, srch1, result1, srch2, result2, srch3, result3,
default)
```

### General rules

- DECODE compares values of the value expression to be converted and the search values one by one. If the values match, a corresponding result value is returned. If no values match, the default value is returned if it has been specified. A NULL value is returned if a default value has not been specified.
- If the same search value is specified more than once, then the result value returned is the one listed for the first occurrence of the search value.
- The following data types can be used in result values and in the default value:
  - CHAR
  - VARCHAR
  - VARCHAR2
  - NCHAR
  - NCHAR VARYING
  - NVARCHAR2
  - TEXT
  - INTEGER
  - BIGINT
  - NUMERIC
  - DATE
  - TIME WITHOUT TIME ZONE
  - TIMESTAMP WITHOUT TIME ZONE
  - TIMESTAMP WITH TIME ZONE
- The same data type must be specified for the values to be converted and the search values. However, note that different data types may also be specified if a literal is specified in the search value, and the value expression to be converted contains data types that can be converted.
- If the result values and default value are all literals, the data types for these values will be as shown below:
  - If all values are string literals, all will become character types.
  - If there is one or more numeric literal, all will become numeric types.
  - If there is one or more literal cast to the datetime/time types, all will become datetime/time types.
- If the result values and default value contain a mixture of literals and non-literals, the literals will be converted to the data types of the non-literals.

- The same data type must be specified for all result values and for the default value. However, different data types can be specified if the data type of any of the result values or default value can be converted - these data types are listed below:

**Table F.114. Data type combinations that can be converted by DECODE (summary)**

		Other result values or default value		
		Numeric type	Character type	Date/time type
<b>Result value (any)</b>	Numeric type	Y	N	N
	Character type	N	Y	N
	Date/time type	N	N	S(*1)

Y: Can be converted

S: Some data types can be converted

N: Cannot be converted

\*1: The data types that can be converted for date/time types are listed below:

**Table F.115. Result value and default value date/time data types that can be converted by DECODE**

		Other result values or default value			
		DATE	TIME WITHOUT TIME ZONE	TIMESTAMP WITHOUT TIME ZONE	TIMESTAMP WITH TIME ZONE
<b>Result value (any)</b>	DATE	Y	N	Y	Y
	TIME WITHOUT TIME ZONE	N	Y	N	N
	TIMESTAMP WITHOUT TIME ZONE	Y	N	Y	Y
	TIMESTAMP WITH TIME ZONE	Y	N	Y	Y

Y: Can be converted

N: Cannot be converted

- The data type of the return value will be the data type within the result or default value that is longest and has the highest precision.

**Example**

In the following example, the value of col3 in table t1 is compared and converted to a different value. If the col3 value matches search value 1, the result value returned is "one". If the col3 value does not match any of search values 1, 2, or 3, the default value "other number" is returned.

```
SELECT col1,
       DECODE(col3, 1, 'one',
              2, 'two',
```

```

3, 'three',
'other number') "num-word"
FROM t1;
col1 | num-word
-----+-----
1001 | one
1002 | two
1003 | three
(3 rows)

```

### F.56.5.5.2. LNNVL

#### Description

Determines if a value is TRUE or FALSE for the specified condition.

#### Syntax

```
LNNVL(cond BOOLEAN) returns BOOLEAN
```

#### General rules

- LNNVL determines if a value is TRUE or FALSE for the specified condition. If the result of the condition is FALSE or NULL, TRUE is returned. If the result of the condition is TRUE, FALSE is returned.
- The expression for returning TRUE or FALSE is specified in the condition.
- The data type of the return value is BOOLEAN.

#### Example

In the following example, col1 and col3 of table t1 are returned when col3 has a value of 2000 or less, or null values.

```

SELECT col1,col3 FROM t1 WHERE LNNVL( col3 > 2000 );
col1 | col3
-----+-----
1001 | 1000
1002 | 2000
2002 |
(3 row)

```

### F.56.5.5.3. NANVL

#### Description

Returns a substitute value when a value is not a number (NaN).

#### Syntax

```

NANVL(expr FLOAT4, substitute FLOAT4) returns FLOAT4
NANVL(expr FLOAT8, substitute FLOAT8) returns FLOAT8
NANVL(expr NUMERIC, substitute NUMERIC) returns NUMERIC
NANVL(expr FLOAT4, substitute VARCHAR) returns FLOAT4

```

```
NANVL(expr FLOAT8, substitute VARCHAR) returns FLOAT8
NANVL(expr NUMERIC, substitute VARCHAR) returns NUMERIC
```

### General rules

- NANVL returns a substitute value when the specified value is not a number (NaN). The substitute value can be either a number or a string that can be converted to a number.
- For *expr* and *substitute*, specify a numeric data type. If *expr* and *substitute* have different data types, they will be converted to the data type with greater length or precision, and that is the data type that will be returned.
- For *substitute*, you can also specify a string indicating the numeric value.
- The data type used for the return value if a string is specified for the substitute value will be the same as the data type of *expr*.

### Example

In the following example, "0" is returned if the value of col1 in table t1 is a NaN value.

```
SELECT col1, NANVL(col3,0) FROM t1;
 col1 | nanvl
-----+-----
 2001 |      0
(1 row)
```

## F.56.5.5.4. NVL

### Description

Returns a substitute value when a value is NULL.

### Syntax

```
NVL(expr1 anyelement, expr2 anyelement) return anyelement
```

### General rules

- NVL returns a substitute value when the specified value is NULL. When *expr1* is NULL, *expr2* is returned. When *expr1* is not NULL, *expr1* is returned.
- Specify the same data types for *expr1* and *expr2*. However, if a constant is specified in *expr2*, and the data type can also be converted by *expr1*, different data types can be specified. When this happens, the conversion by *expr2* is done to suit the data type in *expr1*, so the value of *expr2* returned when *expr1* is a NULL value will be the value converted in the data type of *expr1*. This is not necessary for types (numeric, int) and (bigint, int).

### Example

In the following example, "IS NULL" is returned if the value of col1 in table t1 is a NULL value.

```
SELECT col2, NVL(col1, 'IS NULL') "nv1" FROM t1;
 col2 |   nv1
-----+-----
  aaa | IS NULL
```

(1 row)

### F.56.5.5.5. NVL2

#### Description

Returns a substitute value based on whether a value is NULL or not NULL.

#### Syntax

```
NVL2(expr anyelement, substitute1 anyelement, substitute2  
anyelement) return anyelement
```

#### General rules

- NVL2 returns a substitute value based on whether the specified value is NULL or not NULL. When *expr* is NULL, *substitute2* is returned. When it is not NULL, *substitute1* is returned.
- Specify the same data types for *expr*, *substitute1*, and *substitute2*. However, if a literal is specified in *substitute1* or *substitute2*, and the data type can also be converted by *expr*, different data types can be specified. When this happens, *substitute1* or *substitute2* is converted to suit the data type in *expr*, so the value of *substitute2* returned when *expr* is a NULL value will be the value converted to the data type of *expr*.

#### Example

In the following example, if a value in column *col1* in table *t1* is NULL, "IS NULL" is returned, and if not NULL, "IS NOT NULL" is returned.

```
SELECT col2, NVL2(col1, 'IS NOT NULL', 'IS NULL') FROM t1;  
col2 |  nv12  
-----+-----  
aaa  |  IS NULL  
bbb  |  IS NOT NULL  
(2 row)
```

### F.56.5.6. Aggregate Functions

The following aggregation functions are supported:

- ANY\_VALUE
- BIT\_AND\_AGG
- BIT\_OR\_AGG
- BIT\_XOR\_AGG
- KURTOSIS\_POP
- KURTOSIS\_SAMP
- LISTAGG
- MEDIAN
- SKEWNESS\_POP



- SKEWNESS\_SAMP

### F.56.5.6.1. ANY\_VALUE

#### Description

ANY\_VALUE returns a single non-deterministic value of expr.

#### Syntax

```
ANY_VALUE(expr anyelement) returns anyelement
```

#### General rules

- Use ANY\_VALUE to optimize a query that has a GROUP BY clause. ANY\_VALUE returns a value of an expression in a group. It is optimized to return the first value.
- It ensures that there are no comparisons for any incoming row and also eliminates the necessity to specify every column as part of the GROUP BY clause.
- Because it does not compare values, ANY\_VALUE returns a value more quickly than MIN or MAX in a GROUP BY query.
- Returns any value within each group based on the GROUP BY specification. Returns NULL if all rows in the group have NULL expression values.
- The result of ANY\_VALUE is not deterministic.

#### Note

- If using ANY\_VALUE, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

```
create table test_any_value(key1 int, key2 int);
insert into test_any_value values(1, 1);
select any_value(key2) from test_any_value group by key1;
 any_value
-----
          1
(1 row)
```

### F.56.5.6.2. BIT\_AND\_AGG

#### Description

BIT\_AND\_AGG is a bitwise aggregation function that returns the result of a bitwise AND operation.

#### Syntax

BIT\_AND\_AGG(numeric) returns int

**General rules**

- You can use BIT\_AND\_AGG as part of a GROUP BY query, window function, or as an analytical function.
- For a given set of values, the result of a bitwise aggregate is always deterministic and independent of ordering.
- The data type of the return value is int.

**Note**

- If using BIT\_AND\_AGG, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
select bit_and_agg(column1) from (values (1),(2),(4),(8)) x;
 bit_and_agg
-----
          0
(1 row)
```

**F.56.5.6.3. BIT\_OR\_AGG****Description**

BIT\_OR\_AGG is a bitwise aggregation function that returns the result of a bitwise OR operation.

**Syntax**

BIT\_OR\_AGG(numeric) returns int

**General rules**

- You can use BIT\_OR\_AGG as part of a GROUP BY query, window function, or as an analytical function.
- For a given set of values, the result of a bitwise aggregate is always deterministic and independent of ordering.
- The data type of the return value is int.

**Note**

- If using BIT\_OR\_AGG, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.

- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
select bit_or_agg(column1) from (values (1),(2),(4),(8)) x;
   bit_or_agg
-----
              15
(1 row)
```

**F.56.5.6.4. BIT\_XOR\_AGG****Description**

BIT\_XOR\_AGG is a bitwise aggregation function that returns the result of a bitwise XOR operation.

**Syntax**

```
BIT_XOR_AGG(numeric) returns int
```

**General rules**

- You can use BIT\_XOR\_AGG as part of a GROUP BY query, window function, or as an analytical function.
- For a given set of values, the result of a bitwise aggregate is always deterministic and independent of ordering.
- The data type of the return value is int.

**Note**

- If using BIT\_XOR\_AGG, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oracle" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
select bit_xor_agg(column1) from (values (1),(3),(4),(8)) x;
   bit_xor_agg
-----
              14
(1 row)
```

**F.56.5.6.5. KURTOSIS\_POP****Description**

The population kurtosis function KURTOSIS\_POP is primarily used to determine the characteristics of outliers in a given distribution.

**Syntax**

```
KURTOSIS_POP(numeric) returns numeric
```

**General rules**

- NULL values in expr are ignored.
- Returns NULL if all rows in the group have NULL expr values.
- Returns 0 if there are one or two rows in expr.
- For a given set of values, the result of population kurtosis (KURTOSIS\_POP) and sample kurtosis (KURTOSIS\_SAMP) are always deterministic. However, the values of KURTOSIS\_POP and KURTOSIS\_SAMP differ. As the number of values in the data set increases, the difference between the computed values of KURTOSIS\_SAMP and KURTOSIS\_POP decreases.

**Note**

- If using the KURTOSIS\_POP function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
select kurtosis_pop(column1) from (values (1),(2),(4),(8)) x;
      kurtosis_pop
-----
-1.09897920604914942667
(1 row)
```

**F.56.5.6.6. KURTOSIS\_SAMP****Description**

The sample kurtosis function KURTOSIS\_SAMP is primarily used to determine the characteristics of outliers in a given distribution.

**Syntax**

```
KURTOSIS_SAMP(numeric) returns numeric
```

**General rules**

- NULL values in expr are ignored.
- Returns NULL if all rows in the group have NULL expr values.
- Returns 0 if there are one or two rows in expr.

- For a given set of values, the result of sample kurtosis (KURTOSIS\_SAMP) and population kurtosis (KURTOSIS\_POP) are always deterministic. However, the values of KURTOSIS\_SAMP and KURTOSIS\_POP differ. As the number of values in the data set increases, the difference between the computed values of KURTOSIS\_SAMP and KURTOSIS\_POP decreases.

**Note**

- If using the KURTOSIS\_SAMP function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
select kurtosis_samp(column1) from (values (1),(2),(4),(8)) x;
      kurtosis_samp
-----
0.7576559546313793
(1 row)
```

### F.56.5.6.7. LISTAGG

**Description**

Returns a concatenated, delimited list of string values.

**Syntax**

```
LISTAGG(strExpr TEXT) returns TEXT
LISTAGG(strExpr TEXT, delimiter TEXT) [ ]returns TEXT
LISTAGG(strExpr TEXT, delimiter TEXT ON OVERFLOW TRUNCATE)
[ ]returns TEXT
LISTAGG(strExpr TEXT, delimiter TEXT ON OVERFLOW ERROR)
[ ]returns TEXT
```

**General rules**

- LISTAGG concatenates and delimits a set of string values and returns the result.
- For *delimiter*, specify a string. If the delimiter is omitted, a list of strings without a delimiter is returned.
- In LightDB, LISTAGG support using distinct in function with within group clauses. e.g: LISTAGG(distinct c1) within group(order by c1)
- In LightDB, LISTAGG support using on overflow truncate# e.g: LISTAGG(c1, ':' on overflow truncate)
- In LightDB, LISTAGG support using on overflow error# e.g: LISTAGG(c1, ':' on overflow error)
- In LightDB, LISTAGG support using within group clauses with over clauses. In this scenario we cannot use distinct in function yet. e.g: LISTAGG(c1) within group(order by c1) over(partition by c2)

- The data type of the return value is TEXT.

### Example

In the following example, the result with values of column col2 in table t1 delimited by ':' is returned.

```
SELECT LISTAGG(col2,':') FROM t1;
      listagg
-----
AAAAA:BBBBB:CCCCC
(1 row)
```

In the following example, using within group with over.

```
CREATE TABLE EMP
( EMPNO    NUMBER(4, 0),
  ENAME    VARCHAR2(10),
  JOB      VARCHAR2(9),
  MGR      NUMBER(4, 0),
  HIREDATE DATE,
  SAL      NUMBER(7, 2),
  COMM     NUMBER(7, 2),
  DEPTNO   NUMBER(2, 0),
  DNAME    VARCHAR2(100),
  CONSTRAINT PK_EMP PRIMARY KEY (EMPNO)
);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7369, 'SMITH', 'CLERK', 7902,
  to_date('1980-12-17','yyyy-mm-dd'), 800.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7499, 'ALLEN', 'SALESMAN', 7698,
  to_date('1981-02-20','yyyy-mm-dd'), 1600.00, 300.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7521, 'WARD', 'SALESMAN', 7698,
  to_date('1981-02-22','yyyy-mm-dd'), 1250.00, 500.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7566, 'JONES', 'MANAGER', 7839,
  to_date('1981-04-02','yyyy-mm-dd'), 2975.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7654, 'MARTIN', 'SALESMAN', 7698,
  to_date('1981-09-28','yyyy-mm-dd'), 1250.00, 1400.00, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7698, 'BLAKE', 'MANAGER', 7839,
  to_date('1981-05-01','yyyy-mm-dd'), 2850.00, null, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7782, 'CLARK', 'MANAGER', 7839,
  to_date('1981-06-09','yyyy-mm-dd'), 2450.00, null, 10, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7788, 'SCOTT', 'ANALYST', 7566,
  to_date('1987-04-19','yyyy-mm-dd'), 3000.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7839, 'KING', 'PRESIDENT', null,
  to_date('1981-11-17','yyyy-mm-dd'), 5000.00, null, 10, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
  DEPTNO, DNAME) values (7844, 'TURNER', 'SALESMAN', 7698,
  to_date('1981-09-08','yyyy-mm-dd'), 1500.00, 0.00, 30, null);
```

```
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
DEPTNO, DNAME) values (7876, 'ADAMS', 'CLERK', 7788,
to_date('1987-05-23','yyyy-mm-dd'), 1100.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
DEPTNO, DNAME) values (7900, 'JAMES', 'CLERK', 7698,
to_date('1981-12-03','yyyy-mm-dd'), 950.00, null, 30, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
DEPTNO, DNAME) values (7902, 'FORD', 'ANALYST', 7566,
to_date('1981-12-03','yyyy-mm-dd'), 3000.00, null, 20, null);
insert into EMP (EMPNO, ENAME, JOB, MGR, HIREDATE, SAL, COMM,
DEPTNO, DNAME) values (7934, 'MILLER', 'CLERK', 7782,
to_date('1982-01-23','yyyy-mm-dd'), 1300.00, null, 10, null);
```

```
select listagg(ename, ',') within group(order by ename)
over(partition by deptno) as enames,
deptno,
ename
from EMP;
```

enames	deptno	ename
CLARK,KING,MILLER	10	CLARK
CLARK,KING,MILLER	10	KING
CLARK,KING,MILLER	10	MILLER
ADAMS,FORD,JONES,SCOTT,SMITH	20	ADAMS
ADAMS,FORD,JONES,SCOTT,SMITH	20	FORD
ADAMS,FORD,JONES,SCOTT,SMITH	20	JONES
ADAMS,FORD,JONES,SCOTT,SMITH	20	SCOTT
ADAMS,FORD,JONES,SCOTT,SMITH	20	SMITH
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	ALLEN
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	BLAKE
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	JAMES
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	MARTIN
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	TURNER
ALLEN,BLAKE,JAMES,MARTIN,TURNER,WARD	30	WARD

(14 rows)

### F.56.5.6.8. MEDIAN

#### Description

Calculates the median of a set of numbers.

#### Syntax

```
MEDIAN(numExpr REAL) returns REAL
MEDIAN(numExpr DOUBLE PRECISION) returns DOUBLE PRECISION
```

#### General rules

- MEDIAN returns the median of a set of numbers.
- The numbers must be numeric data type.
- The data type of the return value will be REAL if the numbers are REAL type, or DOUBLE PRECISION if any other type is specified.

**Example**

In the following example, the median of column col3 in table t1 is returned.

```
SELECT MEDIAN(col3) FROM t1;
   median
-----
      2000
(1 row)
```

**F.56.5.6.9. SKEWNESS\_POP****Description**

SKEWNESS\_POP is an aggregate function that is primarily used to determine symmetry in a given distribution.

**Syntax**

```
SKEWNESS_POP(numeric) returns numeric
```

**General rules**

- NULL values in expr are ignored.
- Returns NULL if all rows in the group have NULL expr values.
- Returns 0 if there are one or two rows in expr.
- For a given set of values, the result of population skewness (SKEWNESS\_POP) and sample skewness (SKEWNESS\_SAMP) are always deterministic. However, the values of SKEWNESS\_POP and SKEWNESS\_SAMP differ. As the number of values in the data set increases, the difference between the computed values of SKEWNESS\_SAMP and SKEWNESS\_POP decreases.

**Note**

- If using the SKEWNESS\_POP function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

```
SELECT SKEWNESS_POP(column1) from (values (1),(2),(4),(8)) x;
   skewness_pop
-----
0.65680773449969915746
(1 row)
```



### F.56.5.6.10. SKEWNESS\_SAMP

#### Description

SKEWNESS\_SAMP is an aggregate function that is primarily used to determine symmetry in a given distribution.

#### Syntax

```
SKEWNESS_SAMP(numeric) returns numeric
```

#### General rules

- NULL values in expr are ignored.
- Returns NULL if all rows in the group have NULL expr values.
- Returns 0 if there are one or two rows in expr.
- For a given set of values, the result of population skewness (SKEWNESS\_POP) and sample skewness (SKEWNESS\_SAMP) are always deterministic. However, the values of SKEWNESS\_POP and SKEWNESS\_SAMP differ. As the number of values in the data set increases, the difference between the computed values of SKEWNESS\_SAMP and SKEWNESS\_POP decreases.

#### Note

- If using the SKEWNESS\_SAMP function, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using oracle" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

```
SELECT SKEWNESS_SAMP(column1) from (values (1),(2),(4),(8)) x;  
      skewness_samp  
-----  
1.13762436695768880892  
(1 row)
```

### F.56.5.7. Functions That Return Internal Information

The following functions that return internal information are supported:

- DUMP
- NLS\_CHARSET\_ID
- NLS\_CHARSET\_NAME
- SYS\_CONTEXT
- USERENV

### F.56.5.7.1. DUMP

#### Description

Returns internal information of a value.

#### Syntax

```
DUMP(expr TEXT) returns VARCHAR
DUMP(expr TEXT, fmt INTEGER) returns VARCHAR
```

#### General rules

- DUMP returns the internal information of the values specified in expressions in a display format that is in accordance with the output format.
- The internal code (Typ) of the data type, the data length (Len) and the internal expression of the data are output as internal information.
- Any data type can be specified for the expressions.
- The display format (base *n*) of the internal expression of the data is specified for the output format. The base numbers that can be specified are 8, 10, and 16. If omitted, 10 is used as the default.
- The data type of the return value is VARCHAR.

#### Note

The information output by DUMP will be the complete internal information. Therefore, the values may change due to product updates, and so on.

#### Example

In the following example, the internal information of column `coll` in table `t1` is returned.

```
SELECT coll, DUMP(coll) FROM t1;
coll | dump
-----+-----
1001 | Typ=25 Len=8: 32,0,0,0,49,48,48,49
1002 | Typ=25 Len=8: 32,0,0,0,49,48,48,50
1003 | Typ=25 Len=8: 32,0,0,0,49,48,48,51
(3 row)
```

### F.56.5.7.2. NLS\_CHARSET\_ID

#### Description

NLS\_CHARSET\_ID returns the character set ID number corresponding to character set name string.

#### Syntax

```
NLS_CHARSET_ID(str text) returns integer
```

#### General rules

- Invalid character set names return null.

**Note**

- The character set name is from Oracle, use this function only for compatibility.
- If using the NLS\_CHARSET\_ID function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraofce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

The following example returns the character set ID of a character set:

```
SELECT NLS_CHARSET_ID( 'AL32UTF8' ) FROM DUAL;
 nls_charset_id
-----
                873
(1 row)
```

**F.56.5.7.3. NLS\_CHARSET\_NAME****Description**

NLS\_CHARSET\_NAME returns the name of the character set corresponding to ID number number.

**Syntax**

```
NLS_CHARSET_NAME(str text) returns integer
```

**General rules**

- If number is not recognized as a valid character set ID, then this function returns null.

**Note**

- The character set name is from Oracle, use this function only for compatibility.
- If using the NLS\_CHARSET\_NAME function, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using oraofce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

The following example returns the character set corresponding to character set ID number 873:

```
SELECT NLS_CHARSET_NAME( 873 ) FROM DUAL;
 nls_charset_name
```

```
-----
AL32UTF8
(1 row)
```

#### F.56.5.7.4. SYS\_CONTEXT

##### Description

Returns the value of parameter associated with the context namespace at the current instant

##### Syntax

```
SYS_CONTEXT(namespace text, parameter text, length int4
default 256) returns text
```

##### General rules

- For namespace and parameter, you can specify either a string or an expression that resolves to a string designating a namespace or an attribute.
- The context namespace must already have been created, and the associated parameter and its value must also have been set.
- The namespace must be a valid identifier. The parameter name can be any string. It is not case sensitive, but it cannot exceed 4000 bytes in length.

##### Note

LightDB provides the following built-in namespaces:

- USERENV - Describes the current session. The predefined parameters of namespace USERENV are listed in table Table F.116
- SYS\_SESSION\_ROLES - Indicates whether a specified role is currently enabled for the session.

**Table F.116. Predefined Parameters of Namespace USERENV**

Parameters	Overview
CLIENT_IDENTIFIER	The name of the program used for the database session
CLIENT_INFO	The name of the program used for the database session
CLIENT_PROGRAM_NAME	The name of the program used for the database session
CDB_NAME	Current database
CON_ID	Always 1
CON_NAME	Current database
CURRENT_SCHEMA	Current schema
CURRENT_SCHEMAID	Current schema id
CURRENT_USER	Current user
CURRENT_USERID	Current user id
DATABASE_ROLE	The role is one of the following: PRIMARY, PHYSICAL STANDBY

Parameters	Overview
DB_NAME	Current database
DB_UNIQUE_NAME	Current database
HOST	Name of the host machine from which the client has connected
INSTANCE	Always 1
INSTANCE_NAME	Always 'LightDB'
IP_ADDRESS	IP address of the machine from which the client is connected
ISDBA	Returns TRUE if the user has been authenticated as having DBA privileges
LANG	The abbreviated name for the language, a shorter form than the existing 'LANGUAGE' parameter
LANGUAGE	The language and territory currently used by your session, along with the database character set
MODULE	The name of the program used for the database session
NETWORK_PROTOCOL	Network protocol being used for communication
NLS_DATE_FORMAT	The date format for the session
ORACLE_HOME	The full path name for the data home directory
PID	Current process ID
SERVER_HOST	listen_addresses
SERVICE_NAME	Current database
SESSION_USER	Current user
SESSION_USERID	Current user id
SESSIONID	Current session process id
SID	Current session process id

**Note**

- If using SYS\_CONTEXT, it is necessary to specify "oracle" for search\_path in advance.

**See**

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

**Example**

The following statement returns the name of the user who logged onto the database:

```
SELECT SYS_CONTEXT ( 'USERENV', 'SESSION_USER' ) FROM DUAL;
 sys_context
-----
 lightdb
(1 row)
```

### F.56.5.7.5. USERENV

#### Description

Returns information about the current session

#### Syntax

```
USERENV(parameter text) returns text
```

#### General rules

- This information can be useful for writing an application-specific audit trail table or for determining the language-specific characters currently used by your session.
- Table Table F.116 describes the values for the parameter argument.

#### Note

- If using USERENV, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

The following example returns the LANGUAGE parameter of the current session:

```
SELECT USERENV( 'LANGUAGE' ) "Language" FROM DUAL ;
  Language
-----
en_US.UTF-8
(1 row)
```

### F.56.5.8. Datetime Operator

The following datetime operators are supported for the DATE type of orafce.

**Table F.117. Datetime operator**

Operation	Example	Result
+	DATE'2016/01/01' + 10	2016-01-11 00:00:00
-	DATE'2016/03/20' - 35	2016-02-14 00:00:00
-	DATE'2016/09/01' - DATE'2015/12/31'	245

#### Note

If using datetime operators for the DATE type of orafce, it is necessary to specify "oracle" for search\_path in advance.

#### See

Refer to "Notes on Using orafce" for information on how to edit search\_path.

## F.56.5.9. Other functions

The following functions is used for other purpose:

- EMPTY\_CLOB
- EMPTY\_BLOB
- ORA\_HASH
- VSIZE
- DEPS\_SAVE\_AND\_DROP\_DEPENDENCIES/DEPS\_RESTORE\_DEPENDENCIES
- PLVSTR.IS\_PREFIX
- PLVDATE.ISLEAPYEAR

### F.56.5.9.1. EMPTY\_CLOB

#### Description

Return an empty CLOB

#### Syntax

```
EMPTY_CLOB() RETURNS clob
```

#### General rules

- can be used to initialize a CLOB variable, or, in an INSERT or UPDATE statement, to initialize a CLOB column or attribute to EMPTY. EMPTY means that the CLOB is initialized, but not populated with data.
- has a length of zero but is not null.

#### Note

- If using the EMPTY\_CLOB function, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

```
select length(empty_clob()) FROM DUAL;
length
-----
      0
(1 row)
```

```
select count(*) from dual where empty_clob() is null;
count
-----
```

```
      0
(1 row)
```

```
create table foo (a int, b clob default empty_clob());
insert into foo(a) values(1);
insert into foo values (2, 'hello');
select count(*) from foo where b is not null;
  count
-----
```

```
      2
(1 row)
select count(*) from foo where length(b) > 0;
  count
-----
```

```
      1
(1 row)
```

### F.56.5.9.2. EMPTY\_BLOB

#### Description

Return an empty BLOB

#### Syntax

```
EMPTY_BLOB() RETURNS blob
```

#### General rules

- can be used to initialize a BLOB variable, or, in an INSERT or UPDATE statement, to initialize a BLOB column or attribute to EMPTY. EMPTY means that the BLOB is initialized, but not populated with data.
- has a length of zero but is not null.

#### Example

```
select length(empty_blob()) FROM DUAL;
  length
-----
      0
(1 row)
```

```
select count(*) from dual where empty_blob() is null;
  count
-----
      0
(1 row)
```

```
create table foo (a int, b blob default empty_blob());
insert into foo(a) values(1);
```



```
insert into foo values (2, to_blob('616263'));
select count(*) from foo where b is not null;
  count
-----
       2
(1 row)
select count(*) from foo where length(b) > 0;
  count
-----
       1
(1 row)
```

### F.56.5.9.3. ORA\_HASH

#### Description

ORA\_HASH is a function that computes a hash value for a given expression. This function is useful for operations such as analyzing a subset of data and generating a random sample.

#### Syntax

```
ORA_HASH(p_data anyelement, p_buckets int4, p_seed int4)
RETURNS int
```

#### General rules

- The p\_data argument determines the data for which you want LightDB Database to compute a hash value. There are no restrictions on the length of data represented by expr, which commonly resolves to a column name.
- The optional p\_buckets argument determines the maximum bucket value returned by the hash function. You can specify any value between 0 and 2147483647. The default is 0.
- The optional p\_seed argument enables LightDB to produce many different results for the same set of data. LightDB applies the hash function to the combination of expr and p\_seed. You can specify any value between 0 and 2147483647. The default is 0.
- The data type of the return value is int.

#### Note

- If using ORA\_HASH, it is necessary to specify "oracle" for search\_path in advance.

#### See

- Refer to "Notes on Using oracle" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

#### Example

```
select ora_hash('abcdAbcdasd'::text) FROM DUAL;
  ora_hash
-----
 303228277
(1 row)
```

#### F.56.5.9.4. VSIZE

##### Description

VSIZE returns the number of bytes in the internal representation of expr. If expr is null, then this function returns null.

##### Syntax

```
VSIZE(anyelement) RETURNS integer
```

##### General rules

- Same with pg\_column\_size.

##### Note

- If using VSIZE, it is necessary to specify "oracle" for search\_path in advance.

##### See

- Refer to "Notes on Using orafce" for information on how to edit search\_path.
- Refer to "Server Administration" > "Server Configuration" > "Setting Parameters" in the LightDB Documentation for information on how to set the server parameters.

##### Example

```
select vsize(123456789) FROM DUAL;
 vsize
-----
      4
(1 row)
```

#### F.56.5.9.5. DEPS\_SAVE\_AND\_DROP\_DEPENDENCIES/ DEPS\_RESTORE\_DEPENDENCIES

##### Description

These functions are used to modify tables that have view dependencies. Recursively backup all dependent views, then modify base tables, then recreate all backedup views.

DEPS\_SAVE\_AND\_DROP\_DEPENDENCIES save and drop dependencies for table.

DEPS\_RESTORE\_DEPENDENCIES restore dependencies for table.

##### Syntax

```
DEPS_SAVE_AND_DROP_DEPENDENCIES(name, name default
current_schema()::name, jsonb default '{} '::jsonb) RETURNS void
DEPS_RESTORE_DEPENDENCIES(name, name default
current_schema()::name, jsonb default '{} '::jsonb)
```

##### General rules

- Create under lt\_catalog.

- dependencies is saved in lt\_catalog.deps\_saved\_ddl table.
- dry\_run Run without actually dropping dependencies, default false.
- verbose Show debug log, , default false.
- populate\_materialized\_view Enable or disable materialized view refresh-on-create via WITH [NO] DATA flag, default false.

**Note**

- If using DEPS\_SAVE\_AND\_DROP\_DEPENDENCIES/DEPS\_RESTORE\_DEPENDENCIES, it is not necessary to specify "oracle" for search\_path in advance.

**Example**

```
create table test_t(key1 int);
create view test_t_v as select * from test_t;
begin;
select deps_save_and_drop_dependencies('test_t');
alter table test_t modify key1 number;
select * from deps_restore_dependencies('test_t');
commit;
```

**F.56.5.9.6. PLVSTR.IS\_PREFIX**

**Description**

PLVSTR.IS\_PREFIX return true if a string or number is the prefix of another string or number.

**Syntax**

```
PLVSTR.IS_PREFIX(p bigint, prefix bigint) RETURNS boolean
PLVSTR.IS_PREFIX(p integer, prefix integer) RETURNS boolean
PLVSTR.IS_PREFIX(p text, prefix text) RETURNS boolean
```

**General rules**

- This function can be useful for testing whether a string or number begins with something.

**Example**

```
select plvstr.is_prefix(111, 11) FROM DUAL;
is_prefix
-----
t
(1 row)
select plvstr.is_prefix('abc', 'AB') from dual;
is_prefix
-----
f
(1 row)
```

**F.56.5.9.7. PLVDATE.ISLEAPYEAR**

**Description**

PLVDATE.ISLEAPEAR return true if the date is a leap year.

**Syntax**

```
PLVDATE.ISLEAPYEAR(date) RETURNS boolean
```

**Example**

```
select plvdate.isleapyear(date '2023-01-01') FROM DUAL;  
isleapyear
```

```
-----  
f
```

```
select plvdate.isleapyear(date '2020-01-01') from dual;  
isleapyear
```

```
-----  
t
```

## F.56.6. Package Reference

A "package" is a group of features, brought together by schemas, that have a single functionality, and are used by calling from PL/pgSQL.

The following packages are supported:

- DBMS\_ALERT
- DBMS\_ASSERT
- DBMS\_LOB
- DBMS\_OUTPUT
- DBMS\_PIPE
- DBMS\_RANDOM
- DBMS\_UTILITY
- DBMS\_JOB
- DBMS\_LOCK
- DBMS\_METADATA
- DBMS\_OBFUSCATION\_TOOLKIT
- DBMS\_SNAPSHOT
- UTL\_FILE
- UTL\_RAW
- UTL\_URL
- UTL\_ENCODE

To call the different functionalities from PL/pgSQL, use the `PERFORM` statement or `SELECT` statement, using the package name to qualify the name of the functionality. Refer to the explanations for each of the package functionalities for information on the format for calling.

### F.56.6.1. DBMS\_ALERT

#### Overview

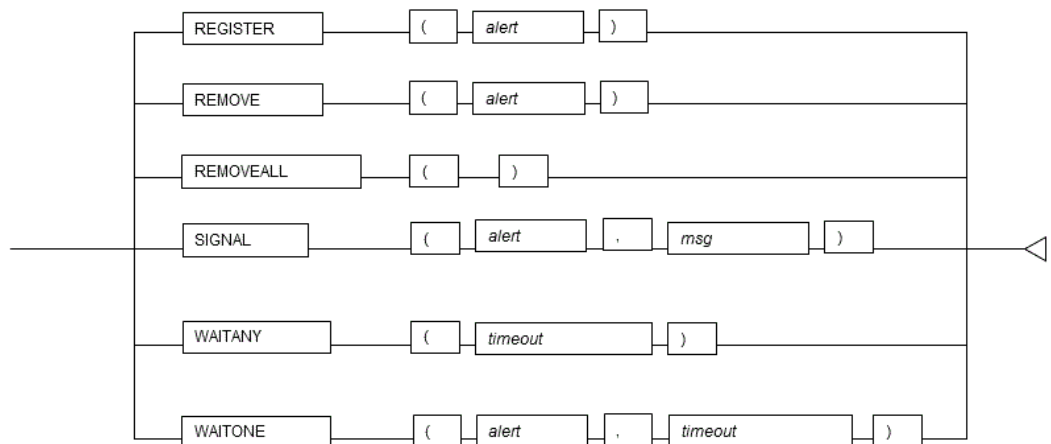
The `DBMS_ALERT` package sends alerts from a PL/pgSQL session to multiple other PL/pgSQL sessions.

This package can be used when processing 1:N, such as when notifying alerts from a given PL/pgSQL session to another PL/pgSQL session at the same time.

**Table F.118. DBMS\_ALERT Features**

Feature	Description
REGISTER	Registers the specified alert.
REMOVE	Removes the specified alert.
REMOVEALL	Removes all alerts from a session.
SIGNAL	Notifies alerts.
WAITANY	Waits for notification of any alerts for which a session is registered.
WAITONE	Waits for notification of a specific alert for which a session is registered.

#### Syntax



#### F.56.6.1.1. Description of Features

This section explains each feature of `DBMS_ALERT`.

##### REGISTER

- `REGISTER` registers the specified alert to a session. By registering alerts to a session, `SIGNAL` notifications can be received.
- Specify the name of the alert.
- Alerts are case-sensitive.
- Multiple alerts can be registered within a single session. If registering multiple alerts, call `REGISTER` for each alert.

### Example

```
PERFORM DBMS_ALERT.REGISTER('sample_alert');
```

### REMOVE

- REMOVE removes the specified alert from a session.
- Specify the name of the alert.
- Alerts are case-sensitive.
- The message left by the alert will be removed.

### Example

```
PERFORM DBMS_ALERT.REMOVE('sample_alert');
```

### REMOVEALL

- REMOVEALL removes all alerts registered within a session.
- All messages left by the alerts will be removed.

### Example

```
PERFORM DBMS_ALERT.REMOVEALL();
```

### SIGNAL

- SIGNAL sends a message notification for the specified alert.
- Specify the name of the alert for which message notifications are sent.
- Alerts are case-sensitive.
- In the message, specify the alert message for notifications.
- Message notifications are not complete at the stage when SIGNAL is executed. Message notifications are sent upon committing the transaction. Message notifications are discarded if a rollback is performed after SIGNAL is executed.
- If message notifications are sent for the same alert from multiple sessions, the messages will be accumulated without being removed.

### Example

```
PERFORM DBMS_ALERT.SIGNAL('ALERT001', 'message001');
```

### Note

If SIGNAL is issued continuously and the accumulated messages exceed a certain amount, an insufficient memory error may be output. If the memory becomes insufficient, call AITANY or WAITONE to receive an alert, and reduce the accumulated messages.

**WAITANY**

- WAITANY waits for notification of any alerts registered for a session.
- Specify the maximum wait time *timeout* in seconds to wait for an alert.
- Use a SELECT statement to obtain the notified information, which is stored in the name, message and status columns.
- The name column stores the alert names. The data type of name is TEXT.
- The message column stores the messages of notified alerts. The data type of message is TEXT.
- The status column stores the status code returned by the operation: 0-an alert occurred; 1-a timeout occurred. The data type of status is INTEGER.

**Example**

```
DECLARE
    alert_name          TEXT := 'sample_alert';
    alert_message       TEXT;
    alert_status        INTEGER;
BEGIN
    SELECT name,message,status INTO
    alert_name,alert_message,alert_status FROM DBMS_ALERT.WAITANY(60);
```

**WAITONE**

- WAITONE waits for notification of the specified alert.
- Specify the name of the alert to wait for.
- Alerts are case-sensitive.
- Specify the maximum wait time *timeout* in seconds to wait for the alert.
- Use a SELECT statement to obtain the notified information, which is stored in the message and status columns.
- The message column stores the messages of notified alerts. The data type of message is TEXT.
- The status column stores the status code returned by the operation: 0-an alert occurred; 1-a timeout occurred. The data type of status is INTEGER.

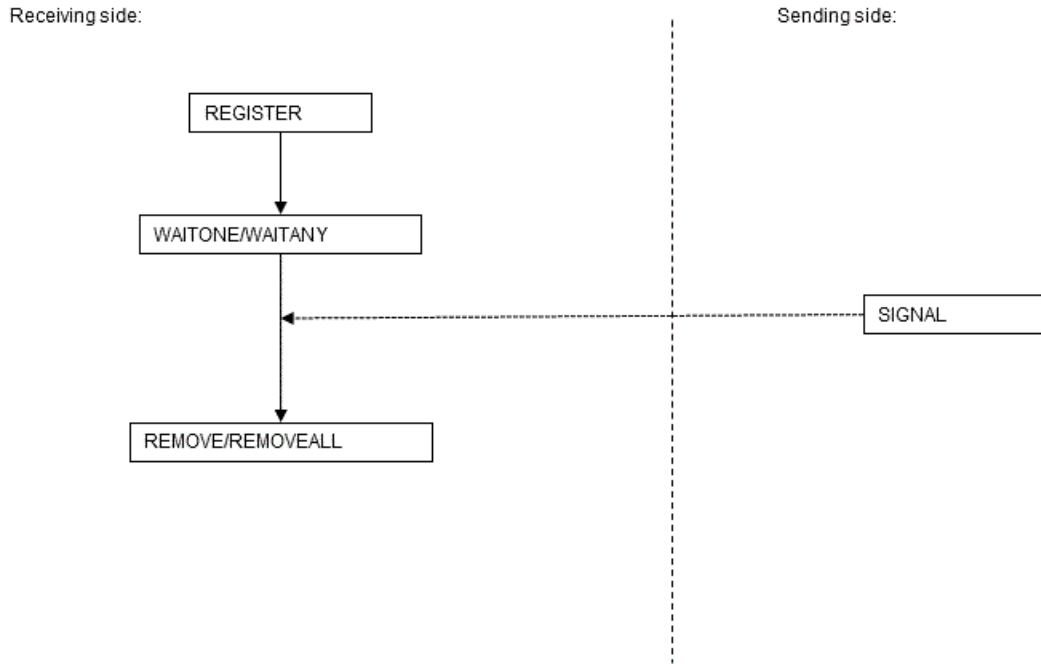
**Example**

```
DECLARE
    alert_message       TEXT;
    alert_status        INTEGER;
BEGIN
    SELECT message,status INTO alert_message,alert_status FROM
    DBMS_ALERT.WAITONE('sample_alert', 60);
```

**F.56.6.1.2. Usage Example**

Below is a usage example of the processing flow of DBMS\_ALERT.

**DBMS\_ALERT flow**



**Note**

- The target of message notifications by `SIGNAL` is sessions for which `REGISTER` is executed at the time of executing `SIGNAL`.
- On the receiving side, always ensure that `REMOVE` or `REMOVEALL` is used to remove alerts as soon as the alerts are no longer needed. If a session is closed without removing the alerts, it may no longer be possible to receive a `SIGNAL` for alerts of the same name in another session.
- `DBMS_ALERT` and `DBMS_PIPE` use the same memory environment. Therefore, when insufficient memory is detected for `DBMS_PIPE`, it is possible that insufficient memory will also be detected for `DBMS_ALERT`.

**Usage example**

- Sending side

```
CREATE FUNCTION send_dbms_alert_exe() RETURNS VOID AS $$
BEGIN
    PERFORM DBMS_ALERT.SIGNAL('sample_alert','SIGNAL ALERT');
END;
$$ LANGUAGE plpgsql;
SELECT send_dbms_alert_exe();
DROP FUNCTION send_dbms_alert_exe();
```

- Receiving side

```
CREATE FUNCTION receive_dbms_alert_exe() RETURNS VOID AS $$
DECLARE
    alert_name TEXT := 'sample_alert';
    alert_message TEXT;
    alert_status INTEGER;
BEGIN
    PERFORM DBMS_ALERT.REGISTER(alert_name);
```



```

SELECT message,status INTO alert_message,alert_status FROM
DBMS_ALERT.WAITONE(alert_name,300);
RAISE NOTICE 'Message : %', alert_message;
RAISE NOTICE 'Status : %', alert_status;
PERFORM DBMS_ALERT.REMOVE(alert_name);
END;
$$ LANGUAGE plpgsql;
SELECT receive_dbms_alert_exe();
DROP FUNCTION receive_dbms_alert_exe();

```

## F.56.6.2. DBMS\_ASSERT

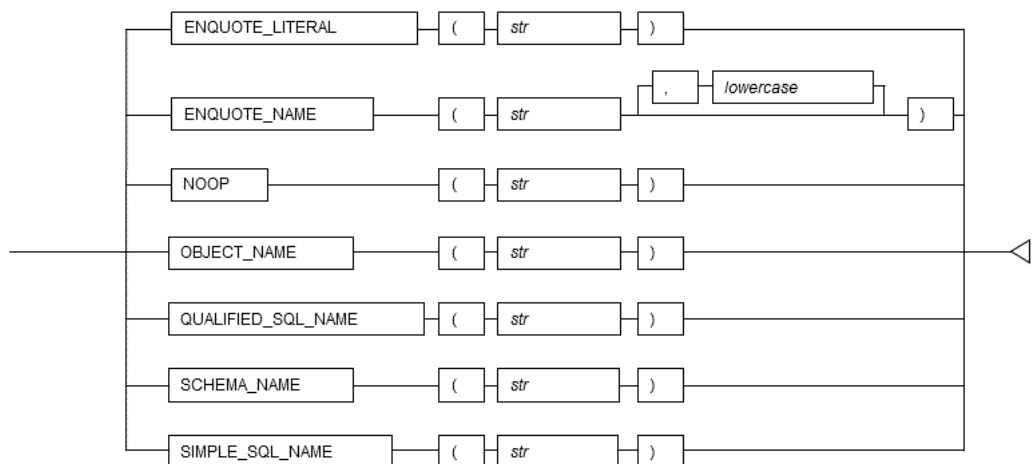
### Overview

Performs verification of the properties of input values in PL/pgSQL.

**Table F.119. DBMS\_ASSERT Features**

Feature	Description
ENQUOTE_LITERAL	Returns the specified string enclosed in single quotation marks.
ENQUOTE_NAME	Returns the specified string enclosed in double quotation marks.
NOOP	Returns the specified string as is.
OBJECT_NAME	Verifies if the specified string is a defined identifier.
QUALIFIED_SQL_NAME	Verifies if the specified string is in the appropriate format as an identifier.
SCHEMA_NAME	Verifies if the specified string is a defined schema.
SIMPLE_SQL_NAME	Verifies if the specified string is in the appropriate format as a single identifier.

### Syntax



### F.56.6.2.1. Description of Features

This section explains each feature of DBMS\_ASSERT.

**ENQUOTE\_LITERAL**

- ENQUOTE\_LITERAL returns the specified string enclosed in single quotation marks.
- Specify a string enclosed in single quotation marks.
- The data type of the return value is VARCHAR.

**Example**

```
DECLARE
    q_literal    VARCHAR(256);
BEGIN
    q_literal := DBMS_ASSERT.ENQUOTE_LITERAL('literal_word');
```

**ENQUOTE\_NAME**

- ENQUOTE\_NAME returns the specified string enclosed in double quotation marks.
- Specify a string enclosed in double quotation marks.
- For lowercase conversion, specify TRUE or FALSE. Specify TRUE to convert uppercase characters in the string to lowercase. If FALSE is specified, conversion to lowercase will not take place. The default is TRUE.
- If all the characters in the string are lowercase, they will not be enclosed in double quotation marks.
- The data type of the return value is VARCHAR.

**See**

Refer to "The SQL Language" > "Data Types" > "Boolean Type" in the LightDB Documentation for information on boolean type (TRUE/FALSE) values.

**Example**

```
DECLARE
    dq_literal    VARCHAR(256);
BEGIN
    dq_literal := DBMS_ASSERT.ENQUOTE_NAME('TBL001');
```

**NOOP**

- NOOP returns the specified string as is.
- Specify a string.
- The data type of the return value is VARCHAR.

**Example**

```
DECLARE
    literal    VARCHAR(256);
BEGIN
    literal := DBMS_ASSERT.NOOP('NOOP_WORD');
```

**OBJECT\_NAME**

- OBJECT\_NAME verifies if the specified string is a defined identifier.
- Specify the identifier for verification. If the identifier has been defined, the specified identifier will be returned. Otherwise, the following error will occur.

```
ERROR:  invalid object name
```

- The data type of the return value is VARCHAR.

#### Example

```
DECLARE
    object_name    VARCHAR(256);
BEGIN
    object_name := DBMS_ASSERT.OBJECT_NAME('SCM001.TBL001');
```

#### QUALIFIED\_SQL\_NAME

- QUALIFIED\_SQL\_NAME verifies if the specified string is in the appropriate format as an identifier.
- Specify the identifier for verification. If the string can be used as an identifier, the specified identifier will be returned. Otherwise, the following error will occur.

```
ERROR:  string is not qualified SQL name
```

- The data type of the return value is VARCHAR.

#### See

Refer to "The SQL Language" > "Lexical Structure" > "Identifiers and Key Words" in the LightDB Documentation for information on the formats that can be used as identifiers.

#### Example

```
DECLARE
    object_name    VARCHAR(256);
BEGIN
    object_name :=
DBMS_ASSERT.QUALIFIED_SQL_NAME('SCM002.TBL001');
```

#### SCHEMA\_NAME

- SCHEMA\_NAME verifies if the specified string is a defined schema.
- Specify a schema name for verification. If the schema has been defined, the specified schema name will be returned. Otherwise, the following error will occur.

```
ERROR:  invalid schema name
```

- The data type of the return value is VARCHAR.

#### Example

```

DECLARE
    schema_name    VARCHAR(256);
BEGIN
    schema_name := DBMS_ASSERT.SCHEMA_NAME('SCM001');

```

### **SIMPLE\_SQL\_NAME**

- SIMPLE\_SQL\_NAME verifies if the specified string is in the appropriate format as a single identifier.
- Specify an identifier for verification. If the specified string can be used as an identifier, the specified identifier will be returned. Otherwise, the following error will occur.

```

ERROR: string is not qualified SQL name

```

- The data type of the return value is VARCHAR.

### **See**

Refer to "The SQL Language" > "Lexical Structure" > "Identifiers and Key Words" in the LightDB Documentation for information on the formats that can be used as identifiers. Note that an error will occur if an identifier using fullwidth characters is specified. If fullwidth characters are included, specify a quoted identifier.

### **Example**

```

DECLARE
    simple_name    VARCHAR(256);
BEGIN
    simple_name := DBMS_ASSERT.SIMPLE_SQL_NAME('COL01');

```

## **F.56.6.2.2. Usage Example**

A usage example of DBMS\_ASSERT is shown below.

```

CREATE FUNCTION dbms_assert_exe() RETURNS VOID AS $$
DECLARE
    w_schema VARCHAR(20) := 'public';
    w_table  VARCHAR(20) := 'T1';
    w_object VARCHAR(40);
BEGIN
    PERFORM DBMS_ASSERT.NOOP(w_schema);
    PERFORM DBMS_ASSERT.SIMPLE_SQL_NAME(w_table);
    PERFORM DBMS_ASSERT.SCHEMA_NAME(w_schema);
    w_object := w_schema || '.' || w_table;
    PERFORM DBMS_ASSERT.QUALIFIED_SQL_NAME(w_object);
    PERFORM DBMS_ASSERT.OBJECT_NAME(w_object);
    RAISE NOTICE 'OBJECT      : %',
DBMS_ASSERT.ENQUOTE_LITERAL(w_object);
    RAISE NOTICE 'TABLE_NAME : %',
DBMS_ASSERT.ENQUOTE_NAME(w_table);
END;
$$

```

```

LANGUAGE plpgsql;
SELECT dbms_assert_exe();
DROP FUNCTION dbms_assert_exe();

```

### F.56.6.3. DBMS\_LOB

#### Overview

Some functions compatible with DBMS\_LOB package.

**Table F.120. DBMS\_LOB Features**

Feature	Description
INSTR	Returns starting index of specified LOB.
SUBSTR	Extracts the substring of LOB.
GETLENGTH	Returns the number of characters in the LOB.
APPEND	Appends the contents of the source LOB to the destination LOB.
CLOSE	Closes a previously opened internal or external LOB.(invalid)
COMPARE	Compares two entire LOBs or parts of two LOBs.
COPY	Copies all, or part, of the source LOB to the destination LOB.
CREATETEMPORAR	Creates a temporary BLOB or CLOB and its corresponding index in the user's default temporary tablespace.(invalid)
ERASE	Erases all or part of a LOB.
FREETEMPORARY	Erases all or part of a LOB.
OPEN	Frees the temporary BLOB or CLOB in the default temporary tablespace.(invalid)
READ	Reads data from the LOB starting at the specified offset.
TRIM	Trims the LOB value to the specified shorter length.
WRITE	Writes data to the LOB from a specified offset.
WRITEAPPEND	Writes a buffer to the end of a LOB.
COMPARE	Compares two entire LOBs or parts of two LOBs.

#### Syntax

```

INSTR(STR TEXT, PATT TEXT, START INTEGER DEFAULT 1, NTH
INTEGER DEFAULT 1) RETURNS INTEGER
INSTR(STR BLOB, PATT TEXT, START INTEGER DEFAULT 1, NTH
INTEGER DEFAULT 1) RETURNS INTEGER
SUBSTR(STR CLOB, AMOUNT INTEGER DEFAULT 32767, START_OFFSET
INTEGER DEFAULT 1) RETURNS VARCHAR2
SUBSTR(STR BLOB, AMOUNT INTEGER DEFAULT 32767, START_OFFSET
INTEGER DEFAULT 1) RETURNS RAW

```

```

GETLENGTH(STR CLOB) RETURNS INTEGER
GETLENGTH(STR BLOB) RETURNS INTEGER
APPEND(dest_lob BLOB,src_lob BLOB)/APPEND(CLOB,CLOB)
COMPARE(lob_1 BLOB,lob_2 BLOB,amount INT4 DEFAULT
2147483647,offset_1 INT4 DEFAULT 1,offset_2 INT4 DEFAULT 1)
RETURNS INTEGER
COMPARE(CLOB,CLOB,INT4 DEFAULT 2147483647,INT4 DEFAULT 1,INT4
DEFAULT 1) RETURNS INTEGER
COPY(dest_lob BLOB,src_lob BLOB,amount INT4,dest_offset INT4
DEFAULT 1,src_offset INT4 DEFAULT 1)/COPY(CLOB,CLOB,INT4,INT4
DEFAULT 1,INT4 DEFAULT 1)
ERASE(lob_loc BLOB,amount INT4,p_offset INT4 DEFAULT 1)/
ERASE(CLOB,INT4,INT4 DEFAULT 1)
READ(lob_loc BLOB,amount INT4,p_offset INT4,buffer RAW)/
READ(CLOB,INT4,INT4,TEXT)
TRIM(lob_loc BLOB,newlen INT4)/TRIM(CLOB,INT4)
WRITE(lob_loc BLOB,amount INT4,p_offset INT4,buffer RAW)/
WRITE(CLOB,INT4,INT4,TEXT)
WRITEAPPEND(lob_loc BLOB,amount INT4,buffer RAW)/
WRITEAPPEND(CLOB,INT4,TEXT)

```

## Features

### F.56.6.3.1. Description

This section explains each feature of DBMS\_LOB.

#### INSTR

- Offset of the start of the matched pattern, in bytes or characters.It returns 0 if the pattern is not found.
- It retruns null if any one or more of the IN parameters was NULL or INVALID.
- It returns NULL if offset < 1.

#### Example

```

select dbms_lob.INSTR('Thomas', 'om') from dual;
select dbms_lob.INSTR('Thomas'::blob,
utl_raw.CAST_TO_RAW('om')) from dual;

```

#### SUBSTR

- Extracts the substring of string starting at the start'th character if that is specified, and stopping after count characters if that is specified.
- It returns NULL if any input parameter is NULL
- It returns NULL if amount < 1.
- It returns NULL if offset < 1.

#### Example

```

select dbms_lob.substr('1234567',1,2) from dual;
select dbms_lob.substr('1234567'::blob,1,2) from dual;

```

**GETLENGTH**

- The length of the text in bytes or characters as an INTEGER.
- NULL is returned if the input str is NULL.

**Example**

```
select DBMS_LOB.GETLENGTH('abc') from dual;
```

**APPEND**

- Appends the contents of the source LOB to the destination LOB.

**Example**

```
declare
    l_blob          blob := 'abcd'::blob;
    l_clob          clob := 'abcd'::clob;
begin
    dbms_output.serveroutput(true);
    dbms_lob.append(l_blob, 'ext'::blob);
    dbms_output.put_line(l_blob::text);

    dbms_lob.append(l_clob, 'ext'::clob);
    dbms_output.put_line(l_clob);
end;
/
```

**COMPARE**

- Compares two entire LOBs or parts of two LOBs.
- Returns 0 if `lob\_1` equals `lob\_2`, -1 if `lob\_1` is less than `lob\_2`, 1 if `lob\_1` is greater than `lob\_2`.
- Returns NULL if any of amount, offset\_1 or offset\_2 is not a valid LOB offset value. A valid offset is within the range of 1 to LOBMAXSIZE inclusive.

**Example**

```
declare
    l_result        int;
    l_blob          blob := 'abcd'::blob;
    l_clob          clob := 'abcd'::clob;
    l_raw_result    raw;
    l_amout         INTEGER := 100;
    l_text_result   text;
begin
    dbms_output.serveroutput(true);
    l_result := dbms_lob.compare('abcd'::blob, 'abcd'::blob);
    dbms_output.put_line(l_result);
    l_result := dbms_lob.compare('abcd'::clob, 'abcd'::clob);
    dbms_output.put_line(l_result);

end;
```

/

**COPY**

- Copies all, or part, of the source LOB to the destination LOB. You can specify the offsets for both the source and destination LOBs, and the number of bytes or characters to copy.
- If the offset you specify in the destination LOB is beyond the end of the data currently in this LOB, then zero-byte fillers or spaces are inserted in the destination BLOB or CLOB respectively. If the offset is less than the current length of the destination LOB, then existing data is overwritten.

**Example**

```
declare
    l_result          int;
    l_blob            blob := 'abcd'::blob;
    l_clob            clob := 'abcd'::clob;
    l_raw_result      raw;
    l_amout           INTEGER := 100;
    l_text_result     text;
begin
    dbms_output.serveroutput(true);
    dbms_lob.copy(l_blob, 'new_blob'::blob, 100);
    dbms_output.put_line(l_blob::text);
    dbms_lob.copy(l_blob, 'xnew_blob'::blob, 100, 1, 2);
    dbms_output.put_line(l_blob::text);
    dbms_lob.copy(l_blob, 'xnew_blob'::blob, 100, 2, 2);
    dbms_output.put_line(l_blob::text);
end;
/
```

**ERASE**

- Erases an entire internal LOB or part of an internal LOB.
- When data is erased from the middle of a LOB, zero-byte fillers or spaces are written for BLOBs or CLOBs respectively.
- The actual number of bytes or characters erased can differ from the number you specified in the amount parameter if the end of the LOB value is reached before erasing the specified number. The actual number of characters or bytes erased is returned in the amount parameter.

**Example**

```
declare
    l_result          int;
    l_blob            blob := 'abcd'::blob;
    l_clob            clob := 'abcd'::clob;
    l_raw_result      raw;
    l_amout           INTEGER := 100;
    l_text_result     text;
begin
    dbms_output.serveroutput(true);

    l_blob := 'abcd'::blob;
    l_amout := 100;
```



```
dbms_output.put_line(l_blob::text);
dbms_lob.erase(l_blob, l_amount);
dbms_output.put_line(l_blob::text);

l_clob := 'abcd'::clob;
l_amount := 4;
dbms_lob.erase(l_clob, l_amount);
dbms_output.put_line(l_clob);
end;
/
```

## READ

- This procedure reads a piece of a LOB, and returns the specified amount into the buffer parameter, starting from an absolute offset from the beginning of the LOB.
- The number of bytes or characters actually read is returned in the amount parameter. If the input offset points past the End of LOB, then amount is set to 0, and a NO\_DATA\_FOUND exception is raised.

## Example

```
declare
  l_result      int;
  l_blob        blob := 'abcd'::blob;
  l_clob        clob := 'abcd'::clob;
  l_raw_result  raw;
  l_amount      INTEGER := 100;
  l_text_result text;
begin
  dbms_output.serveroutput(true);

  l_amount := 5;
  dbms_lob.read('abcde'::blob, l_amount, 1, l_raw_result);
  dbms_output.put_line(l_raw_result);

  l_amount := 5;
  dbms_lob.read('abcde'::clob, l_amount, 1, l_text_result);
  dbms_output.put_line(l_text_result);
end;
/
```

## TRIM

- This procedure trims the value of the internal LOB to the length you specify in the newlen parameter. Specify the length in bytes for BLOBs, and specify the length in characters for CLOBs.

## Example

```
declare
  l_result      int;
  l_blob        blob := 'abcd'::blob;
  l_clob        clob := 'abcd'::clob;
  l_raw_result  raw;
  l_amount      INTEGER := 100;
  l_text_result text;
```

```
begin
  dbms_output.serveroutput(true);

  l_blob := 'abcde'::blob;
  dbms_lob.trim(l_blob, 1);
  dbms_output.put_line(l_blob::text);

  l_clob := 'abcde'::clob;
  dbms_lob.trim(l_clob, 1);
  dbms_output.put_line(l_clob);
end;
/
```

## WRITE

- This procedure writes a specified amount of data into an internal LOB, starting from an absolute offset from the beginning of the LOB. The data is written from the buffer parameter.
- WRITE replaces (overwrites) any data that already exists in the LOB at the offset, for the length you specify.

### Example

```
declare
  l_result      int;
  l_blob        blob := 'abcd'::blob;
  l_clob        clob := 'abcd'::clob;
  l_raw_result  raw;
  l_amout       INTEGER := 100;
  l_text_result text;
begin
  dbms_output.serveroutput(true);

  l_blob := 'abcde'::blob;
  dbms_lob.write(l_blob, pg_catalog.length(utl_raw.CAST_TO_RAW('#
#')), 2, utl_raw.CAST_TO_RAW('##'));
  dbms_output.put_line(l_blob::text);

  -- write clob
  l_clob := 'abcde'::clob;
  dbms_lob.write(l_clob, 2, 2, '##'::text);
  dbms_output.put_line(l_clob);
end;
/
```

## WRITEAPPEND

- This procedure writes a specified amount of data to the end of an internal LOB. The data is written from the buffer parameter.

### Example

```
declare
  l_result      int;
  l_blob        blob := 'abcd'::blob;
  l_clob        clob := 'abcd'::clob;
```

```

l_raw_result    raw;
l_amout        INTEGER := 100;
l_text_result  text;
begin
  dbms_output.serveroutput(true);

  -- writeappend blob
  l_blob := 'abcde'::blob;
  dbms_lob.writeappend(l_blob,
pg_catalog.length(utl_raw.CAST_TO_RAW('##')),
utl_raw.CAST_TO_RAW('##'));
  dbms_output.put_line(l_blob::text);

  -- write clob
  l_clob := 'abcde'::clob;
  dbms_lob.writeappend(l_clob, 2,'##'::text);
  dbms_output.put_line(l_clob);
end;
/

```

### F.56.6.3.2. Usage Example

A usage example of DBMS\_LOB is shown below.

```

CREATE PROCEDURE dbms_lob_exe() AS $$
DECLARE
  str1 text;
  str2 text;
  pos INTEGER;
  count INTEGER;
BEGIN
  str2 := dbms_lob.substr('1234567',2,3);
  pos := dbms_lob.instr('Tech on the net', 'e');
  count := dbms_lob.getlength('1234567');
  raise info 'str2=%,pos=%,count=%', str2, pos, count;
END;
$$ LANGUAGE plpgsql;
call dbms_lob_exe();
DROP PROCEDURE dbms_lob_exe();

```

### F.56.6.4. DBMS\_OUTPUT

#### Overview

Sends messages to clients such as ltsql from PL/pgSQL.

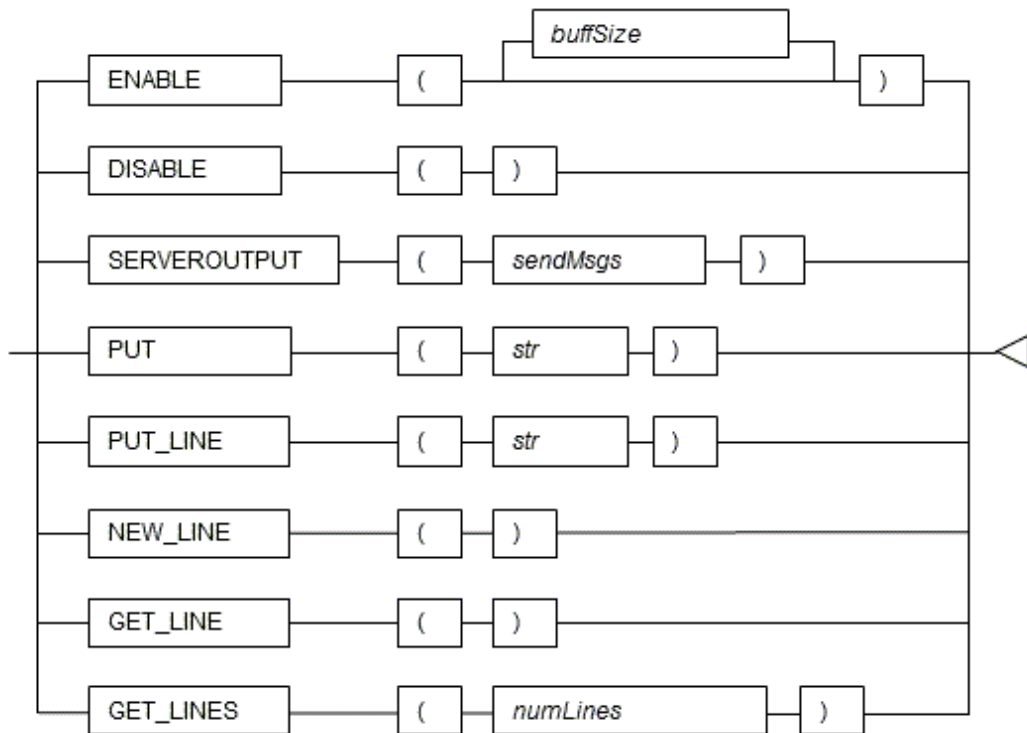
#### Features

**Table F.121. DBMS\_OUTPUT Features**

Feature	Description
ENABLE	Enables features of this package.
DISABLE	Disables features of this package.
SERVEROUTPUT	Controls whether messages are sent.

Feature	Description
PUT	Sends messages.
PUT_LINE	Sends messages with a newline character appended.
NEW_LINE	Sends a newline character. It cannot be used with parameters, Supports two usages: <code>dbms_output.new_line</code> and <code>dbms_output.new_line()</code> .
GET_LINE	Retrieves a line from the message buffer.
GET_LINES	Retrieves multiple lines from the message buffer.

**Syntax**



**F.56.6.4.1. Description**

This section explains each feature of DBMS\_OUTPUT.

**ENABLE**

- ENABLE enables the use of PUT, PUT\_LINE, NEW\_LINE, GET\_LINE, and GET\_LINES.
- With multiple executions of ENABLE, the value specified last is the buffer size (in bytes). Specify a buffer size from 2000 to 1000000.
- The default value of the buffer size is 20000. If NULL is specified as the buffer size, 1000000 will be used.
- If ENABLE has not been executed, PUT, PUT\_LINE, NEW\_LINE, GET\_LINE, and GET\_LINES are ignored even if they are executed.

**Example**

```
PERFORM DBMS_OUTPUT.ENABLE(20000);
```

### **DISABLE**

- DISABLE disables the use of PUT, PUT\_LINE, NEW\_LINE, GET\_LINE, and GET\_LINES.
- Remaining buffer information is discarded.

### **Example**

```
PERFORM DBMS_OUTPUT.DISABLE();
```

### **SERVEROUTPUT**

- SERVEROUTPUT controls whether messages are sent.
- Specify TRUE or FALSE for *sendMsgs*.
- If TRUE is specified, when PUT, PUT\_LINE, or NEW\_LINE is executed, the message is sent to a client such as ltsql and not stored in the buffer.
- If FALSE is specified, when PUT, PUT\_LINE, or NEW\_LINE is executed, the message is stored in the buffer and not sent to a client such as ltsql.

### **See**

Refer to "The SQL Language" > "Data Types" > "Boolean Type" in the LightDB Documentation for information on boolean type (TRUE/FALSE) values.

### **Example**

```
PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
```

### **PUT**

- PUT sets the message to be sent.
- The string is the message to be sent.
- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as ltsql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.
- PUT does not append a newline character. To append a newline character, execute NEW\_LINE.
- If a string longer than the buffer size specified in ENABLE is sent, an error occurs.

### **Example**

```
PERFORM DBMS_OUTPUT.PUT('abc');
```

### **PUT\_LINE**

- PUT\_LINE sets the message to be sent appended with a newline character.

- The string is the message to be sent.
- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as ltsql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.
- If a string longer than the buffer size specified in ENABLE is sent, an error occurs.

**Example**

```
PERFORM DBMS_OUTPUT.PUT_LINE( ' abc ' );
```

**NEW\_LINE**

- NEW\_LINE appends a newline character to the message created with PUT.
- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as ltsql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.

**Example**

```
PERFORM DBMS_OUTPUT.NEW_LINE( ) ;
```

**GET\_LINE**

- GET\_LINE retrieves a line from the message buffer.
- Use a SELECT statement to obtain the retrieved line and status code returned by the operation, which are stored in the line and status columns.
- The line column stores the line retrieved from the buffer. The data type of line is TEXT.
- The status column stores the status code returned by the operation: 0-completed successfully; 1-failed because there are no more lines in the buffer. The data type of status is INTEGER.
- If GET\_LINE or GET\_LINES is executed and then PUT, PUT\_LINE or PUT\_LINES is executed while messages that have not been retrieved from the buffer still exist, the messages not retrieved from the buffer will be discarded.

**Example**

```
DECLARE
    buff1  VARCHAR( 20 );
    stts1  INTEGER;
BEGIN
    SELECT line,status INTO buff1,stts1 FROM
DBMS_OUTPUT.GET_LINE( ) ;
```

**GET\_LINES**

- GET\_LINES retrieves multiple lines from the message buffer.
- Specify the number of lines to retrieve from the buffer.
- Use a SELECT statement to obtain the retrieved lines and the number of lines retrieved, which are stored in the lines and numlines columns.

- The lines column stores the lines retrieved from the buffer. The data type of lines is TEXT.
- The numlines column stores the number of lines retrieved from the buffer. If this number is less than the number of lines requested, then there are no more lines in the buffer. The data type of numlines is INTEGER.
- If GET\_LINE or GET\_LINES is executed and then PUT, PUT\_LINE, or NEW\_LINE is executed while messages that have not been retrieved from the buffer still exist, the messages not retrieved from the buffer will be discarded.

**Example**

```
DECLARE
    buff    VARCHAR(20)[10];
    stts    INTEGER := 10;
BEGIN
    SELECT lines, numlines INTO buff,stts FROM
DBMS_OUTPUT.GET_LINES(stts);
```

**F.56.6.4.2. Usage Example**

A usage example of DBMS\_OUTPUT is shown below.

```
CREATE FUNCTION dbms_output_exe() RETURNS VOID AS $$
DECLARE
    buff1 VARCHAR(20);
    buff2 VARCHAR(20);
    stts1 INTEGER;
    stts2 INTEGER;
BEGIN
    PERFORM DBMS_OUTPUT.DISABLE();
    PERFORM DBMS_OUTPUT.ENABLE();
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(FALSE);
    PERFORM DBMS_OUTPUT.PUT('DBMS_OUTPUT TEST 1');
    PERFORM DBMS_OUTPUT.NEW_LINE();
    PERFORM DBMS_OUTPUT.PUT_LINE('DBMS_OUTPUT TEST 2');
    SELECT line,status INTO buff1,stts1 FROM
DBMS_OUTPUT.GET_LINE();
    SELECT line,status INTO buff2,stts2 FROM
DBMS_OUTPUT.GET_LINE();
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
    PERFORM DBMS_OUTPUT.PUT_LINE(buff1);
    PERFORM DBMS_OUTPUT.PUT_LINE(buff2);
END;
$$ LANGUAGE plpgsql;
SELECT dbms_output_exe();
DROP FUNCTION dbms_output_exe();
```

**F.56.6.5. DBMS\_PIPE****Overview**

Performs communication between sessions that execute PL/pgSQL.

This package can be used for 1:1 communication, such as when data is being exchanged between sessions executing PL/pgSQL.

For pipes, there are explicit pipes and implicit pipes, and furthermore, for explicit pipes, you can select public pipes and private pipes. The characteristics of each type are as follows:

### Types of pipes

**Table F.122. Types of pipes**

Type	Characteristics
Explicit pipe	<ul style="list-style-type: none"> <li>- CREATE_PIPE is used to create a pipe explicitly.</li> <li>- While creating a pipe, you can select between a public pipe and private pipe.</li> <li>- It is necessary to use REMOVE_PIPE to explicitly remove a pipe.</li> </ul>
Implicit pipe	<ul style="list-style-type: none"> <li>- Created automatically when SEND_MESSAGE and RECEIVE_MESSAGE are used.</li> <li>- The pipe that is created becomes a public pipe.</li> <li>- When messages are received using RECEIVE_MESSAGE, if there are no additional messages remaining in the pipe, the pipe will be removed automatically.</li> </ul>
Public pipe	<ul style="list-style-type: none"> <li>- Can be created as an explicit pipe or implicit pipe.</li> <li>- Can also be used by users other than the creator.</li> </ul>
Private pipe	<ul style="list-style-type: none"> <li>- Can only be created as an explicit pipe.</li> <li>- Can only be used by its creator.</li> </ul>

### Note

- Up to 50 pipes can be used concurrently by a single instance.
- In cases where pipes are frequently created and removed repetitively, use public pipes. If you create a private pipe, internal information (the creator of the private pipe) will remain even after the pipe is removed. Thus, repeatedly creating and removing pipes may ultimately cause memory to run out.
- If a timeout occurs without receiving a message when an implicit pipe is created by RECEIVE\_MESSAGE, the pipe will not be removed.

### Features

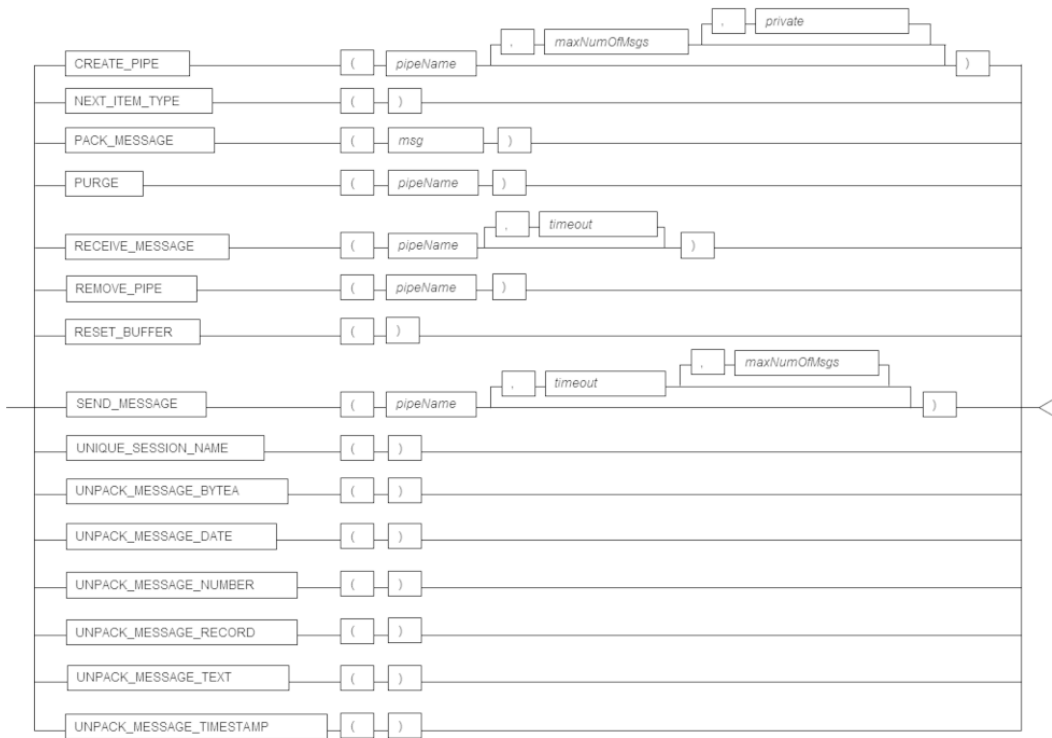
**Table F.123. DBMS\_PIPE Features**

Feature	Description
CREATE_PIPE	Creates a public or private pipe.
NEXT_ITEM_TYPE	Determines the data type of the next item in the local buffer, and returns that type.
PACK_MESSAGE	Sets a message in the local buffer.
PURGE	Empties the contents of the specified pipe.
RECEIVE_MESSAGE	Sets a received message in the local buffer.



Feature	Description
REMOVE_PIPE	Removes the specified pipe.
RESET_BUFFER	Resets the set position of the local buffer.
SEND_MESSAGE	Sends the contents of the local buffer.
UNIQUE_SESSION_NAME	Returns a unique session name.
UNPACK_MESSAGE_BYTEA	Receives a message in the local buffer in BYTEA type.
UNPACK_MESSAGE_DATE	Receives a message in the local buffer in DATE type.
UNPACK_MESSAGE_NUMBER	Receives a message in the local buffer in NUMERIC type.
UNPACK_MESSAGE_RECORD	Receives a message in the local buffer in RECORD type.
UNPACK_MESSAGE_TEXT	Receives a message in the local buffer in TEXT type.
UNPACK_MESSAGE_TIMESTAMP	Receives a message in the local buffer in TIMESTAMP type.

**Syntax**



**F.56.6.5.1. Description of Features**

This section explains each feature of DBMS\_PIPE.

**CREATE\_PIPE**

- CREATE\_PIPE explicitly creates a pipe environment for data communication.
- Specify the name of the pipe to be created.
- Pipe names are case-sensitive.

- Specify the maximum number of messages that can be sent or received. If omitted, 0 (cannot send messages) will be used. Specify from 1 to 32767.
- Specify TRUE or FALSE for *private*. If TRUE is specified, a private pipe will be created. If FALSE is specified, a public pipe will be created. The default is FALSE.
- An error will occur if a pipe of the same name has already been created.

**See**

Refer to "The SQL Language" > "Data Types" > "Boolean Type" in the LightDB Documentation for information on boolean type (TRUE/FALSE) values.

**Example**

```
PERFORM DBMS_PIPE.CREATE_PIPE('P01', 100, FALSE);
```

**NEXT\_ITEM\_TYPE**

- NEXT\_ITEM\_TYPE returns the next data type in the local buffer.
- The data type of the return value is INTEGER. One of the following values is returned:

**Table F.124. Values returned by NEXT\_ITEM\_TYPE**

Return value	Data type
9	NUMERIC type
11	TEXT type
12	DATE type
13	TIMESTAMP type
23	BYTEA type
24	RECORD type
0	No data in the buffer

**Example**

```
DECLARE
    i_iType    INTEGER;
BEGIN
    i_iType := DBMS_PIPE.NEXT_ITEM_TYPE();
```

**PACK\_MESSAGE**

- PACK\_MESSAGE sets the specified message in the local buffer.
- Specify the data to be set in the local buffer. The following data types can be used:
  - Character type (\*1)
  - Integer type (\*2)
  - NUMERIC type
  - DATE type

- TIMESTAMP type (\*3)
- BYTEA type
- RECORD type

\*1: The character type is converted internally to TEXT type.

\*2: The integer type is converted internally to NUMERIC type.

\*3: The TIMESTAMP type is converted internally to TIMESTAMP WITH TIME ZONE type.

- Each time PACK\_MESSAGE is called, a new message is added to the local buffer.
- The size of the local buffer is approximately 8 KB. However, each message has overhead, so the total size that can be stored is actually less than 8 KB. To clear the local buffer, send a message (SEND\_MESSAGE), or reset the buffer (RESET\_BUFFER) to its initial state.

### Example

```
PERFORM DBMS_PIPE.PACK_MESSAGE('Message Test001');
```

### PURGE

- PURGE removes the messages in the pipe.
- Specify the name of the pipe for which the messages are to be removed.
- Pipe names are case-sensitive.

### Example

```
PERFORM DBMS_PIPE.PURGE('P01');
```

### Note

When PURGE is executed, the local buffer is used to remove the messages in the pipe. Therefore, if there are any messages remaining in the pipe, the local buffer will be overwritten by PURGE.

### RECEIVE\_MESSAGE

- RECEIVE\_MESSAGE receives messages that exist in the specified pipe, and sets those messages in the local buffer.
- Messages are received in the units in which they are sent to the pipe by SEND\_MESSAGE. Received messages are removed from the pipe after being set in the local buffer.
- Specify the name of the pipe for which the messages are to be received.
- Pipe names are case-sensitive.
- Specify the maximum wait time *timeout* in seconds to wait for a message. If omitted, the default is 31536000 seconds (1 year).
- The data type of the return value is INTEGER. If a message is received successfully, 0 is returned. If a timeout occurs, 1 is returned.

**Example**

```
DECLARE
    i_Ret    INTEGER;
BEGIN
    i_Ret := DBMS_PIPE.RECEIVE_MESSAGE('P01', 60);
```

**REMOVE\_PIPE**

- REMOVE\_PIPE removes the specified pipe.
- Specify the name of the pipe to be removed.
- Pipe names are case-sensitive.

**Example**

```
PERFORM DBMS_PIPE.REMOVE_PIPE('P01');
```

**RESET\_BUFFER**

- RESET\_BUFFER resets the set position of the local buffer. Any unnecessary data remaining in the local buffer can be discarded using this operation.

**Example**

```
PERFORM DBMS_PIPE.RESET_BUFFER();
```

**SEND\_MESSAGE**

- SEND\_MESSAGE sends data stored in the local buffer to the specified pipe.
- Specify the name of the pipe that the data is to be sent to.
- Pipe names are case-sensitive.
- Specify the maximum wait time *timeout* in seconds for sending data stored in the local buffer. If omitted, the default is 31536000 seconds (1 year).
- Specify the maximum number of messages that can be sent or received. If omitted, the maximum number of messages set in CREATE\_PIPE is used. If omitted in the implicit pipe, the number of messages will be unlimited. Specify from 1 to 32767.
- If the maximum number of messages is specified in both SEND\_MESSAGE and CREATE\_PIPE, the larger of the values will be used.
- The data type of the return value is INTEGER. If a message is received successfully, 0 is returned. If a timeout occurs, 1 is returned.

**Example**

```
DECLARE
    i_Ret    INTEGER;
BEGIN
```

```
i_Ret := DBMS_PIPE.SEND_MESSAGE('P01', 10, 20);
```

### Note

A timeout will occur during sending if the maximum number of messages is reached, or if the message being sent is too large. If a timeout occurs, use `RECEIVE_MESSAGE` to receive any messages that are in the pipe.

### UNIQUE\_SESSION\_NAME

- `UNIQUE_SESSION_NAME` returns a name that is unique among all the sessions. This name can be used as the pipe name.
- Multiple calls from the same session always return the same name.
- The data type of the return value is `VARCHAR`. Returns a string of up to 30 characters.

### Example

```
DECLARE
    p_Name    VARCHAR(30);
BEGIN
    p_Name := DBMS_PIPE.UNIQUE_SESSION_NAME();
```

### UNPACK\_MESSAGE\_BYTEA

- `UNPACK_MESSAGE_BYTEA` receives `BYTEA` type messages in the local buffer.
- Messages are received in the unit set in the local buffer by `PACK_MESSAGE`. Received messages are removed from the local buffer.
- The data type of the return value is `BYTEA`.
- If no messages exist in the local buffer, a `NULL` value is returned.
- For the data type, it is necessary to align with the data type set by `PACK_MESSAGE`. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL:  unpack unexpected type: xx
```

### Example

```
DECLARE
    g_Bytea   BYTEA;
BEGIN
    g_Bytea := DBMS_PIPE.UNPACK_MESSAGE_BYTEA();
```

### UNPACK\_MESSAGE\_DATE

- `UNPACK_MESSAGE_DATE` receives `DATE` type messages in the local buffer.
- Messages are received in the unit set in the local buffer by `PACK_MESSAGE`. Received messages are removed from the local buffer.

- The data type of the return value is DATE.
- If no messages exist in the local buffer, a NULL value is returned.
- For the data type, it is necessary to align with the data type set by PACK\_MESSAGE. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL: unpack unexpected type: xx
```

### Example

```
DECLARE
    g_Date    DATE;
BEGIN
    g_Date := DBMS_PIPE.UNPACK_MESSAGE_DATE();
```

### Note

If the "oracle" schema is set in search\_path, the DATE type of oracle will be used, so for receiving data, use UNPACK\_MESSAGE\_TIMESTAMP. UNPACK\_MESSAGE\_DATE is the interface for the DATE type of LightDB.

### UNPACK\_MESSAGE\_NUMBER

- UNPACK\_MESSAGE\_NUMBER receives NUMERIC type messages in the local buffer.
- Messages are received in the unit set in the local buffer by PACK\_MESSAGE. Received messages are removed from the local buffer.
- The data type of the return value is NUMERIC.
- If no messages exist in the local buffer, a NULL value is returned.
- For the data type, it is necessary to align with the data type set by PACK\_MESSAGE. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL: unpack unexpected type: xx
```

### Example

```
DECLARE
    g_Number    NUMERIC;
BEGIN
    g_Number := DBMS_PIPE.UNPACK_MESSAGE_NUMBER();
```

### UNPACK\_MESSAGE\_RECORD

- UNPACK\_MESSAGE\_RECORD receives RECORD type messages in the local buffer.
- Messages are received in the unit set in the local buffer by PACK\_MESSAGE. Received messages are removed from the local buffer.

- The data type of the return value is RECORD.
- If no messages exist in the local buffer, a NULL value is returned.
- For the data type, it is necessary to align with the data type set by PACK\_MESSAGE. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL: unpack unexpected type: xx
```

### Example

```
DECLARE
    msg1      TEXT;
    status    NUMERIC;
BEGIN
    SELECT col1, col2 INTO msg1, status FROM
DBMS_PIPE.UNPACK_MESSAGE_RECORD();
```

### UNPACK\_MESSAGE\_TEXT

- UNPACK\_MESSAGE\_TEXT receives TEXT type messages in the local buffer.
- Messages are received in the unit set in the local buffer by PACK\_MESSAGE. Received messages are removed from the local buffer.
- The data type of the return value is TEXT.
- If no messages exist in the local buffer, a NULL value is returned.
- For the data type, it is necessary to align with the data type set by PACK\_MESSAGE. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL: unpack unexpected type: xx
```

### Example

```
DECLARE
    g_Text    TEXT;
BEGIN
    g_Text := DBMS_PIPE.UNPACK_MESSAGE_TEXT();
```

### UNPACK\_MESSAGE\_TIMESTAMP

- UNPACK\_MESSAGE\_TIMESTAMP receives TIMESTAMP WITH TIME ZONE type messages in the local buffer.
- Messages are received in the unit set in the local buffer by PACK\_MESSAGE. Received messages are removed from the local buffer.
- The data type of the return value is TIMESTAMP WITH TIME ZONE.

- If no messages exist in the local buffer, a NULL value is returned.
- For the data type, it is necessary to align with the data type set by PACK\_MESSAGE. If the data type is different, the following error will occur.

```
ERROR: datatype mismatch
DETAIL: unpack unexpected type: xx
```

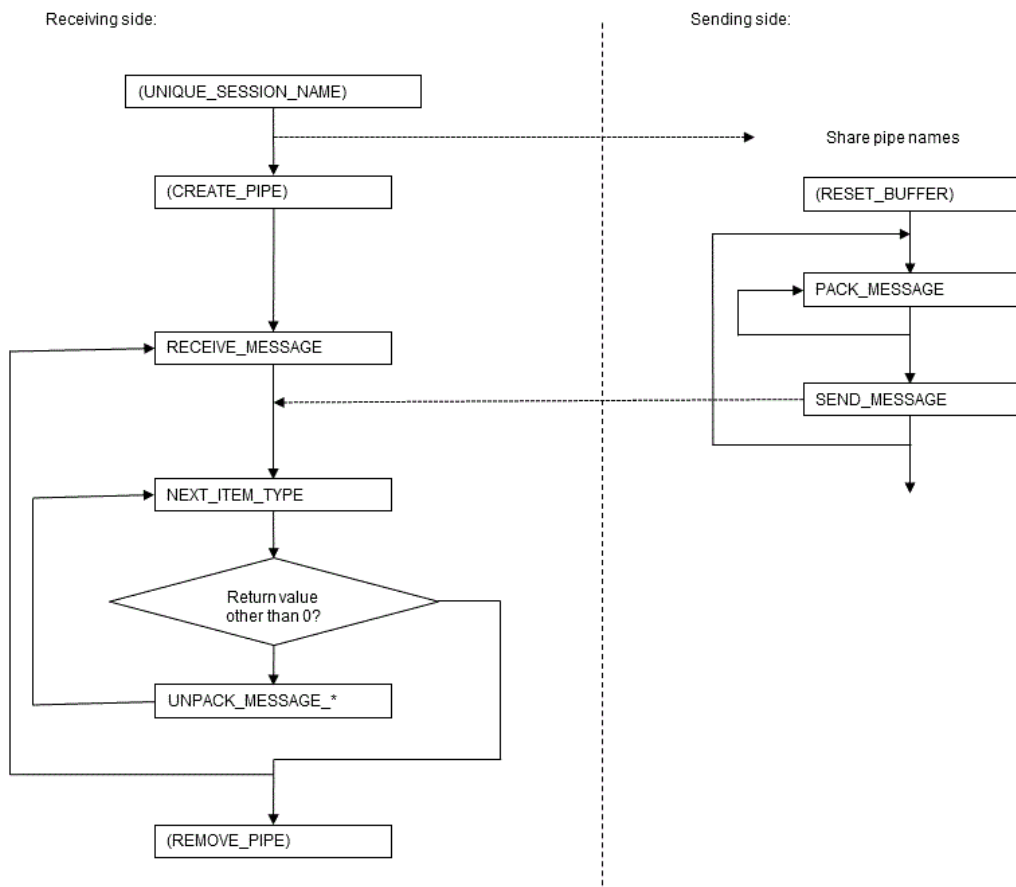
**Example**

```
DECLARE
    g_Timestampz    TIMESTAMP WITH TIME ZONE;
BEGIN
    g_Timestampz := DBMS_PIPE.UNPACK_MESSAGE_TIMESTAMP();
```

**F.56.6.5.2. Usage Example**

Below is a usage example of the processing flow of DBMS\_PIPE.

**Flow of DBMS\_PIPE**



**Note**

- When CREATE\_PIPE is used to explicitly create a pipe, ensure to use REMOVE\_PIPE to remove the pipe. If a pipe is not removed explicitly, once created, it will remain until the instance is stopped.



- In the flow diagram, CREATE\_PIPE and REMOVE\_PIPE are described on the receiving side, however, these can be executed on the sending side. In order to maintain consistency, it is recommended to create and remove pipes on one side.
- An error will occur for CREATE\_PIPE if a pipe of the same name already exists. Implicitly created pipes are also the target of SEND\_MESSAGE and RECEIVE\_MESSAGE, so when executing CREATE\_PIPE, ensure that SEND\_MESSAGE and RECEIVE\_MESSAGE are not called beforehand.
- DBMS\_ALERT and DBMS\_PIPE use the same memory environment. Therefore, when insufficient memory is detected for DBMS\_ALERT, it is possible that insufficient memory will also be detected for DBMS\_PIPE.

### Information

The information of pipes that are in use can be viewed in the DBMS\_PIPE.DB\_PIPES view.

```
SELECT * from dbms_pipe.db_pipes;
name | items | size | limit | private | owner
-----+-----+-----+-----+-----+-----
P01  |      1 |   18 |   100 | f        |
(1 row)
```

### Usage example

- Sending side

```
CREATE FUNCTION send_dbms_pipe_exe(IN pipe_mess text) RETURNS
void AS $$
DECLARE
    pipe_name text := 'sample_pipe';
    pipe_time timestamp := current_timestamp;
    pipe_stat int;
BEGIN
    PERFORM DBMS_PIPE.RESET_BUFFER();
    PERFORM DBMS_PIPE.PACK_MESSAGE(pipe_mess);
    PERFORM DBMS_PIPE.PACK_MESSAGE(pipe_time);
    pipe_stat := DBMS_PIPE.SEND_MESSAGE(pipe_name);
    RAISE NOTICE 'PIPE_NAME: % SEND Return Value =%', pipe_name,
pipe_stat;
END;
$$ LANGUAGE plpgsql;

SELECT send_dbms_pipe_exe('Sample Message.');
```

- Receiving side

```
CREATE FUNCTION receive_dbms_pipe_exe() RETURNS void AS $$
DECLARE
    pipe_name text := 'sample_pipe';
    pipe_text text;
    pipe_num numeric;
    pipe_date date;
```

```

pipe_time timestamp with time zone;
pipe_byte bytea;
pipe_reco record;
pipe_item int;
pipe_stat int;
BEGIN
pipe_stat := DBMS_PIPE.RECEIVE_MESSAGE(pipe_name,300);
RAISE NOTICE 'Return Value = %', pipe_stat;
    LOOP
pipe_item := DBMS_PIPE.NEXT_ITEM_TYPE();
RAISE NOTICE 'Next Item : %', pipe_item;
IF (pipe_item = 9) THEN
pipe_num := DBMS_PIPE.UNPACK_MESSAGE_NUMBER();
RAISE NOTICE 'Get Message : %' ,pipe_num;
ELSIF (pipe_item =11) THEN
pipe_text := DBMS_PIPE.UNPACK_MESSAGE_TEXT();
RAISE NOTICE 'Get Message : %' ,pipe_text;
ELSIF (pipe_item = 12) THEN
pipe_date := DBMS_PIPE.UNPACK_MESSAGE_DATE();
RAISE NOTICE 'Get Message : %' ,pipe_date;
ELSIF (pipe_item = 13) THEN
pipe_time := DBMS_PIPE.UNPACK_MESSAGE_TIMESTAMP();
RAISE NOTICE 'Get Message : %' ,pipe_time;
ELSIF (pipe_item = 23) THEN
pipe_byte := DBMS_PIPE.UNPACK_MESSAGE_BYTEA();
RAISE NOTICE 'Get Message : %' ,pipe_byte;
ELSIF (pipe_item = 24) THEN
pipe_reco := DBMS_PIPE.UNPACK_MESSAGE_RECORD();
RAISE NOTICE 'Get Message : %' ,pipe_reco;
ELSE
EXIT;
END IF;
END LOOP;
PERFORM DBMS_PIPE.REMOVE_PIPE(pipe_name);
END;
$$ LANGUAGE plpgsql;

SELECT receive_dbms_pipe_exe();
DROP FUNCTION receive_dbms_pipe_exe();

```

## F.56.6.6. DBMS\_RANDOM

### Overview

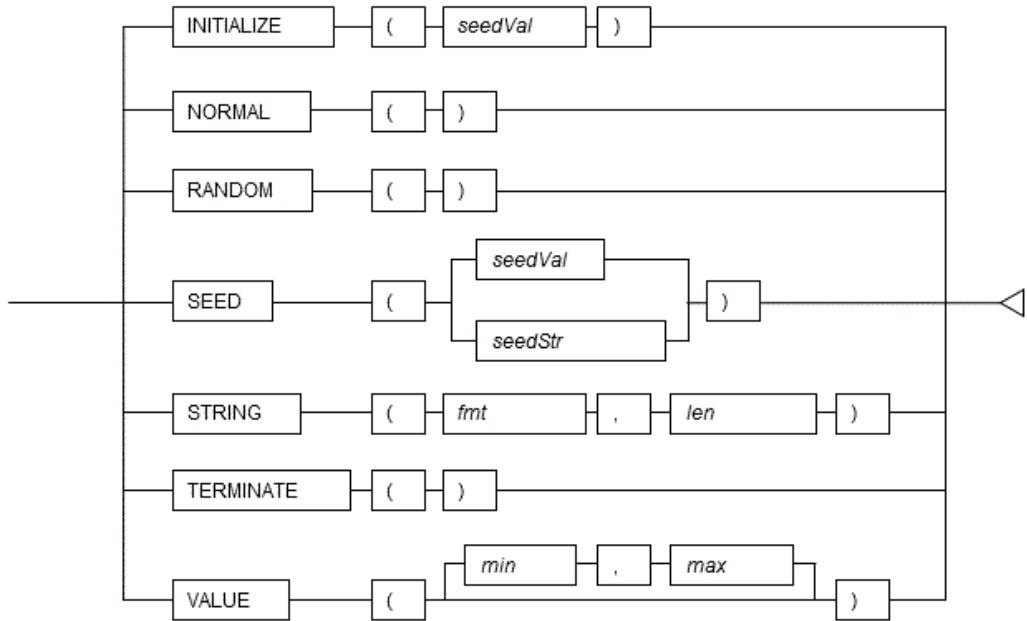
Generates random numbers in PL/pgSQL.

**Table F.125. DBMS\_RANDOM Features**

Feature	Description
INITIALIZE	Initializes the generation of random numbers.
NORMAL	Returns a normally distributed random number.
RANDOM	Generates a random number.
SEED	Resets the seed value.
STRING	Generates a random string.
TERMINATE	Terminates generation of random numbers.

Feature	Description
VALUE	Generates a random decimal number between 0 and 1, or between specified values.

**Syntax**



**F.56.6.6.1. Description of Features**

This section explains each feature of DBMS\_RANDOM.

**INITIALIZE**

- INITIALIZE initializes the generation of random numbers using the specified seed value.
- For *seedVal*, specify a SMALLINT or INTEGER type.

**Example**

```
PERFORM DBMS_RANDOM.INITIALIZE(999);
```

**NORMAL**

- NORMAL generates and returns a normally distributed random number.
- The return value type is DOUBLE PRECISION.

**Example**

```
DECLARE
  d_RunNum DOUBLE PRECISION;
BEGIN
  d_RunNum := DBMS_RANDOM.NORMAL();
```

## RANDOM

- RANDOM generates and returns a random number.
- The data type of the return value is INTEGER.

### Example

```

DECLARE
    d_RunInt    INTEGER;
BEGIN
    d_RunInt := DBMS_RANDOM.RANDOM();

```

## SEED

- SEED initializes the generation of a random number using the specified seed value or seed string.
- For *seedVal*, specify a SMALLINT or INTEGER type.
- Any string can be specified for the seed string.

### Example

```

PERFORM DBMS_RANDOM.SEED( '123' );

```

## STRING

- STRING generates and returns a random string in accordance with the specified display format and string length.
- For the display format *fmt*, specify any of the following values. An error will occur if any other value is specified.

**Table F.126. Values that can be specified for the display format**

Setting value	Generated string
'u', 'U'	Uppercase letters only
'l', 'L'	Lowercase letters only
'a', 'A'	Mixture of uppercase and lowercase letters
'x', 'X'	Uppercase letters and numbers
'p', 'P'	Any displayable character

- Specify the length of the string to be generated. Specify a SMALLINT or INTEGER type.
- The data type of the return value is TEXT.

### Example

```

DECLARE
    d_RunStr    TEXT;
BEGIN
    d_RunStr := DBMS_RANDOM.STRING( 'a', 20 );

```

**TERMINATE**

- Call TERMINATE to terminate generation of random numbers.

**Information**

TERMINATE does not do anything, but has been included for compatibility with Oracle databases.

**Example**

```
PERFORM DBMS_RANDOM.TERMINATE();
```

**VALUE**

- VALUE generates and returns a random number within the specified range.
- For *min* and *max*, specify a numeric data type. A random number between and inclusive of the minimum value and maximum value is generated.
- If the minimum value and maximum value are omitted, a random decimal number between 0 and 1 will be generated.
- The data type of the return value is DOUBLE PRECISION.

**Example**

```
DECLARE
    d_RunDb1    DOUBLE PRECISION;
BEGIN
    d_RunDb1 := DBMS_RANDOM.VALUE();
```

**F.56.6.6.2. Usage Example**

A usage example of DBMS\_RANDOM is shown below.

```
CREATE FUNCTION dbms_random_exe() RETURNS VOID AS $$
DECLARE
    w_rkey VARCHAR(10) := 'rnd111';
    i_rkey INTEGER := 97310;
BEGIN
    PERFORM DBMS_RANDOM.INITIALIZE(i_rkey);
    RAISE NOTICE 'RANDOM -> NORMAL : %', DBMS_RANDOM.NORMAL();
    RAISE NOTICE 'RANDOM -> RANDOM : %', DBMS_RANDOM.RANDOM();
    RAISE NOTICE 'RANDOM -> STRING : %',
DBMS_RANDOM.STRING('a',10);
    RAISE NOTICE 'RANDOM -> VALUE : %', DBMS_RANDOM.VALUE();
    PERFORM DBMS_RANDOM.SEED(w_rkey);
    RAISE NOTICE 'RANDOM -> NORMAL : %', DBMS_RANDOM.NORMAL();
    RAISE NOTICE 'RANDOM -> RANDOM : %', DBMS_RANDOM.RANDOM();
    RAISE NOTICE 'RANDOM -> STRING : %',
DBMS_RANDOM.STRING('p',10);
    RAISE NOTICE 'RANDOM -> VALUE : %',
DBMS_RANDOM.VALUE(1,100);
    PERFORM DBMS_RANDOM.TERMINATE();
END;
$$ LANGUAGE plpgsql;
```

```
SELECT dbms_random_exe();
DROP FUNCTION dbms_random_exe();
```

## F.56.6.7. DBMS\_UTILITY

### Overview

Provides utilities of PL/pgSQL.

**Table F.127. DBMS\_UTILITY Features**

Feature	Description
FORMAT_CALL_STACK	Returns the current call stack.
GET_HASH_VALUE	A hash value based on the input string.
CANONICALIZE	Canonicalizes a given string.
COMMA_TO_TABLE	Converts a comma-delimited list of names into a PL/SQL table of names.
TABLE_TO_COMMA	Converts a PL/SQL table of names into a comma-delimited list of names.
DB_VERSION	Returns version information for the database.
EXEC_DDL_STATEMENT	Executes the DDL statement in parse_string.
GET_TIME	Finds out the current time in hundredths of a second.

### Syntax

```
FORMAT_CALL_STACK(fmt text);
FORMAT_CALL_STACK();
GET_HASH_VALUE(name VARCHAR2,base INTEGER,hash_size INTEGER)
CANONICALIZE(name TEXT,canon_name TEXT,canon_len INT4)
COMMA_TO_TABLE(list TEXT,tablen INT4,tab TEXT[])
TABLE_TO_COMMA(tab TEXT[],tablen INT4,list TEXT)
DB_VERSION(version TEXT,compatibility TEXT)
EXEC_DDL_STATEMENT(parse_string TEXT)
```

### F.56.6.7.1. Description of Features

This section explains each feature of DBMS\_UTILITY.

#### FORMAT\_CALL\_STACK

- FORMAT\_CALL\_STACK returns the current call stack of PL/pgSQL.
- For the display format `fmt`, specify any of the following values. An error will occur if any other value is specified.

**Table F.128. Values that can be specified for the display format**

Setting value	Displayed content
'o'	Standard-format call stack display (with header)
's'	Standard-format call stack display (without header)

Setting value	Displayed content
'p'	Comma-delimited call stack display (without header)

- If the display format is omitted, display format 'o' will be used.
- The data type of the return value is TEXT.

**Example**

```

DECLARE
    s_StackTrace    TEXT
BEGIN
    s_StackTrace := DBMS_UTILITY.FORMAT_CALL_STACK();

```

**Note**

If a locale other than English is specified for the message locale, the call stack result may not be retrieved correctly. To correctly retrieve the call stack result, specify English as the message locale.

**GET\_HASH\_VALUE**

- A hash value based on the input string where the hash value should be between base and base + hash\_size - 1.

**Example**

```

PERFORM DBMS_UTILITY.GET_HASH_VALUE('abcdef', 0, 10000);

```

**CANONICALIZE**

- The procedure handles a single reserved or key word (such as 'table'), and strips off white spaces for a single identifier so that ' table ' becomes TABLE.

**Example**

```

declare
    l_result    text := '';
begin
    dbms_output.serveroutput(True);
    dbms_utility.canonicalize('table', l_result, 100);
    dbms_output.put_line(l_result);
end;
/

```

**COMMA\_TO\_TABLE**

- These procedures converts a comma-delimited list of names into a PL/SQL table of names.
- The list must be a non-empty comma-delimited list: Anything other than a comma-delimited list is rejected. Commas inside double quotes do not count.

**Example**

```
declare
    tablen          int4;
    tab             text[];
begin
    dbms_output.serveroutput(True);
    dbms_utility.comma_to_table('table, "Table", "Table,122324" ,
    Tablesd', tablen, tab);
    dbms_output.put_line(tablen);
    dbms_output.put_line(array_to_string(tab, ','));
end;
/
```

### TABLE\_TO\_COMMA

- This procedure converts a PL/SQL table of names into a comma-delimited list of names.

#### Example

```
declare
    tablen          int4;
    l_str           text;
begin
    dbms_output.serveroutput(True);

    dbms_utility.table_to_comma('{table, " \"table
\"\", \"\"table.1234567890\" \"\", \" tablezx\",NULL}'::text[], tablen,
    l_str);
    dbms_output.put_line(tablen);
    dbms_output.put_line(l_str);

end;
/
```

### DB\_VERSION

- This procedure returns version information for the database.

#### Example

```
declare
    lt_version      text;
    compatibility   text;
begin
    dbms_output.serveroutput(True);
    dbms_utility.db_version(lt_version, compatibility);
    dbms_output.put_line(lt_version);
    dbms_output.put_line(oracle.nvl(compatibility, 'NULL'));
end;
/
```

### EXEC\_DDL\_STATEMENT

- his procedure executes the DDL statement in parse\_string.

#### Example



```
declare
  l_result          text := '';
begin
  dbms_output.serveroutput(True);
  dbms_utility.exec_ddl_statement('create table if not exists
public.test_exec_ddl_stmt (id int, name text);');
end;
/
```

### GET\_TIME

- This function returns a measure of current time in hundredths of a second. The difference between the times returned from two calls measures the total elapsed time (not just CPU processing time) between those two points.

#### Example

```
DO $$
DECLARE
  start_time integer;
  end_time integer;
BEGIN
  start_time := DBMS_UTILITY.GET_TIME();
  PERFORM pg_sleep(2);
  end_time := DBMS_UTILITY.GET_TIME();
  -- clamp long runtime on slow build machines to the 2s the
  testsuite is expecting
  IF end_time BETWEEN start_time + 300 AND start_time + 1000
  THEN end_time := start_time + 250; END IF;
  RAISE NOTICE 'Execution time: % seconds',
trunc((end_time - start_time)::numeric/100);
END
$$;
```

### F.56.6.7.2. Usage Example

A usage example of DBMS\_UTILITY is shown below.

```
CREATE FUNCTION dbms_utility1_exe() RETURNS VOID AS $$
DECLARE
  s_StackTrace TEXT;
  v_hashvalue numeric(38,0);
BEGIN
  s_StackTrace := DBMS_UTILITY.FORMAT_CALL_STACK();
  RAISE NOTICE '%', s_StackTrace;
  v_hashvalue := DBMS_UTILITY.GET_HASH_VALUE('abcdef',0,10000);
  RAISE NOTICE 'v_hashvalue=%', v_hashvalue;
END;
$$ LANGUAGE plpgsql;

CREATE FUNCTION dbms_utility2_exe() RETURNS VOID AS $$
BEGIN
  PERFORM dbms_utility1_exe();
END;
```

```

$$ LANGUAGE plpgsql;

SELECT dbms_utility2_exe();
DROP FUNCTION dbms_utility2_exe();
DROP FUNCTION dbms_utility1_exe();

declare
    l_result          text := '';
begin
    dbms_output.serveroutput(True);
    dbms_utility.exec_ddl_statement('create table if not exists
public.test_exec_ddl_stmt (id int, name text);');
    l_result := dbms_metadata.get_ddl('table',
'test_exec_ddl_stmt');
    dbms_output.put_line(l_result);
    dbms_utility.exec_ddl_statement(' truncate table
public.test_exec_ddl_stmt');
    dbms_output.put_line('truncate SUCCESS');
    dbms_utility.exec_ddl_statement('drop table if exists
public.test_exec_ddl_stmt ; ');
    dbms_output.put_line('drop SUCCESS');
end;
/

```

## F.56.6.8. DBMS\_JOB

### Overview

Schedules and manages jobs in the It\_cron.

**Table F.129. DBMS\_JOB Features**

Feature	Description
BROKEN	Disables job execution.(invalid)
CHANGE	Alters any of the user-definable parameters associated with a job.
INSTANCE	Assigns a job to be run by a instance.(invalid)
INTERVAL	Alters the interval between executions for a specified job.
NEXT_DATE	Alters the next execution time for a specified job.(invalid)
REMOVE	Removes specified job from the job queue.
RUN	Forces a specified job to run.(invalid)
SUBMIT	Submits a new job to the job queue.
USER_EXPORT	Re-creates a given job for export.
WHAT	Alters the job description for a specified job.

### Syntax

```

CHANGE(job INT8,what TEXT,next_date TIMESTAMP,interval
TEXT,instance INT4 default null,force BOOL default 'false')
INTERVAL(job INT8,interval TEXT)
REMOVE(job INT8)

```

```
SUBMIT(job INT8,what TEXT,next_date TIMESTAMP default
sysdate,interval TEXT default 'null',no_parse BOOL default
'false',instance INT4 default null,force BOOL default 'false')
USER_EXPORT(job INT8,mycall TEXT)
WHAT(job INT8,what TEXT)
```

### F.56.6.8.1. Description of Features

This section explains each feature of `dbms_job`.

#### **CHANGE**

- This procedure changes any of the fields a user can set in a job.

#### **Example**

```
dbms_job.change(l_job_id, 'select 3', sysdate, '0 11 * * *');
```

#### **INTERVAL**

- This procedure changes how often a job runs.
- The interval parameter format is `lt_cron`'s format.

#### **Example**

```
dbms_job.interval(l_job_id, '0 11 * * *');
```

#### **REMOVE**

- This procedure removes an existing job from the job queue.

#### **Example**

```
dbms_job.remove(2);
```

#### **SUBMIT**

- This procedure submits a new job.
- The job submitted by this procedure will not have name. It's suggested to submit by `'select cron.Schedule(name,xxx)'`.

#### **Example**

```
dbms_job.submit(l_job_id, 'select 1',sysdate, '0 10 * * *');
```

#### **USER\_EXPORT**

- Produces the text of a call to re-create the given job.

#### **Example**

```
dbms_job.user_export(2, l_result);
```

#### WHAT

- This procedure changes what an existing job does.

#### Example

```
dbms_job.what(2, 'select 2');
```

### F.56.6.8.2. Usage Example

A usage example of DBMS\_JOB is shown below.

```
declare
    l_job_id    int8;
    l_result    text := '';
begin
    dbms_output.serveroutput(true);

    -- use dbms_job.submit will not have jobname
    dbms_job.submit(l_job_id, 'select 1',sysdate, '0 10 * * *');
    dbms_output.put_line('submit job, job id: '||l_job_id);

    dbms_job.user_export(l_job_id, l_result);
    dbms_output.put_line('user_export(job id: '||l_job_id||'): '||
l_result);

    -- update can't be used for job without name
    dbms_job.what(l_job_id, 'select 2');
    dbms_job.user_export(l_job_id, l_result);
    dbms_output.put_line('after dbms_job.what user_export(job
id: '||l_job_id||'): '||l_result);

    dbms_job.interval(l_job_id, '0 11 * * *');
    dbms_job.user_export(l_job_id, l_result);
    dbms_output.put_line('after dbms_job.interval user_export(job
id: '||l_job_id||'): '||l_result);

    dbms_job.change(l_job_id, 'select 3', sysdate, '0 11 * * *');
    dbms_job.user_export(l_job_id, l_result);
    dbms_output.put_line('after dbms_job.change user_export(job
id: '||l_job_id||'): '||l_result);

    dbms_job.next_date(l_job_id, sysdate);
    dbms_job.broken(l_job_id, True);
    dbms_job.instance(l_job_id, 10);
    dbms_job.run(l_job_id);

    dbms_job.remove(l_job_id);

end;
/
```

## F.56.6.9. DBMS\_LOCK

### Overview

Provides an interface to Lock Management services.

**Table F.130. DBMS\_LOCK Features**

Feature	Description
sleep	Puts a session to sleep for a specific time.

### Syntax

```
SLEEP(pi_seconds FLOAT8)
```

### F.56.6.9.1. Description of Features

This section explains each feature of dbms\_job.

#### SLEEP

- This procedure suspends the session for a specified period of time.
- suspends in seconds, to suspend the session.

#### Example

```
dbms_lock.sleep(0.1);
```

## F.56.6.10. DBMS\_METADATA

### Overview

Provides a way for you to retrieve metadata from the database dictionary.

**Table F.131. DBMS\_METADATA Features**

Feature	Description
get_ddl	Let you fetch metadata for objects.

### Syntax

```
GET_DDL(object_type VARCHAR,name VARCHAR,schema VARCHAR
DEFAULT current_schema(),VARCHAR DEFAULT 'COMPATIBLE',VARCHAR
DEFAULT 'ORACLE',VARCHAR DEFAULT 'DDL',BOOL DEFAULT 'false')
RETURNS TEXT
```

### F.56.6.10.1. Description of Features

This section explains each feature of dbms\_job.

**GET\_DDL**

- Let you fetch metadata for objects.

**Example**

```
select dbms_metadata.get_ddl('constraint', 'key1_check') from dual;
```

**F.56.6.11. DBMS\_OBFUSCATION\_TOOLKIT****Overview**

Enables an application to encrypt data using either the Data Encryption Standard (DES) or the Triple DES algorithms.

**Table F.132. DBMS\_OBFUSCATION\_TOOLKIT Features**

Feature	Description
md5	Generates MD5 hashes of data.

**Syntax**

```
MD5(input_string TEXT) RETURNS RAW
```

**F.56.6.11.1. Description of Features**

This section explains each feature of dbms\_job.

**MD5**

- Generates MD5 hashes of data.

**Example**

```
select dbms_obfuscation_toolkit.md5(input_string => '##')::text
from dual;
```

**F.56.6.12. DBMS\_SNAPSHOT****Overview**

Enables you to refresh snapshots(MVIEW).

**Table F.133. DBMS\_SNAPSHOT Features**

Feature	Description
refresh	Refreshes a list of snapshots.

**Syntax**

```
REFRESH(list TEXT,method TEXT default 'C')
```

### F.56.6.12.1. Description of Features

This section explains each feature of `dbms_job`.

#### REFRESH

- This procedure refreshes a list of snapshots(MVIEW).

#### Example

```
select
  dbms_snapshot.refresh('mv_test_dbms_snapshot,mv_test_dbms_snapshot1')
from dual;
```

### F.56.6.13. UTL\_FILE

#### Overview

Text files can be written and read using PL/pgSQL.

To perform these file operations, the directory for the operation target must be registered in the `UTL_FILE.UTL_FILE_DIR` table beforehand. Use the `INSERT` statement as the database administrator or a user who has `INSERT` privileges to register the directory. Also, if the directory is no longer necessary, delete it from the same table. Refer to "Registering and Deleting Directories" for information on the how to register and delete the directory.

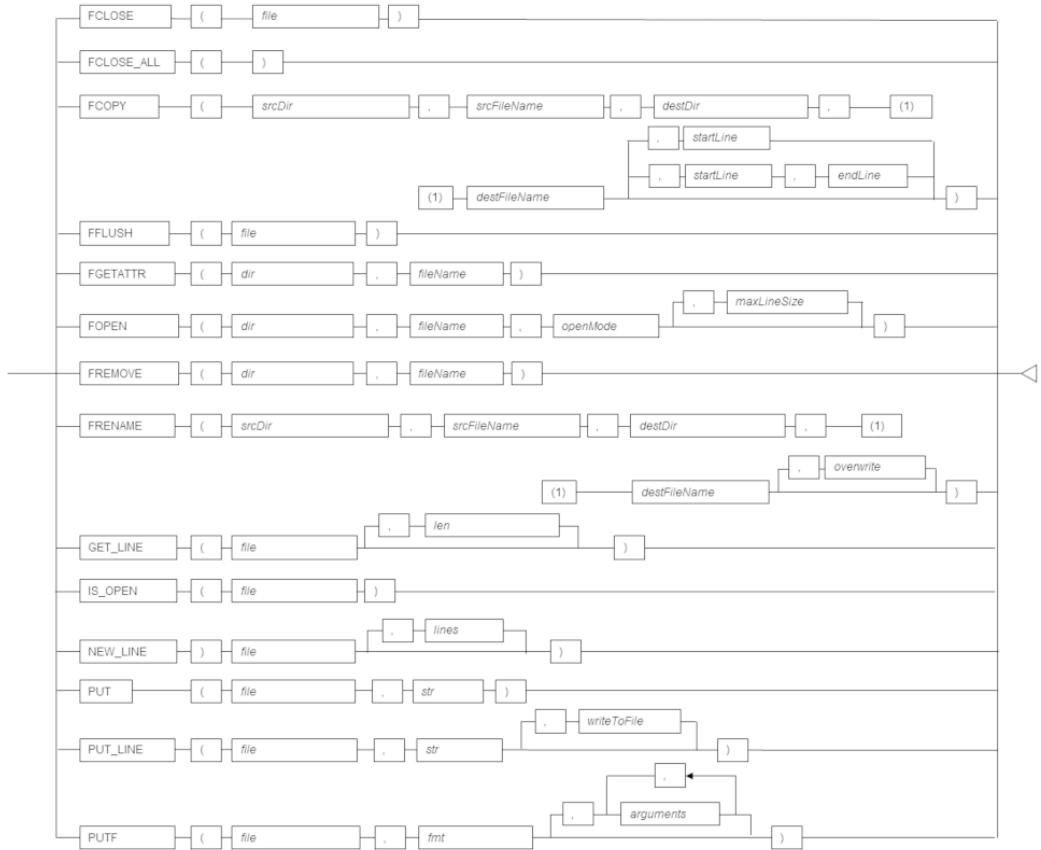
Declare the file handler explained hereafter as follows in PL/pgSQL:

```
DECLARE f UTL_FILE.FILE_TYPE;
```

**Table F.134. UTL\_FILE Features**

Feature	Description
FCLOSE	Closes a file.
FCLOSE_ALL	Closes all files open in a session.
FCOPY	Copies a whole file or a contiguous portion thereof.
FFLUSH	Flushes the buffer.
FGETATTR	Retrieves the attributes of a file.
FOPEN	Opens a file.
FREMOVE	Deletes a file.
FRENAME	Renames a file.
GET_LINE	Reads a line from a text file.
IS_OPEN	Checks if a file is open.
NEW_LINE	Writes newline characters.
PUT	Writes a string.
PUT_LINE	Appends a newline character to a string and writes the string.
PUTF	Writes a formatted string.

#### Syntax



### F.56.6.13.1. Registering and Deleting Directories

#### Registering the directory

1. Check if the directory is already registered (if it is, then step 2 is not necessary).

```
SELECT * FROM UTL_FILE.UTL_FILE_DIR WHERE dir='/home/pgsql';
```

2. Register the directory.

```
INSERT INTO UTL_FILE.UTL_FILE_DIR VALUES('/home/pgsql');
```

#### Deleting the directory

```
DELETE FROM UTL_FILE.UTL_FILE_DIR WHERE dir='/home/lightdb';
```

### F.56.6.13.2. Description

This section explains each feature of UTL\_FILE.

#### FCLOSE

- FCLOSE closes a file that is open.
- Specify an open file handle.



- The value returned is a NULL value.

**Example**

```
f := UTL_FILE.FCLOSE(f);
```

**FCLOSE\_ALL**

- FCLOSE\_ALL closes all files open in a session.
- Files closed with FCLOSE\_ALL can no longer be read or written.

**Example**

```
PERFORM UTL_FILE.FCLOSE_ALL();
```

**FCOPY**

- FCOPY copies a whole file or a contiguous portion thereof. The whole file is copied if *startLine* and *endLine* are not specified.
- Specify the directory location of the source file.
- Specify the source file.
- Specify the directory where the destination file will be created.
- Specify the name of the destination file.
- Specify the line number at which to begin copying. Specify a value greater than 0. If not specified, 1 is used.
- Specify the line number at which to stop copying. If not specified, the last line number of the file is used.

**Example**

```
PERFORM UTL_FILE.FCOPY('/home/lightdb', 'regress_ltsql.txt',  
'/home/lightdb', 'regress_ltsql2.txt');
```

**FFLUSH**

- FFLUSH forcibly writes the buffer data to a file.
- Specify an open file handle.

**Example**

```
PERFORM UTL_FILE.FFLUSH(f);
```

**FGETATTR**

- FGETATTR retrieves file attributes: file existence, file size, and information about the block size of the file.

- Specify the directory where the file exists.
- Specify the relevant file name.
- Use a SELECT statement to obtain the file attributes, which are stored in the fexists, file\_length, and blocksize columns.
- The fexists column stores a boolean (TRUE/FALSE) value. If the file exists, fexists is set to TRUE. If the file does not exist, fexists is set to FALSE. The data type of fexists is BOOLEAN.
- The file\_length column stores the length of the file in bytes. If the file does not exist, file\_length is NULL. The data type of file\_length is INTEGER.
- The blocksize column stores the block size of the file in bytes. If the file does not exist, blocksize is NULL. The data type of blocksize is INTEGER.

**Example**

```
SELECT fexists, file_length, blocksize INTO file_flag,
file_len, size
FROM UTL_FILE.FGETATTR('/home/lightdb', 'regress_ltsql.txt');
```

**FOPEN**

- FOPEN opens a file.
- Specify the directory where the file exists.
- Specify the file name.
- Specify the mode for opening the file:  
r: Read  
w: Write  
a: Add
- Specify the maximum string length (in bytes) that can be processed with one operation. If omitted, the default is 1024. Specify a value from 1 to 32767.
- Up to 50 files per session can be open at the same time.

**Example**

```
f := UTL_FILE.FOPEN('/home/
pgsql', 'regress_pgsql.txt', 'r', 1024);
```

**FREMOVE**

- FREMOVE deletes a file.
- Specify the directory where the file exists.
- Specify the file name.

**Example**

```
PERFORM UTL_FILE.REMOVE( '/home/lightdb',  
'regress_ltsql.txt' );
```

### **FRENAME**

- FRENAME renames a file.
- Specify the directory location of the source file.
- Specify the source file to be renamed.
- Specify the directory where the renamed file will be created.
- Specify the new name of the file.
- Specify whether to overwrite a file if one exists with the same name and in the same location as the renamed file. If TRUE is specified, the existing file will be overwritten. If FALSE is specified, an error occurs. If omitted, FALSE is set.

### **See**

Refer to "The SQL Language" > "Data Types" > "Boolean Type" in the LightDB Documentation for information on boolean type (TRUE/FALSE) values.

### **Example**

```
PERFORM UTL_FILE.FRENAME( '/home/lightdb', 'regress_ltsql.txt',  
'/home/lightdb', 'regress_ltsql2.txt', TRUE );
```

### **GET\_LINE**

- GET\_LINE reads a line from a file.
- Specify the file handle returned by FOPEN using r (read) mode.
- Specify the number of bytes to read from the file. If not specified, the maximum string length specified at FOPEN will be used.
- The return value is the buffer that receives the line read from the file.
- Newline characters are not loaded to the buffer.
- An empty string is returned if a blank line is loaded.
- Specify the maximum length (in bytes) of the data to be read. Specify a value from 1 to 32767. If not specified, the maximum string length specified at FOPEN is set. If no maximum string length is specified at FOPEN, 1024 is set.
- If the line length is greater than the specified number of bytes to read, the remainder of the line is read on the next call.
- A NO\_DATA\_FOUND exception will occur when trying to read past the last line.

### **Example**

```
buff := UTL_FILE.GET_LINE(f);
```

### **IS\_OPEN**

- IS\_OPEN checks if a file is open.
- Specify the file handle.
- The return value is a BOOLEAN type. TRUE represents an open state and FALSE represents a closed state.

**See**

Refer to "The SQL Language" > "Data Types" > "Boolean Type" in the LightDB Documentation for information on boolean type (TRUE/FALSE) values.

**Example**

```
IF UTL_FILE.IS_OPEN(f) THEN
    PERFORM UTL_FILE.FCLOSE(f);
END IF;
```

**NEW\_LINE**

- NEW\_LINE writes one or more newline characters.
- Specify an open file handle.
- Specify the number of newline characters to be written to the file. If omitted, "1" is used.

**Example**

```
PERFORM UTL_FILE.NEW_LINE(f, 2);
```

**PUT**

- PUT writes a string to a file.
- Specify the file handle that was opened with FOPEN using w (write) or a (append).
- Specify the string to be written to the file.
- The maximum length (in bytes) of the string to be written is the maximum string length specified at FOPEN.
- PUT does not append a newline character. To append a newline character, execute NEW\_LINE.

**Example**

```
PERFORM UTL_FILE.PUT(f, 'ABC');
```

**PUT\_LINE**

- PUT\_LINE appends a newline character to a string and writes the string.
- Specify the file handle that was opened with FOPEN w (write) or a (append).
- Specify whether to forcibly write to the file. If TRUE is specified, file writing is forced. If FALSE is specified, file writing is asynchronous. If omitted, FALSE will be set.
- The maximum length of the string (in bytes) is the maximum string length specified at FOPEN.

**Example**

```
PERFORM UTL_FILE.PUT_LINE(f, 'ABC', TRUE);
```

**PUTF**

- PUTF writes a formatted string.
- Specify the file handle that was opened with FOPEN w (write) or a (append).
- Specify the format, which is a string that includes the formatting characters \n and %s.
- The \n in the format is code for a newline character.
- Specify the same number of input values as there are %s in the format. Up to a maximum of five input values can be specified. The %s in the format are replaced with the corresponding input characters. If an input value corresponding to %s is not specified, it is replaced with an empty string.

**Example**

```
PERFORM UTL_FILE.PUTF(f, '[1=%s, 2=%s, 3=%s, 4=%s, 5=%s]\n',  
'1', '2', '3', '4', '5');
```

**F.56.6.13.3. Usage Example**

The procedure when using UTL\_FILE, and a usage example, are shown below.

**1. Preparation**

Before starting a new job that uses UTL\_FILE, register the directory in the UTL\_FILE.UTL\_FILE\_DIR table.

Refer to "Registering and Deleting Directories" for information on how to register the directory.

**2. Performing a job**

Perform a job that uses UTL\_FILE. The example is shown below.

```
CREATE OR REPLACE FUNCTION gen_file(mydir TEXT, infile TEXT,  
outfile TEXT, copyfile TEXT) RETURNS void AS $$  
  DECLARE  
    v1 VARCHAR(32767);  
    inf UTL_FILE.FILE_TYPE;  
    otf UTL_FILE.FILE_TYPE;  
  BEGIN  
    inf := UTL_FILE.FOPEN(mydir, infile, 'r', 256);  
    otf := UTL_FILE.FOPEN(mydir, outfile, 'w');  
    v1 := UTL_FILE.GET_LINE(inf, 256);  
    PERFORM UTL_FILE.PUT_LINE(otf, v1, TRUE);  
    v1 := UTL_FILE.GET_LINE(inf, 256);  
    PERFORM UTL_FILE.PUTF(otf, '%s\n', v1);  
    v1 := UTL_FILE.GET_LINE(inf, 256);  
    PERFORM UTL_FILE.PUT(otf, v1);  
    PERFORM UTL_FILE.NEW_LINE(otf);  
    PERFORM UTL_FILE.FFLUSH(otf);
```

```

inf := UTL_FILE.FCLOSE(inf);
otf := UTL_FILE.FCLOSE(otf);

PERFORM UTL_FILE.FCOPY(mydir, outfile, mydir, copyfile, 2,
3);
PERFORM UTL_FILE.FRENAME(mydir, outfile, mydir,
'rename.txt');

END;
$$ LANGUAGE plpgsql;

SELECT gen_file('/home/pgsql', 'input.txt', 'output.txt',
'copyfile.txt');

```

### 3. Post-processing

If you remove a job that uses UTL\_FILE, delete the directory information from the UTL\_FILE.UTL\_FILE\_DIR table. Ensure that the directory information is not being used by another job before deleting it.

Refer to "Registering and Deleting Directories" for information on how to delete the directory.

## F.56.6.14. UTL\_RAW

### Overview

Provides SQL functions for manipulating RAW datatypes.

**Table F.135. UTL\_RAW Features**

Feature	Description
BIT_AND	Performs bitwise logical "and" of the values in RAW r1 with RAW r2 and returns the "anded" result RAW.
BIT_COMPLEMENT	Performs bitwise logical "complement" of the values in RAW r and returns the "complement'ed" result RAW.
BIT_OR	Performs bitwise logical "or" of the values in RAW r1 with RAW r2 and returns the "or'd" result RAW.
BIT_XOR	Performs bitwise logical "exclusive or" of the values in RAW r1 with RAW r2 and returns the "xor'd" result RAW.
CAST_FROM_BINARY_INTEGER	Returns the RAW binary representation of a BINARY_INTEGER value.
CAST_FROM_NUMBER	Returns the RAW binary representation of a NUMBER value.
CAST_TO_BINARY_INTEGER	Casts the RAW binary representation of a BINARY_INTEGER into a BINARY_INTEGER.
CAST_TO_NUMBER	Casts the RAW binary representation of a NUMBER into a NUMBER.
CAST_TO_RAW	Converts a text value into a RAW value.
CAST_TO_VARCHAR2	Converts a RAW value into a text value.

Feature	Description
COMPARE	Compares RAW r1 against RAW r2.
CONCAT	Concatenates up to 12 RAWs into a single RAW.
CONVERT	Converts RAW r from character set from_charset to character set to_charset and returns the resulting RAW.
COPIES	Returns n copies of r concatenated together.
LENGTH	Returns the length in bytes of a RAW r.
OVERLAY	Overlays the specified portion of target RAW with overlay RAW, starting from byte position pos of target and proceeding for len bytes.
REVERSE	Reverses a byte sequence in RAW r from end to end.
TRANSLITERATE	Translates the bytes in the input RAW r according to the bytes in the translation RAWs from_set and to_set.
TRANSLATE	Converts the bytes in the input RAW r according to the bytes in the transliteration RAWs from_set and to_set.
XRANGE	Reverses a byte sequence in RAW r from end to end.
REVERSE	Returns a RAW containing all valid 1-byte encodings in succession, beginning with the value start_byte and ending with the value end_byte.

### Syntax

```

CAST_TO_VARCHAR2(r raw) RETURNS TEXT
CAST_TO_RAW(c TEXT) RETURNS RAW
CONCAT(r1 RAW,r2 RAW,r3 RAW,r4 RAW,r5 RAW,r6 RAW,r7 RAW,r8 RAW,r9
RAW,r10 RAW,r11 RAW,r12 RAW) RETURNS RAW
LENGTH(r RAW) RETURNS INT4
SUBSTR(r RAW,pos INT4,len INT4 DEFAULT null) RETURNS RAW
TRANSLITERATE(r RAW,to_set RAW DEFAULT ''::raw ,from_set RAW
DEFAULT ''::raw,pad RAW DEFAULT '00'::raw) RETURNS RAW
TRANSLATE(r RAW,from_set RAW,to_set RAW) RETURNS RAW
COPIES(r RAW,n INT8) RETURNS RAW
OVERLAY(overlay_str RAW,target RAW,pos INT4 DEFAULT 1,len INT4
DEFAULT NULL,pad RAW DEFAULT '00'::raw) RETURNS RAW
XRANGE(start_byte RAW,end_byte RAW) RETURNS RAW
REVERSE(r RAW) RETURNS RAW
COMPARE(r1 RAW,r2 RAW,pad RAW) RETURNS INT4
CONVERT(r RAW,to_charset TEXT,from_charset TEXT) RETURNS RAW
BIT_AND(r1 RAW,r2 RAW) RETURNS RAW
BIT_OR(r1 RAW,r2 RAW) RETURNS RAW
BIT_XOR(r1 RAW,r2 RAW) RETURNS RAW
BIT_COMPLEMENT(r RAW) RETURNS RAW
CAST_TO_NUMBER(r RAW)RETURNS NUMERIC
CAST_FROM_NUMBER(n NUMERIC) RETURNS RAW
CAST_TO_BINARY_INTEGER(r RAW,endianess INT)RETURNS INT4
CAST_FROM_BINARY_INTEGER(n INT4,endianess INT) RETURNS RAW

```

### F.56.6.14.1. Description of Features

This section explains each feature of `dbms_job`.

#### **CAST\_TO\_VARCHAR2**

- This function converts a RAW value represented using some number of data bytes into a text value with that number of data bytes.

#### **Example**

```
select utl_raw.cast_to_varchar2('43616D65726F6E') from dual;
```

#### **CAST\_TO\_RAW**

- This function converts a text value represented using some number of data bytes into a RAW value with that number of data bytes. The data itself is not modified in any way, but its datatype is recast to a RAW datatype.

#### **Example**

```
select utl_raw.cast_to_raw('##') from dual;
```

#### **CONCAT**

- This function concatenates up to 12 RAWs into a single RAW.

#### **Example**

```
select utl_raw.concat('1', '0102', 'f', '1a2b' ) from dual;
```

#### **LENGTH**

- This function returns the length in bytes of a RAW `r`.

#### **Example**

```
select UTL_RAW.length('FFFF'::raw) from dual;
```

#### **SUBSTR**

- If `pos` is positive, then `SUBSTR` counts from the beginning of `r` to find the first byte. If `pos` is negative, then `SUBSTR` counts backward from the end of the `r`. The value `pos` can be 0.

#### **Example**

```
select utl_raw.substr('0102030405', 3, 2 ) from dual;
```

#### **TRANSLITERATE**

- This function converts the bytes in the input RAW `r` according to the bytes in the transliteration RAWs `from_set` and `to_set`. Successive bytes in `r` are looked up in the `from_set`, and, if not found,



copied unaltered to the result RAW. If found, then they are replaced in the result RAW by either corresponding bytes in the to\_set, or the pad byte when no correspondence exists.

**Example**

```
select utl_raw.transliterate( '010203040502', '0709', '01020304',  
  'ff' ) from dual;
```

**TRANSLATE**

- This function translates the bytes in the input RAW r according to the bytes in the translation RAWs from\_set and to\_set. If a byte in r has a matching byte in from\_set, then it is replaced by the byte in the corresponding position in to\_set, or deleted.

**Example**

```
select utl_raw.translate( '0102030405', '0304', '09' ) from dual;
```

**COPIES**

- This function returns n copies of r concatenated together.

**Example**

```
select utl_raw.copies( '010203', 3 ) from dual;
```

**OVERLAY**

- This function overlays the specified portion of target RAW with overlay\_str RAW, starting from byte position pos of target and proceeding for len bytes.
- If overlay\_str has less than len bytes, then it is extended to len bytes using the pad byte. If overlay\_str exceeds len bytes, then the extra bytes in overlay\_str are ignored. If len bytes beginning at position pos of target exceeds the length of target, then target is extended to contain the entire length of overlay\_str.

**Example**

```
select utl_raw.overlay( 'aabb', '010203', 5, 1, 'FF' ) from dual;
```

**XRANGE**

- This function returns a RAW value containing the succession of one-byte encodings beginning and ending with the specified byte-codes.
- If the start\_byte value is greater than the end\_byte value, then the succession of resulting bytes begins with start\_byte, wraps through x'FF' back to x'00', then ends at end\_byte.

**Example**

```
select utl_raw.xrange( 'FA', '01' ) from dual;
```

**REVERSE**

- This function reverses a byte sequence in RAW r from end to end. For example, x'0102F3' would be reversed to x'F30201', and 'xyz' would be reversed to 'zyx'. The result length is the same as the input RAW length.

**Example**

```
select utl_raw.reverse( '010203040506070809' ) from dual;
```

**COMPARE**

- This function compares two RAW values. If they differ in length, then the shorter is extended on the right according to the optional pad parameter.

**Example**

```
select utl_raw.compare( '010203', '01020304', '04' ) from dual;
```

**CONVERT**

- This function converts RAW r from character set from\_charset to character set to\_charset and returns the resulting RAW.
- Both from\_charset and to\_charset must be supported character sets defined to the LightDB server.

**Example**

```
select utl_raw.convert( rawout( '##'::BYTEA)::text::raw, 'GBK', 'UTF8' )  
from dual;
```

**BIT\_AND**

- This function performs bitwise logical "and" of the values in RAW r1 with RAW r2 and returns the "anded" result RAW.
- If r1 and r2 differ in length, the shorter of the two RAWs will extend to same length by add '00'. (it is not same with oracle).

**Example**

```
select utl_raw.bit_and('1234ffdd', 'fff1234f') from dual;
```

**BIT\_OR**

- This function performs bitwise logical "or" of the values in RAW r1 with RAW r2 and returns the or'd result RAW.
- If r1 and r2 differ in length, the shorter of the two RAWs will extend to same length by add '00'. (it is not same with oracle).

**Example**

```
select utl_raw.bit_or('1234ffdd', 'fff1234f') from dual;
```

### **BIT\_XOR**

- This function performs bitwise logical "exclusive or" of the values in RAW r1 with RAW r2 and returns the xor'd result RAW.
- If r1 and r2 differ in length, the shorter of the two RAWs will extend to same length by add '00'. (it is not same with oracle).

#### **Example**

```
select utl_raw.bit_xor('1234ffdd','1234ffee') from dual;
```

### **BIT\_COMPLEMENT**

- This function performs bitwise logical "complement" of the values in RAW r and returns the complement'ed result RAW. The result length equals the input RAW r length.

#### **Example**

```
select UTL_raw.bit_complement('1122FF') from dual;
```

### **CAST\_TO\_NUMBER**

- This function casts the RAW binary representation of a NUMBER into a NUMBER.

#### **Example**

```
select utl_raw.cast_TO_number('C10215') from dual;
```

### **CAST\_FROM\_NUMBER**

- This function returns the RAW binary representation of a NUMBER value.

#### **Example**

```
select UTL_raw.cast_from_number(1.2) from dual;
```

### **CAST\_TO\_BINARY\_INTEGER**

- This function casts the RAW binary representation of a INTEGER into a INTEGER.(oracle is BINARY\_INTEGER)

#### **Example**

```
select utl_raw.cast_to_binary_integer('FF00') from dual;
```

### **CAST\_FROM\_BINARY\_INTEGER**

- This function returns the RAW binary representation of a INTEGER value.(oracle is BINARY\_INTEGER)

#### **Example**

```
select utl_raw.cast_from_binary_integer(65280) from dual;
```

## F.56.6.15. UTL\_URL

### Overview

Has two functions that provide escape and unescape mechanisms for URL characters.

**Table F.136. UTL\_URL Features**

Feature	Description
ESCAPE	Returns a URL with illegal characters (and optionally reserved characters) escaped using the %2-digit-hex-code format.
UNESCAPE	Unescapes the escape character sequences to their original forms in a URL. Convert the %XX escape character sequences to the original characters.

### Syntax

```
ESCAPE(url TEXT,escape_reserved_chars BOOL DEFAULT
FALSE,url_charset TEXT DEFAULT 'UTF8') RETURNS TEXT
UNESCAPE(url TEXT,url_charset TEXT DEFAULT 'UTF8') RETURNS TEXT
```

### F.56.6.15.1. Description of Features

This section explains each feature of dbms\_job.

#### ESCAPE

- This function returns a URL with illegal characters (and optionally reserved characters) escaped using the %2-digit-hex-code format.

#### Example

```
select utl_url.escape('http://###.com') from dual;
```

#### UNESCAPE

- This function unescapes the escape character sequences to its original form in a URL, to convert the %XX escape character sequences to the original characters.

#### Example

```
select utl_url.unescape('http%3A%2F%2F
%E6%96%B0%E5%B9%B4%E5%A5%BD.com', 'utf8') from dual;
```

## F.56.6.16. UTL\_ENCODE

### Overview

Provides functions that encode RAW data into a standard encoded format.

**Table F.137. UTL\_ENCODE Features**

Feature	Description
BASE64_DECODE	Reads the base 64-encoded RAW input string and decodes it to its original RAW value.
BASE64_ENCODE	Encodes the binary representation of the RAW value into base 64 elements and returns it in the form of a RAW string.
MIMEHEADER_DECODE	Decodes a string from mime header format.
MIMEHEADER_ENCODE	Encodes a string into mime header format.
QUOTED_PRINTABLE_DECODE	Reads the text quoted printable format input string and decodes it to the corresponding RAW string.
QUOTED_PRINTABLE_ENCODE	Reads the RAW input string and encodes it to the corresponding quoted printable format string.
TEXT_DECODE	Decodes a character set sensitive text string.
TEXT_ENCODE	Encodes a character set sensitive text string.
UUDECODE	Reads the RAW uuencode format input string and decodes it to the corresponding RAW string.
UUENCODE	Reads the RAW input string and encodes it to the corresponding uuencode format string.

**Syntax**

```

BASE64_DECODE(r RAW) RETURNS RAW
BASE64_ENCODE(r RAW) RETURNS RAW
MIMEHEADER_DECODE(buf TEXT) RETURNS TEXT
MIMEHEADER_ENCODE(buf TEXT,encode_charset TEXT default
  'UTF8'::text,encoding INT4 default 2::int4) RETURNS TEXT
QUOTED_PRINTABLE_DECODE(r RAW) RETURNS RAW
QUOTED_PRINTABLE_ENCODE(r RAW) RETURNS RAW
TEXT_DECODE(buf TEXT,encode_charset TEXT default
  'UTF8'::text,encoding INT4 default 2::int4) RETURNS TEXT
TEXT_ENCODE(buf TEXT,encode_charset TEXT default
  'UTF8'::text,encoding INT4 default 2::int4) RETURNS TEXT
UUDECODE(r RAW) RETURNS RAW
UUENCODE(r RAW,type INT default 1::int,filename TEXT default
  'uuencode.txt',permission TEXT default '0') RETURNS RAW

```

**F.56.6.16.1. Description of Features**

This section explains each feature of dbms\_job.

**BASE64\_DECODE**

- This function reads the base 64-encoded RAW input string and decodes it to its original RAW value.

**Example**

```
select utl_encode.base64_decode('3572574C364B2B56') from dual;
```

**BASE64\_ENCODE**

- This function encodes the binary representation of the RAW value into base 64 elements and returns it in the form of a RAW string.

**Example**

```
select utl_encode.base64_encode(rawtohex('##')::raw) from dual;
```

**MIMEHEADER\_DECODE**

- Decodes a string from mime header format(=?<charset> ?<encoding> ?<encoded text>?= ').

**Example**

```
select UTL_ENCODE.mimeheader_decode('=?UTF-8?Q?
What=20is=20the=20date=20=E7=8E=8B=20=3D20=20/=20\=3F?= ' ) from
dual;
```

**MIMEHEADER\_ENCODE**

- This function produces as output an "encoded word" of the form(=?<charset> ?<encoding> ?<encoded text>?= ').
- The ENCODING input parameter accepts as valid values UTL\_ENCODE.QUOTED\_PRINTABLE or UTL\_ENCODE.BASE64 or NULL. If NULL, quoted-printable encoding is selected as a default value.
- The <charset> value is specified as the input parameter encode\_charset.

**Example**

```
select utl_encode.MIMEHEADER_ENCODE('What is the date # =20 / \?',
encode_charset =>'UTF8', encoding => 1 ) from dual;
```

**QUOTED\_PRINTABLE\_DECODE**

- This function reads the raw quoted printable format input string and decodes it to the corresponding RAW string.

**Example**

```
select
utl_encode.quoted_printable_decode('3D45353D42453D3830313233345C61732064663D33
from dual;
```

**QUOTED\_PRINTABLE\_ENCODE**

- This function reads the RAW input string and encodes it to the corresponding quoted printable format string.

**Example**

```
select
utl_encode.quoted_printable_decode('3D45353D42453D3830313233345C61732064663D33
from dual;
```

**TEXT\_DECODE**

- This function converts the input text to the target character set as specified by the `encode_charset` parameter, if not NULL. The encoded text is converted to the base character set of database.
- You can decode from either quoted-printable or base64 format, with regard to each encoding parameter. 1 for base64, 2 for quoted-printable, default is quoted-printable format.

**Example**

```
select utl_encode.text_decode('=CD=F91234\as
df=3DAB',encode_charset => 'GBK',encoding => 2) from dual;
```

**TEXT\_ENCODE**

- This function converts the input text to the target character set as specified by the `encode_charset` parameter, if not NULL. The text is encoded to either base64 or quoted-printable format, as specified by the encoding parameter.

**Example**

```
select utl_encode.text_encode('#12\as df=AB',encode_charset =>
'GBK', encoding => 1) from dual;
```

**UUDECODE**

- This function reads the RAW uuencode format input string and decodes it to the corresponding RAW string.

**Example**

```
select UTL_ENCODE.uudecode(rawtohex(' ,6[C9&5FA$R,S0`')::raw) from
dual;
```

**UUENCODE**

- This function reads the RAW input string and encodes it to the corresponding uuencode format string.

**Example**

```
select UTL_ENCODE.uuencode('5BB8D91959A113233340')::raw) from dual;
```

## F.56.7. Transaction behavior

Most of the transaction behavior are exactly same, however the below stuff is not.

### F.56.7.1. Handled Statement Failure.

```
create table t (a int primary key, b int);
begin;
insert into t values(1,1);
insert into t values(1, 1);
commit;
```

Oracle : commit can succeed. t has 1 row after that.

LightDB: commit failed due to the 2nd insert failed. so t has 0 row.

## F.56.7.2. DML with Subquery

Case 1:

```
create table dml(a int, b int);
insert into dml values(1, 1), (2,2);

-- session 1:
begin;
delete from dml where a in (select min(a) from dml);

--session 2:
delete from dml where a in (select min(a) from dml);

-- session 1:
commit;
```

In Oracle: 1 row deleted in sess 2. so 0 rows in the dml at last.

In LightDB: 0 rows are deleted in sess 2, so 1 rows in the dml at last.

Oracle probably detects the min(a) is changed and rollback/rerun the statement.

The same reason can cause the below difference as well.

```
create table su (a int, b int);
insert into su values(1, 1);

- session 1:
begin;
update su set b = 2 where b = 1;

- sess 2:
select * from su where a in (select a from su where b = 1) for
update;

- sess 1:
commit;
```

In Oracle, 0 row is selected. In LightDB, 1 row (1, 2) is selected.

A best practice would be never use subquery in DML & SLEECT ... FOR UPDATE. Even in Oracle, the behavior is inconsistent as well. Oracle between 11.2.0.1 and 11.2.0.3 probably behavior same as LightDB, but other versions not.



## F.56.8. System View Reference

These views are based on oracle 11g, but some views include some fields from the new version.

Views are created under oracle and sys schema.

In order to be compatible with oracle, the following views have the same fields as the corresponding views in oracle , but return NULL for those fields whose field values cannot be obtained or are difficult to obtain.

The supported fields are listed below. Some fields have different meanings from oracle.

### F.56.8.1. [DBA/ALL/USER]\_SEQUENCES

- DBA\_SEQUENCES describes all sequences in the database.
- The ALL\_SEQUENCES view is currently the same as the DBA\_SEQUENCES view, and no permission verification is done like oracle.
- USER\_SEQUENCES describes all sequences owned by the current user.

**Table F.138. ALL\_SEQUENCES**

Column	Description
SEQUENCE_OWNER	Owner of the sequence
SEQUENCE_NAME	Sequence name
MIN_VALUE	Minimum value of the sequence
MAX_VALUE	Maximum value of the sequence
INCREMENT_BY	Value by which sequence is incremented
CYCLE_FLAG	Indicates whether the sequence wraps around on reaching the limit (Y) or not (N)
ORDER_FLAG	Indicates whether sequence numbers are generated in order (Y) or not (N), Under lightdb this is always Y
CACHE_SIZE	Number of sequence numbers to cache
LAST_NUMBER	Last sequence number written to disk.

### F.56.8.2. [DBA/ALL/USER]\_SYNONYMS

- SYNONYMS is not supported in LightDB yet, so these view are empty now.

### F.56.8.3. [DBA/ALL/USER]\_TAB\_COLS, COLS, [DBA/ALL/USER]\_TAB\_COLUMNS

- DBA\_TAB\_COLS describes the columns of all tables, views in the database.
- The ALL\_TAB\_COLS view is currently the same as the DBA\_TAB\_COLS view, and no permission verification is done like oracle.
- USER\_TAB\_COLS describes the columns of the tables and views owned by the current user. This view does not display the OWNER column.
- COLS is same with USER\_TAB\_COLS.
- DBA\_TAB\_COLUMNS describes the columns of all tables and views in the database.

- The ALL\_TAB\_COLUMNS view is currently the same as the DBA\_TAB\_COLUMNS view, and no permission verification is done like oracle.
- USER\_TAB\_COLUMNS describes the columns of the tables and views owned by the current user. This view does not display the OWNER column.
- [DBA/ALL/USER]\_TAB\_COLS view differs from [DBA/ALL/USER]\_TAB\_COLUMNS in that hidden columns are not filtered out(HIDDEN\_COLUMN,VIRTUAL\_COLUMN,SEGMENT\_COLUMN\_ID,INTERNAL\_COLUMN\_ID).

**Table F.139. ALL\_TAB\_COLS**

Column	Description
OWNER	Owner of the table, view
TABLE_NAME	Name of the table, view
COLUMN_NAME	Column name
DATA_TYPE	Datatype of the column
DATA_TYPE_OWNER	Owner of the datatype of the column
DATA_LENGTH	Length of the column (in char for character Types; in byte for other types, for number/ numeric it is always 22)
DATA_PRECISION	Decimal precision for NUMBER datatype; binary precision for FLOAT datatype; NULL for all other datatypes
DATA_SCALE	Digits to the right of the decimal point in a number
NULLABLE	Indicates whether a column allows NULLs. The value is N if there is a NOT NULL constraint on the column or if the column is part of a PRIMARY KEY
COLUMN_ID	Sequence number of the column as created
DEFAULT_LENGTH	Length of the default value for the column
DATA_DEFAULT	Default value for the column
NUM_DISTINCT	Number of distinct values in the column
NUM_NULLS	Number of NULLs in the column
AVG_COL_LEN	Average length of the column (in bytes)
CHAR_LENGTH	Displays the length of the column in characters
CHAR_USED	Indicates that the column uses BYTE length semantics (B) or CHAR length semantics (C), or whether the datatype is not any of the following (NULL)

#### F.56.8.4. [DBA/ALL/USER]\_TAB\_COL\_STATISTICS

- DBA\_TAB\_COL\_STATISTICS contains column statistics and histogram information extracted from "DBA\_TAB\_COLUMNS". Its columns are the same as those in "ALL\_TAB\_COL\_STATISTICS".
- The ALL\_TAB\_COL\_STATISTICS view is currently the same as the DBA\_SEQUENCES view, and no permission verification is done like oracle.
- USER\_TAB\_COL\_STATISTICS displays such information extracted from "USER\_TAB\_COLUMNS". This view does not display the OWNER column.

**Table F.140. ALL\_TAB\_COL\_STATISTICS**

Column	Description
OWNER	Owner of the table
TABLE_NAME	Name of the table
COLUMN_NAME	Column name
NUM_DISTINCT	Number of distinct values in the column
NUM_NULLS	Number of NULLs in the column
AVG_COL_LEN	Average length of the column (in bytes)

**F.56.8.5. [DBA/ALL/USER]\_OBJECTS, OBJ**

- DBA\_OBJECTS describes all objects in the database. Its columns are the same as those in "ALL\_OBJECTS".
- The ALL\_OBJECTS view is currently the same as the DBA\_OBJECTS view, and no permission verification is done like oracle.
- USER\_OBJECTS describes all objects owned by the current user. This view does not display the OWNER column.
- OBJ is same with USER\_OBJECTS.

**Table F.141. ALL\_OBJECTS**

Column	Description
OWNER	Owner of the object
OBJECT_NAME	Name of the object
SUBOBJECT_NAME	Name of the subobject (for example, partition), NULL if not exist
OBJECT_ID	Dictionary object number of the object
DATA_OBJECT_ID	Dictionary object number of the segment that contains the object
OBJECT_TYPE	Type of the object
STATUS	Status of the object: VALID, INVALID
TEMPORARY	Indicates whether the object is temporary (the current session can see only data that it placed in this object itself) (Y) or not (N)

**F.56.8.6. [DBA/ALL/USER]\_CATALOG**

- DBA\_CATALOG lists all tables, views, and sequences in the database(no cluster and synonyms).
- The ALL\_CATALOG view is currently the same as the DBA\_CATALOG view, and no permission verification is done like oracle.
- USER\_OCATALOG displays the tables, views, and sequences in the current user's schema.
- All column in oracle view is supported.

**Table F.142. ALL\_CATALOG**

Column	Description
OWNER	Owner of the TABLE, VIEW, SEQUENCE

Column	Description
TABLE_NAME	Name of the TABLE, VIEW, SEQUENCE
TABLE_TYPE	Type of the TABLE, VIEW, SEQUENCE

### F.56.8.7. DICTIONARY, DICT

- DICTIONARY/DICT contains descriptions of data dictionary tables and views.

**Table F.143. DICTIONARY**

Column	Description
TABLE_NAME	Name of the object
COMMENTS	Text comment on the object

### F.56.8.8. [DBA/ALL/USER]\_DEPENDENCIES

- DBA\_DEPENDENCIES describes all dependencies in the database between procedures, packages, functions, package bodies, and triggers, including dependencies on views created without any database links. This view does not display the SCHEMAID column.
- The ALL\_DEPENDENCIES view is currently the same as the DBA\_DEPENDENCIES view, and no permission verification is done like oracle.
- USER\_DEPENDENCIES describes dependencies between objects in the current user's schema. This view does not display the OWNER column.

**Table F.144. ALL\_DEPENDENCIES**

Column	Description
OWNER	Owner of the object
NAME	Name of the object
TYPE	Type of the object
REFERENCED_OWNER	Owner of the referenced object (remote owner if remote object)
REFERENCED_NAME	Name of the referenced object
REFERENCED_TYPE	Type of the referenced object
DEPENDENCY_TYPE	Type of the dependency (oracle: Indicates whether the dependency is a REF dependency (REF) or not (HARD))

### F.56.8.9. [DBA/ALL/USER]\_SOURCE

- DBA\_SOURCE describes the text source of all stored objects in the database.
- The ALL\_SOURCE view is currently the same as the DBA\_SOURCE view, and no permission verification is done like oracle.
- USER\_SOURCE describes the text source of the stored objects owned by the current user. This view does not display the OWNER column.

**Table F.145. ALL\_SOURCE**

Column	Description
OWNER	Owner of the object

Column	Description
NAME	Name of the object
TYPE	Type of object: FUNCTION, PACKAGE, PACKAGE BODY, PROCEDURE, TRIGGER
LINE	Line number of this line of source
TEXT	Text source of the stored object

### F.56.8.10. [DBA/ALL/USER]\_PROCEDURES

- DBA\_PROCEDURES lists all functions and procedures, along with associated properties.
- The ALL\_PROCEDURES view is currently the same as the DBA\_PROCEDURES view, and no permission verification is done like oracle.
- USER\_PROCEDURES lists all functions and procedures owned by the current user, along with associated properties. It does not contain the OWNER column.
- These views indicates whether or not a function is pipelined, parallel enabled or an aggregate function. If a function is pipelined or an aggregate function, the associated implementation type (if any) is also identified.

**Table F.146. ALL\_PROCEDURES**

Column	Description
OWNER	Owner of the procedure
OBJECT_NAME	Name of the object: top-level function, procedure, or package name
OBJECT_ID	Object number of the object
OBJECT_TYPE	The typename of the object
AGGREGATE	Indicates whether the procedure is an aggregate function (YES) or not (NO)
PARALLEL	Indicates whether the procedure or function is parallel-enabled (YES) or not (NO)
DETERMINISTIC	YES, if the procedure/function is declared to be deterministic; otherwise NO

### F.56.8.11. [DBA/ALL/USER]\_TRIGGERS

- DBA\_TRIGGERS describes all triggers in the database.
- The ALL\_TRIGGERS view is currently the same as the DBA\_TRIGGERS view, and no permission verification is done like oracle.
- USER\_TRIGGERS describes the triggers owned by the current user

**Table F.147. ALL\_TRIGGERS**

Column	Description
OWNER	Owner of the trigger
TRIGGER_NAME	Name of the trigger
TRIGGER_TYPE	When the trigger fires: BEFORE STATEMENT, BEFORE EACH ROW, AFTER STATEMENT, AFTER EACH ROW, INSTEAD OF EACH ROW

Column	Description
TRIGGERING_EVENT	DML that fires the trigger
TABLE_OWNER	Owner of the table on which the trigger is defined
BASE_OBJECT_TYPE	Base object on which the trigger is defined: TABLE, VIEW
TABLE_NAME	Indicates the table or view name on which the trigger is defined
REFERENCING_NAMES	Names used for referencing OLD and NEW column values from within the trigger
WHEN_CLAUSE	Must evaluate to TRUE for TRIGGER_BODY to execute
STATUS	Indicates whether the trigger is enabled (ENABLED) or disabled (DISABLED); a disabled trigger will not fire
ACTION_TYPE	Action type of the trigger body: 'PL/SQL'
TRIGGER_BODY	Statements executed by the trigger when it fires
BEFORE_STATEMENT	Indicates whether the trigger has a BEFORE STATEMENT section (YES) or not (NO)
BEFORE_ROW	Indicates whether the trigger has a BEFORE EACH ROW section (YES) or not (NO)
AFTER_ROW	Indicates whether the trigger has an AFTER EACH ROW section (YES) or not (NO)
AFTER_STATEMENT	Indicates whether the trigger has an AFTER STATEMENT section (YES) or not (NO)
INSTEAD_OF_ROW	Indicates whether the trigger has an INSTEAD OF section (YES) or not (NO)

### F.56.8.12. [DBA/ALL/USER]\_TRIGGER\_COLS

- DBA\_TRIGGER\_COLS describes the use of columns in all triggers in the database.
- The ALL\_TRIGGER\_COLS view is currently the same as the DBA\_TRIGGER\_COLS view, and no permission verification is done like oracle.
- USER\_TRIGGER\_COLS describes the use of columns in the triggers owned by the current user and in triggers on tables owned by the current user.

**Table F.148. ALL\_TRIGGER\_COLS**

Column	Description
TRIGGER_OWNER	Owner of the trigger
TRIGGER_NAME	Name of the trigger
TABLE_OWNER	Owner of the table on which the trigger is defined
TABLE_NAME	Table on which the trigger is defined
COLUMN_NAME	Name of the column used in the trigger

### F.56.8.13. [DBA/ALL/USER]\_TYPES

- DBA\_TYPES describes all object types in the database.

- The ALL\_TYPES view is currently the same as the DBA\_TYPES view, and no permission verification is done like oracle.
- USER\_TYPES describes the object types owned by the current user. This view does not display the OWNER column.

**Table F.149. ALL\_TYPES**

Column	Description
OWNER	Owner of the type
TYPE_NAME	Name of the type
TYPE_OID	Object identifier (OID) of the type
TYPECODE	Typecode of the type
PREDEFINED	Indicates whether the type is a predefined type (YES) or not (NO)

### F.56.8.14. [DBA/ALL/USER]\_CONSTRAINTS

- DBA\_CONSTRAINTS describes all constraint definitions in the database.
- The ALL\_CONSTRAINTS view is currently the same as the DBA\_CONSTRAINTS view, and no permission verification is done like oracle.
- USER\_CONSTRAINTS describes constraint definitions on tables in the current user's schema.

**Table F.150. ALL\_CONSTRAINTS**

Column	Description
OWNER	Owner of the constraint definition
CONSTRAINT_NAME	Name of the constraint definition
CONSTRAINT_TYPE	Type of the constraint definition  c - Check constraint on a table  p - Primary key  u - Unique key  f - Constraint that involves a REF column  t - Constraint triggers  t - exclusivity Constraint
TABLE_NAME	Name associated with the table (or view) with the constraint definition
SEARCH_CONDITION	Text of search condition for a check constraint
R_OWNER	Owner of the table referred to in a referential constraint
DELETE_RULE	Delete rule for a referential constraint: 'NO ACTION', 'RESTRICT', 'CASCADE', 'SET NULL', 'SET DEFAULT'
STATUS	Enforcement status of the constraint: 'ENABLED', 'DISABLED'
DEFERRABLE	Indicates whether the constraint is deferrable (DEFERRABLE) or not (NOT DEFERRABLE)

Column	Description
DEFERRED	Indicates whether the constraint was initially deferred (DEFERRED) or not (IMMEDIATE)
VALIDATED	Has the constraint been validated? Currently, can be false only for foreign keys and CHECK constraints
INDEX_OWNER	Name of the user owning the index
INDEX_NAME	Name of the index (only shown for unique, primary key, foreign key, or exclusion constraint)
INVALID	Indicates whether the constraint is invalid (INVALID) or not (NULL)

### F.56.8.15. [DBA/ALL/USER]\_CONS\_COLUMNS

- DBA\_CONS\_COLUMNS describes all columns in the database that are specified in constraints.
- The ALL\_CONS\_COLUMNS view is currently the same as the DBA\_CONS\_COLUMNS view, and no permission verification is done like oracle.
- USER\_CONS\_COLUMNS describes columns that are owned by the current user and that are specified in constraints.
- All column in oracle are supported

**Table F.151. ALL\_CONS\_COLUMNS**

Column	Description
OWNER	Owner of the constraint definition
CONSTRAINT_NAME	Name of the constraint definition
TABLE_NAME	Name of the table with the constraint definition
COLUMN_NAME	Name of the column or attribute of the object type column specified in the constraint definition
POSITION	Original position of the column or attribute in the definition of the object

### F.56.8.16. [DBA/ALL/USER]\_VIEWS

- DBA\_VIEWS describes all views in the database.
- The ALL\_VIEWS view is currently the same as the DBA\_VIEWS view, and no permission verification is done like oracle.
- USER\_VIEWS describes the views owned by the current user. This view does not display the OWNER column.

**Table F.152. ALL\_VIEWS**

Column	Description
OWNER	Owner of the view
VIEW_NAME	Name of the view
TEXT_LENGTH	Length of the view text



Column	Description
TEXT	View text

### F.56.8.17. [DBA/ALL/USER]\_TABLES, [DBA/ALL/USER]\_ALL\_TABLES, TAB

- DBA\_ALL\_TABLES describes all object tables and relational tables in the database.
- The ALL\_ALL\_TABLES view is currently the same as the DBA\_ALL\_TABLES view, and no permission verification is done like oracle.
- USER\_ALL\_TABLES describes the object tables and relational tables owned by the current user. This view does not display the OWNER column.
- [DBA/ALL/USER]\_TABLES does not display the OBJECT\_ID\_TYPE, TABLE\_TYPE\_OWNER and TABLE\_TYPE column.
- [DBA/ALL/USER]\_TABLES has RESULT\_CACHE column, but [DBA/ALL/USER]\_ALL\_TABLES does not.
- TABS is same with USER\_TABLES.

**Table F.153. ALL\_ALL\_TABLES**

Column	Description
OWNER	Owner of the table
TABLE_NAME	Name of the table
TABLESPACE_NAME	Name of the tablespace containing the table
LOGGING	Indicates whether or not changes to the table are logged
NUM_ROWS	Number of rows in the table
BLOCKS	Number of used blocks in the table
AVG_ROW_LEN	Average row length, including row overhead
LAST_ANALYZED	Date on which the table was most recently analyzed
PARTITIONED	Indicates whether the table is partitioned (YES) or not (NO)
TEMPORARY	Indicates whether the table is temporary (Y) or not (N)
ROW_MOVEMENT	If a partitioned table, indicates whether row movement is enabled (ENABLED) or disabled (DISABLED)  Always is 'ENABLE'

### F.56.8.18. [DBA/ALL/USER]\_TAB\_STATISTICS

- DBA\_TAB\_STATISTICS displays optimizer statistics for all tables in the database.
- The ALL\_TAB\_STATISTICS view is currently the same as the DBA\_TAB\_STATISTICS view, and no permission verification is done like oracle.
- USER\_TAB\_STATISTICS displays optimizer statistics for the tables owned by the current user. This view does not display the OWNER column.

- [DBA/ALL/USER]\_TABLES does not display the OBJECT\_ID\_TYPE, TABLE\_TYPE\_OWNER and TABLE\_TYPE column.

**Table F.154. ALL\_TAB\_STATISTICS**

Column	Description
OWNER	Owner of the object
TABLE_NAME	Name of the table
TABLESPACE_NAME	Name of the tablespace containing the table
PARTITION_NAME	Name of the partition
PARTITION_POSITION	Position of the partition within the table
OBJECT_TYPE	Type of the object#TABLE, PARTIOTION, SUBPARTITION
NUM_ROWS	Number of rows in the object
BLOCKS	Number of used blocks in the object
AVG_ROW_LEN	Average row length, including row overhead
LAST_ANALYZED	Date of the most recent time the table was analyzed

### F.56.8.19. [DBA/ALL/USER]\_TAB\_COMMENTS

- DBA\_TAB\_COMMENTS displays comments on all tables and views in the database.
- The ALL\_TAB\_COMMENTS view is currently the same as the DBA\_TAB\_COMMENTS view, and no permission verification is done like oracle.
- USER\_TAB\_COMMENTS displays comments on the tables and views owned by the current user. This view does not display the OWNER column.

**Table F.155. ALL\_TAB\_COMMENTS**

Column	Description
OWNER	Owner of the object
TABLE_NAME	Name of the object
TABLE_TYPE	Type of the object
COMMENTS	Comment on the object

### F.56.8.20. [DBA/ALL/USER]\_COL\_COMMENTS

- DBA\_COL\_COMMENTS displays comments on the columns of all tables and views in the database.
- The ALL\_COL\_COMMENTS view is currently the same as the DBA\_COL\_COMMENTS view, and no permission verification is done like oracle.
- USER\_COL\_COMMENTS displays comments on the columns of the tables and views owned by the current user. This view does not display the OWNER column.

**Table F.156. ALL\_COL\_COMMENTS**

Column	Description
OWNER	Owner of the object

Column	Description
TABLE_NAME	Name of the object
COLUMN_NAME	Name of the column
COMMENTS	Name of the column

### F.56.8.21. [DBA/ALL/USER]\_TAB\_MODIFICATIONS

- DBA\_TAB\_MODIFICATIONS describes such information for all tables in the database.
- The ALL\_TAB\_MODIFICATIONS view is currently the same as the DBA\_TAB\_MODIFICATIONS view, and no permission verification is done like oracle.
- USER\_TAB\_MODIFICATIONS describes such information for tables owned by the current user. This view does not display the TABLE\_OWNER column.

**Table F.157. ALL\_TAB\_MODIFICATIONS**

Column	Description
TABLE_OWNER	Owner of the modified table
TABLE_NAME	Name of the modified table
INSERTS	Approximate number of inserts since the last time statistics were gathered
UPDATES	Approximate number of updates since the last time statistics were gathered
DELETES	Approximate number of deletes since the last time statistics were gathered
TIMESTAMP	Indicates the last time the table was modified

### F.56.8.22. [DBA/ALL/USER]\_INDEXES, IND

- DBA\_INDEXES describes all indexes in the database.
- The ALL\_INDEXES view is currently the same as the DBA\_INDEXES view, and no permission verification is done like oracle.
- USER\_INDEXES describes the indexes owned by the current user. This view does not display the OWNER column.
- IND is same with USER\_INDEXES.

**Table F.158. ALL\_INDEXES**

Column	Description
OWNER	Owner of the index
INDEX_NAME	Name of the index
INDEX_TYPE	Type of the index, always NORMAL
TABLE_OWNER	Owner of the indexed object
TABLE_NAME	Name of the indexed object
TABLE_TYPE	Type of the indexed object: TABLE, VIEW, INDEX, SEQUENCE
UNIQUENESS	Indicates whether the index is unique (UNIQUE) or nonunique (NONUNIQUE)

Column	Description
TABLESPACE_NAME	Name of the tablespace containing the index
LOGGING	Indicates whether or not changes to the index are logged: 'YES', 'NO'
DISTINCT_KEYS	Number of distinct indexed values
STATUS	Indicates whether a nonpartitioned index is VALID or UNUSABLE
NUM_ROWS	Number of rows in the index
LAST_ANALYZED	Date on which this index was most recently analyzed
PARTITIONED	Indicates whether the index is partitioned (YES) or not (NO)
TEMPORARY	Indicates whether the index is on a temporary table (Y) or not (N)

### F.56.8.23. [DBA/ALL/USER]\_INDEX\_USAGE

- DBA\_INDEX\_USAGE displays cumulative statistics for each index.
- The ALL\_INDEX\_USAGE view is same with DBA\_INDEX\_USAGE(this view is not exist in oracle).
- USER\_INDEX\_USAGE describes cumulative statistics for each index owned by the current user(this view is not exist in oracle). This view does not display the OWNER column.

**Table F.159. DBA\_INDEX\_USAGE**

Column	Description
OBJECT_ID	Object ID for the index
NAME	Index name
OWNER	Index owner
TOTAL_ACCESS_COUNT	Total number of times the index has been accessed
TOTAL_ROWS_RETURNED	Total rows returned by the index

### F.56.8.24. [DBA/ALL/USER]\_IND\_COLUMNS

- DBA\_IND\_COLUMNS describes the columns of indexes on all tables in the database.
- The ALL\_IND\_COLUMNS view is currently the same as the DBA\_IND\_COLUMNS view, and no permission verification is done like oracle.
- USER\_IND\_COLUMNS describes the columns of indexes owned by the current user and columns of indexes on tables owned by the current user. This view does not display the INDEX\_OWNER or TABLE\_OWNER columns.

**Table F.160. ALL\_IND\_COLUMNS**

Column	Description
INDEX_OWNER	Owner of the index
INDEX_NAME	Name of the index
TABLE_OWNER	Owner of the table

Column	Description
TABLE_NAME	Name of the table
COLUMN_NAME	Column name or attribute of the object type column
COLUMN_POSITION	Position of the column or attribute within the index
COLUMN_LENGTH	Indexed length of the column, for number/numeric it is always 22
CHAR_LENGTH	Maximum codepoint length of the column
DESCEND	Indicates whether the column is sorted in descending order (DESC) or ascending order (ASC)

### F.56.8.25. [DBA/ALL/USER]\_IND\_EXPRESSIONS

- DBA\_IND\_EXPRESSIONS describes the expressions of all function-based indexes in the database.
- The ALL\_IND\_EXPRESSIONS view is currently the same as the DBA\_IND\_COLUMNS view, and no permission verification is done like oracle.
- USER\_IND\_EXPRESSIONS describes the expressions of function-based indexes on tables owned by the current user. This view does not display the INDEX\_OWNER or TABLE\_OWNER columns.

**Table F.161. ALL\_IND\_EXPRESSIONS**

Column	Description
INDEX_OWNER	Owner of the index
INDEX_NAME	Name of the index
TABLE_OWNER	Owner of the table
TABLE_NAME	Name of the table
COLUMN_EXPRESSION	Function-based index expression defining the column
COLUMN_POSITION	Position of the column or attribute within the index

### F.56.8.26. [DBA/ALL/USER]\_IND\_STATISTICS

- DBA\_IND\_STATISTICS displays optimizer statistics for all indexes in the database.
- The ALL\_IND\_STATISTICS view is currently the same as the DBA\_IND\_STATISTICS view, and no permission verification is done like oracle.
- USER\_IND\_STATISTICS displays optimizer statistics for the indexes on the tables owned by the current user. This view does not display the OWNER column.

**Table F.162. ALL\_IND\_STATISTICS**

Column	Description
OWNER	Owner of the index
INDEX_NAME	Name of the index
TABLE_OWNER	Owner of the indexed object
TABLE_NAME	Name of the indexed object

Column	Description
PARTITION_NAME	Function-based index expression defining the column
PARTITION_POSITION	Position of the column or attribute within the index
OBJECT_TYPE	Type of the object:INDEX, PARTITION  Always 'INDEX' now, because this view will not to get partition info
DISTINCT_KEYS	Number of distinct keys in the index
NUM_ROWS	Number of rows in the index
LAST_ANALYZED	Date of the most recent time the index was analyzed

### F.56.8.27. [DBA/ALL/USER]\_USERS

- DBA\_USERS describes all users of the database, and contains more columns than ALL\_USERS.
- ALL\_USERS lists all users of the database (USERNAME, USER\_ID, CREATED), but no permission verification is done like oracle.
- USER\_USERS describes the current user, and contains more columns than ALL\_USERS.

**Table F.163. DBA\_USERS**

Column	Description
USERNAME	Name of the user
USER_ID	ID number of the user
PASSWORD	This column is deprecated in favor of the AUTHENTICATION_TYPE column
ACCOUNT_STATUS	Account status, always 'NORMAL'
EXPIRY_DATE	Date of expiration of the account

**Table F.164. ALL\_USERS**

Column	Description
USERNAME	Name of the user
USER_ID	ID number of the user

### F.56.8.28. DBA\_ROLES

- Describes all roles in the database

**Table F.165. DBA\_ROLES**

Column	Description
ROLE	Name of the role
PASSWORD_REQUIRED	This column is deprecated in favor of the AUTHENTICATION_TYPE column, always 'NO'
AUTHENTICATION_TYPE	Indicates the authentication mechanism for the role, always 'NONE'

Column	Description
	NONE - CREATE ROLE role1;
COMMON	Indicates whether a given role is common. always 'YES', does not exist in oracle 11g

### F.56.8.29. [DBA/USER]\_ROLE\_PRIVS

- DBA\_ROLE\_PRIVS describes the roles granted to all users and roles in the database.
- USER\_ROLE\_PRIVS describes the roles granted to the current user.

**Table F.166. DBA\_ROLE\_PRIVS**

Column	Description
GRANTEE	Name of the user or role receiving the grant
GRANTED_ROLE	Granted role name
ADMIN_OPTION	Indicates whether the grant was with the ADMIN OPTION (YES) or not (NO)
DEFAULT_ROLE	Indicates whether the role is designated as a DEFAULT ROLE for the user (YES) or not (NO)  Always 'NO'
COMMON	Indicates how the grant was made  always 'YES', does not exist in oracle 11g

### F.56.8.30. PRODUCT\_COMPONENT\_VERSION

- Contains version and status information for component products.

**Table F.167. PRODUCT\_COMPONENT\_VERSION**

Column	Description
PRODUCT	Product name
VERSION	Version number
STATUS	Status of release

### F.56.8.31. PLAN\_TABLE

- PLAN\_TABLE is automatically created as a global temporary table to hold the output of an EXPLAIN PLAN statement for all users.
- it is not supported by LightDB, so this view is empty for compatibility.

### F.56.8.32. DBA\_DATA\_FILES

- Describes database files

**Table F.168. DBA\_DATA\_FILES**

Column	Description
FILE_NAME	Name of the database file

Column	Description
FILE_ID	File identifier number of the database file
TABLESPACE_NAME	Name of the tablespace to which the file belongs
BYTES	Size of the file in bytes
BLOCKS	Size of the file in Oracle blocks
STATUS	File status: AVAILABLE or INVALID  Always 'AVAILABLE'
RELATIVE_FNO	Relative file number
AUTOEXTENSIBLE	Autoextensible indicator  Always 'YES'
INCREMENT_BY	Number of Oracle blocks used as autoextension increment
ONLINE_STATUS	Online status of the file  Always 'ONLINE'

### F.56.8.33. [DBA/ALL/USER]\_JOBS

- Get info from lt\_cron
- DBA\_JOBS describes all jobs in the database.
- USER\_JOBS describes the jobs owned by the current user.
- ALL\_JOBS is same with USER\_JOBS.

**Table F.169. DBA\_JOBS**

Column	Description
JOB	Identifier of job
LOG_USER	Login user when the job was submitted
PRIV_USER	User whose default privileges apply to this job
SCHEMA_USER	Default schema used to parse the job  Always 'CRON'
LAST_DATE	Date on which this job last successfully executed
LAST_SEC	Same as LAST_DATE. This is when the last successful execution started  'HH24:MI:SS' format
THIS_DATE	Date that this job started executing (usually null if not executing)
THIS_SEC	Same as THIS_DATE. This is when the last successful execution started  'HH24:MI:SS' format
TOTAL_TIME	Total wall clock time spent by the system on this job in the last executed  It is not same with oracle. In oracle, it means total wall clock time spent by the system on



Column	Description
	this job (in seconds) since the first time this job executed, and this value is cumulative
BROKEN	Y: no attempt is made to run this job, N: an attempt is made to run this job  Always 'N'
INTERVAL	String uses the standard cron syntax, ref to lt_cron  Different from oracle
WHAT	LightDB commands  Different from oracle

### F.56.8.34. DBA\_JOBS\_RUNNING

- Get info from lt\_cron
- Lists all jobs that are currently running in the instance.

**Table F.170. DBA\_JOBS\_RUNNING**

Column	Description
SID	Identifier of process that is executing the job
JOB	Identifier of job. This job is currently executing
LAST_DATE	Date on which this job last successfully executed
LAST_SEC	Same as LAST_DATE. This is when the last successful execution started  'HH24:MI:SS' format
THIS_DATE	Date that this job started executing (usually null if not executing)
THIS_SEC	Same as THIS_DATE. This is when the last successful execution started  'HH24:MI:SS' format

### F.56.8.35. [DBA/ALL/USER]\_MVIEWES

- DBA\_MVIEWS describes all materialized views in the database.
- The ALL\_MVIEWS view is currently the same as the DBA\_MVIEWS view, and no permission verification is done like oracle.
- USER\_MVIEWS describes all materialized views owned by the current user.

**Table F.171. ALL\_MVIEWS**

Column	Description
OWNER	Schema in which the materialized view was created
MVIEW_NAME	Name of the materialized view

Column	Description
CONTAINER_NAME	Name of the container in which the materialized view's data is held. Normally this is the same as MVIEW_NAME
QUERY	Query that defines the materialized view
QUERY_LEN	Length (in bytes) of the defining query
UPDATABLE	Indicates whether the materialized view is updatable (Y) or not (N)  Always 'N'
REFRESH_MODE	Refresh mode of the materialized view  Always 'DEMAND', it means database refreshes this materialized view whenever an appropriate refresh procedure is called
REFRESH_METHOD	Default method used to refresh the materialized view  Always 'COMPLETE'
BUILD_MODE	Indicates how the materialized view was populated during creation  Always 'IMMEDIATE'

### F.56.8.36. [DBA/ALL/USER]\_MVIEW\_LOGS

- It is not supported, so use as an empty view for compatibility.
- DBA\_MVIEW\_LOGS describes all materialized view logs in the database.
- ALL\_MVIEW\_LOGS describes all materialized view logs accessible to the current user.
- USER\_MVIEW\_LOGS describes all materialized view logs owned by the current user.

### F.56.8.37. [DBA/ALL/USER]\_MVIEW\_COMMENTS

- DBA\_MVIEW\_COMMENTS displays comments on the materialized views in the database.
- The ALL\_MVIEW\_COMMENTS view is currently the same as the DBA\_MVIEW\_COMMENTS view, and no permission verification is done like oracle.
- USER\_MVIEW\_COMMENTS displays comments on the materialized views owned by the current user. This view does not display the OWNER column.

**Table F.172. ALL\_MVIEW\_COMMENTS**

Column	Description
OWNER	Owner of the materialized view
MVIEW_NAME	Name of the materialized view
COMMENTS	Comment on the materialized view

### F.56.8.38. [DBA/USER]\_TABLESPACES

- DBA\_TABLESPACES describes all tablespaces in the database.

- USER\_TABLESPACES describes the tablespaces accessible to the current user. This view does not display the PLUGGED\_IN column.

**Table F.173. DBA\_TABLESPACES**

Column	Description
TABLESPACE_NAME	Name of the tablespace
BLOCK_SIZE	Tablespace block size (in bytes)
STATUS	Tablespace status Always 'ONLINE'
CONTENTS	Tablespace contents Always 'PERMANENT'

**F.56.8.39. NLS\_[DATABASE/INSTANCE/SESSION]\_PARAMETERS**

- NLS\_DATABASE\_PARAMETERS lists permanent NLS parameters of the database.
- NLS\_INSTANCE\_PARAMETERS lists NLS parameters of the instance.
- NLS\_SESSION\_PARAMETERS lists NLS parameters of the user session.

**Table F.174. NLS\_DATABASE\_PARAMETERS**

Column	Description
PARAMETER	Parameter name
VALUE	Parameter value

**F.56.8.40. [DBA/USER]\_SEGMENTS**

- DBA\_SEGMENTS describes the storage allocated for all segments in the database.
- USER\_SEGMENTS describes the storage allocated for the segments owned by the current user's objects. This view does not display the OWNER, HEADER\_FILE, HEADER\_BLOCK, or RELATIVE\_FNO columns.

**Table F.175. DBA\_SEGMENTS**

Column	Description
OWNER	Username of the segment owner
SEGMENT_NAME	Name, if any, of the segment
PARTITION_NAME	Object Partition Name (Set to NULL for non-partitioned objects)
SEGMENT_TYPE	Type of segment: 'TABLE', 'TABLE PARTITION', 'TABLE SUBPARTITION', 'INDEX', 'INDEX PARTITION', 'INDEX SUBPARTITION'
TABLESPACE_NAME	Name of the tablespace containing the segment
HEADER_FILE	Name of the tablespace containing the segment
BYTES	Size, in bytes, of the segments
BLOCKS	Size, in LightDB blocks, of the segment

### F.56.8.41. [DBA/USER/ALL]\_PART\_TABLES

- DBA\_PART\_TABLES displays the object-level partitioning information for all partitioned tables in the database.
- The ALL\_PART\_TABLES view is currently the same as the DBA\_PART\_TABLES view, and no permission verification is done like oracle.
- USER\_PART\_TABLES displays the object-level partitioning information for the partitioned tables owned by the current user. This view does not display the OWNER column.

The supported fields are listed below. unsupported fields are filed with NULL.

**Table F.176. ALL\_PART\_TABLES**

Column	Description
OWNER	Owner of the partitioned table
TABLE_NAME	Name of the partitioned table
PARTITIONING_TYPE	Type of the partitioning method: RANGE, HASH, LIST
SUBPARTITIONING_TYPE	Type of the composite partitioning method: RANGE, HASH, LIST
PARTITION_COUNT	Number of partitions in the table
PARTITIONING_KEY_COUNT	Number of columns in the partitioning key
SUBPARTITIONING_KEY_COUNT	For a composite-partitioned table, the number of columns in the subpartitioning key
DEF_TABLESPACE_NAME	Default tablespace to be used when adding a partition
DEF_LOGGING	Default LOGGING attribute to be used when adding a partition

### F.56.8.42. [DBA/USER/ALL]\_TAB\_PARTITIONS

- DBA\_TAB\_PARTITIONS displays partition-level partitioning information, partition storage parameters, and partition statistics for all partitions in the database.
- The ALL\_TAB\_PARTITIONS view is currently the same as the DBA\_TAB\_PARTITIONS view, and no permission verification is done like oracle.
- USER\_TAB\_PARTITIONS displays such information for the partitions of all partitioned objects owned by the current user. This view does not display the TABLE\_OWNER column.
- When a new partition is created, the partition name is identical to the name specified in ADD/CREATE/MODIFY statement, for range interval partition we prefix the partition name with "ap", for hash partition that did not has a explicit name, we prefix the partition name with "p".

**Table F.177. ALL\_TAB\_PARTITIONS**

Column	Description
TABLE_OWNER	Owner of the table
TABLE_NAME	Name of the table
COMPOSITE	Indicates whether the table is composite-partitioned (YES) or not (NO)
PARTITION_NAME	Name of the partition

Column	Description
SUBPARTITION_COUNT	If this is a composite partitioned table, the number of subpartitions in the partition
PARTITION_POSITION	Position of the partition within the table
TABLESPACE_NAME	Name of the tablespace containing the partition
LOGGING	Indicates whether or not changes to the table are logged
NUM_ROWS	Number of rows in the partition
BLOCKS	Number of used data blocks in the partition
LAST_ANALYZED	Date on which this partition was most recently analyzed

### F.56.8.43. [DBA/USER/ALL]\_TAB\_SUBPARTITIONS

- DBA\_TAB\_SUBPARTITIONS displays the subpartition name, name of the table and partition to which it belongs, its storage attributes, and statistics for all subpartitions in the database.
- The ALL\_TAB\_SUBPARTITIONS view is currently the same as the DBA\_TAB\_SUBPARTITIONS view, and no permission verification is done like oracle.
- USER\_TAB\_SUBPARTITIONS displays such information for subpartitions of all partitioned objects owned by the current user. This view does not display the TABLE\_OWNER column.
- When a new subpartition is created, the subpartition name is identical to the name specified in the ADD statement, and prefixed with its partition name while created in CREATE statement. When dealing with hash partitions that do not have an explicit name, we prepend the partition name with "p".

**Table F.178. ALL\_TAB\_SUBPARTITIONS**

Column	Description
TABLE_OWNER	Owner of the table
TABLE_NAME	Name of the table
PARTITION_NAME	Name of the partition
SUBPARTITION_NAME	Name of the subpartition
PARTITION_POSITION	Position of the partition within the table
SUBPARTITION_POSITION	Position of the subpartition within the partition
TABLESPACE_NAME	Name of the tablespace containing the partition
LOGGING	Indicates whether or not changes to the table are logged
NUM_ROWS	Number of rows in the subpartition
BLOCKS	Number of blocks in the subpartition
LAST_ANALYZED	Date on which this table was most recently analyzed

### F.56.8.44. [DBA/USER/ALL]\_PART\_KEY\_COLUMNS

- DBA\_PART\_KEY\_COLUMNS describes the partitioning key columns for all partitioned objects in the database.
- The ALL\_PART\_KEY\_COLUMNS view is currently the same as the DBA\_PART\_KEY\_COLUMNS view, and no permission verification is done like oracle.

- `USER_PART_KEY_COLUMNS` describes the partitioning key columns for the partitioned objects owned by the current user. This view does not display the `OWNER` column.

**Table F.179. ALL\_PART\_KEY\_COLUMNS**

Column	Description
<code>OWNER</code>	Owner of the partitioned table or index
<code>NAME</code>	Name of the partitioned table or index
<code>OBJECT_TYPE</code>	Object type: TABLE, INDEX
<code>COLUMN_NAME</code>	Name of the column
<code>COLUMN_POSITION</code>	Position of the column within the partitioning key

**F.56.8.45. [DBA/USER/ALL]\_SUBPART\_KEY\_COLUMNS**

- `DBA_SUBPART_KEY_COLUMNS` displays subpartitioning key columns for composite-partitioned tables (and local indexes on composite-partitioned tables) for all subpartitions in the database.
- The `ALL_SUBPART_KEY_COLUMNS` view is currently the same as the `DBA_SUBPART_KEY_COLUMNS` view, and no permission verification is done like oracle.
- `USER_SUBPART_KEY_COLUMNS` displays this information for subpartitions of all partitioned objects owned by the current user. This view does not display the `OWNER` column.

**Table F.180. ALL\_SUBPART\_KEY\_COLUMNS**

Column	Description
<code>OWNER</code>	Owner of the partitioned table or index
<code>NAME</code>	Name of the partitioned table or index
<code>OBJECT_TYPE</code>	Object type: TABLE, INDEX
<code>COLUMN_NAME</code>	Name of the column
<code>COLUMN_POSITION</code>	Position of the column within the subpartitioning key

**F.56.8.46. [DBA/USER/ALL]\_IND\_PARTITIONS**

- `DBA_IND_PARTITIONS` describes all index partitions in the database.
- The `ALL_IND_PARTITIONS` view is currently the same as the `DBA_IND_PARTITIONS` view, and no permission verification is done like oracle.
- `USER_IND_PARTITIONS` describes the index partitions owned by the current user. This view does not display the `INDEX_OWNER` column.

**Table F.181. ALL\_IND\_PARTITIONS**

Column	Description
<code>INDEX_OWNER</code>	Owner of the index
<code>INDEX_NAME</code>	Name of the index
<code>COMPOSITE</code>	Indicates whether the partition belongs to a local index on a composite-partitioned table (YES) or not (NO)
<code>PARTITION_NAME</code>	Name of the partition

Column	Description
SUBPARTITION_COUNT	If a local index on a composite-partitioned table, the number of subpartitions in the partition
PARTITION_POSITION	Position of the partition within the index
TABLESPACE_NAME	Name of the tablespace containing the partition
LOGGING	Indicates whether or not changes to the index are logged
NUM_ROWS	Number of rows returned
LAST_ANALYZED	Date on which this partition was most recently analyzed

### F.56.8.47. [DBA/USER/ALL]\_PART\_INDEXES

- DBA\_PART\_INDEXES displays the object-level partitioning information for all partitioned indexes in the database.
- The ALL\_PART\_INDEXES view is currently the same as the DBA\_PART\_INDEXES view, and no permission verification is done like oracle.
- USER\_PART\_INDEXES displays the object-level partitioning information for the partitioned indexes owned by the current user. This view does not display the OWNER column.

**Table F.182. ALL\_PART\_INDEXES**

Column	Description
OWNER	Owner of the partitioned index
INDEX_NAME	Name of the partitioned index
TABLE_NAME	Name of the partitioned table
PARTITIONING_TYPE	Type of the partitioning method: RANGE, HASH, LIST
SUBPARTITIONING_TYPE	Type of the composite partitioning method: RANGE, HASH, LIST
PARTITION_COUNT	Number of partitions in the index
PARTITIONING_KEY_COUNT	Number of columns in the partitioning key
SUBPARTITIONING_KEY_COUNT	For a composite-partitioned table, the number of columns in the subpartitioning key
LOCALITY	Indicates whether the partitioned index is local (LOCAL) or global (GLOBAL), always 'LOCAL'
ALIGNMENT	Indicates whether the partitioned index is prefixed (PREFIXED) or non-prefixed (NON_PREFIXED)
DEF_TABLESPACE_NAME	For a local index, the default tablespace to be used when adding or splitting a table partition
DEF_LOGGING	For a local index, the default LOGGING attribute to be used when adding a table partition

### F.56.8.48. COL

- COL describes the columns of the tables and views owned by the current user. This view does not display the OWNER column.

**Table F.183. COL**

Column	Description
TNAME	Name of the table, view
COLNO	Sequence number of the column as created
CNAME	Column name
COLTYPE	Datatype of the column
WIDTH	Length of the column(in char for character Types; in byte for other types, for number/ numeric it is always 22)
SCALE	Digits to the right of the decimal point in a number
PRECISION	Decimal precision for NUMBER datatype; binary precision for FLOAT datatype; NULL for all other datatypes
NULLS	Indicates whether a column allows NULLs. The value is 'NOT NULL' if there is a NOT NULL constraint on the column or if the column is part of a PRIMARY KEY
DEFAULTVAL	Default value for the column

## F.57. pageinspect

The `pageinspect` module provides functions that allow you to inspect the contents of database pages at a low level, which is useful for debugging purposes. All of these functions may be used only by superusers.

### F.57.1. General Functions

`get_raw_page(relname text, fork text, blkno int)` returns `bytea`

`get_raw_page` reads the specified block of the named relation and returns a copy as a `bytea` value. This allows a single time-consistent copy of the block to be obtained. `fork` should be 'main' for the main data fork, 'fsm' for the free space map, 'vm' for the visibility map, or 'init' for the initialization fork.

`get_raw_page(relname text, blkno int)` returns `bytea`

A shorthand version of `get_raw_page`, for reading from the main fork. Equivalent to `get_raw_page(relname, 'main', blkno)`

`page_header(page bytea)` returns `record`

`page_header` shows fields that are common to all LightDB heap and index pages.

A page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM page_header(get_raw_page('pg_class', 0));
   lsn   | checksum | flags | lower | upper | special |
-----+-----+-----+-----+-----+-----+
0/24A1B50 |         0 |      1 |    232 |    368 |    8192 |
8192 |         4 |      0
```



The returned columns correspond to the fields in the `PageHeaderData` struct. See `src/include/storage/bufpage.h` for details.

The `checksum` field is the checksum stored in the page, which might be incorrect if the page is somehow corrupted. If data checksums are not enabled for this instance, then the value stored is meaningless.

`page_checksum(page bytea, blkno int4)` returns `smallint`

`page_checksum` computes the checksum for the page, as if it was located at the given block.

A page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT page_checksum(get_raw_page('pg_class', 0), 0);
       page_checksum
-----
          13443
```

Note that the checksum depends on the block number, so matching block numbers should be passed (except when doing esoteric debugging).

The checksum computed with this function can be compared with the `checksum` result field of the function `page_header`. If data checksums are enabled for this instance, then the two values should be equal.

`fsm_page_contents(page bytea)` returns `text`

`fsm_page_contents` shows the internal node structure of a FSM page. For example:

```
test=# SELECT fsm_page_contents(get_raw_page('pg_class', 'fsm',
      0));
```

The output is a multiline string, with one line per node in the binary tree within the page. Only those nodes that are not zero are printed. The so-called "next" pointer, which points to the next slot to be returned from the page, is also printed.

See `src/backend/storage/freespace/README` for more information on the structure of an FSM page.

## F.57.2. Heap Functions

`heap_page_items(page bytea)` returns `setof record`

`heap_page_items` shows all line pointers on a heap page. For those line pointers that are in use, tuple headers as well as tuple raw data are also shown. All tuples are shown, whether or not the tuples were visible to an MVCC snapshot at the time the raw page was copied.

A heap page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM heap_page_items(get_raw_page('pg_class',
      0));
```

See `src/include/storage/itemid.h` and `src/include/access/htup_details.h` for explanations of the fields returned.

The `heap_tuple_infomask_flags` function can be used to unpack the flag bits of `t_infomask` and `t_infomask2` for heap tuples.

`tuple_data_split(rel_oid oid, t_data bytea, t_infomask integer, t_infomask2 integer, t_bits text [, do_detoast bool])` returns `bytea[]`

`tuple_data_split` splits tuple data into attributes in the same way as backend internals.

```
test=# SELECT tuple_data_split('pg_class'::regclass,
    t_data, t_infomask, t_infomask2, t_bits) FROM
    heap_page_items(get_raw_page('pg_class', 0));
```

This function should be called with the same arguments as the return attributes of `heap_page_items`.

If `do_detoast` is true, attributes will be detoasted as needed. Default value is false.

`heap_page_item_attrs(page bytea, rel_oid regclass [, do_detoast bool])` returns `setof record`

`heap_page_item_attrs` is equivalent to `heap_page_items` except that it returns tuple raw data as an array of attributes that can optionally be detoasted by `do_detoast` which is false by default.

A heap page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM
    heap_page_item_attrs(get_raw_page('pg_class', 0),
    'pg_class'::regclass);
```

`heap_tuple_infomask_flags(t_infomask integer, t_infomask2 integer)` returns `record`

`heap_tuple_infomask_flags` decodes the `t_infomask` and `t_infomask2` returned by `heap_page_items` into a human-readable set of arrays made of flag names, with one column for all the flags and one column for combined flags. For example:

```
test=# SELECT t_ctid, raw_flags, combined_flags
    FROM heap_page_items(get_raw_page('pg_class', 0)),
    LATERAL heap_tuple_infomask_flags(t_infomask,
    t_infomask2)
    WHERE t_infomask IS NOT NULL OR t_infomask2 IS NOT
    NULL;
```

This function should be called with the same arguments as the return attributes of `heap_page_items`.

Combined flags are displayed for source-level macros that take into account the value of more than one raw bit, such as `HEAP_XMIN_FROZEN`.

See `src/include/access/htup_details.h` for explanations of the flag names returned.

## F.57.3. B-Tree Functions

`bt_metap(relname text)` returns `record`

`bt_metap` returns information about a B-tree index's metapage. For example:

```
test=# SELECT * FROM bt_metap('pg_cast_oid_index');
-[ RECORD 1 ]-----+-----
magic          | 340322
version        | 4
root           | 1
level          | 0
fastroot       | 1
fastlevel      | 0
oldest_xact    | 582
last_cleanup_num_tuples | 1000
allequalimage  | f
```

bt\_page\_stats(relname text, blkno int) returns record

bt\_page\_stats returns summary information about single pages of B-tree indexes. For example:

```
test=# SELECT * FROM bt_page_stats('pg_cast_oid_index', 1);
-[ RECORD 1 ]-+-----
blkno          | 1
type           | 1
live_items     | 224
dead_items     | 0
avg_item_size  | 16
page_size      | 8192
free_size      | 3668
btpo_prev      | 0
btpo_next      | 0
btpo           | 0
btpo_flags     | 3
```

bt\_page\_items(relname text, blkno int) returns setof record

bt\_page\_items returns detailed information about all of the items on a B-tree index page. For example:

```
test=# SELECT itemoffset, ctid, itemlen, nulls, vars, data,
dead, htid, tids[0:2] AS some_tids
FROM bt_page_items('tenk2_hundred', 5);
 itemoffset | ctid | itemlen | nulls | vars | data
            | dead | htid | some_tids
-----+-----+-----+-----+-----+-----
1 | (16,1) | 16 | f | f | 30 00 00 00
00 00 00 00
2 | (16,8292) | 616 | f | f | 24 00 00 00
00 00 00 00 | f | (1,6) | {"(1,6)", "(10,22)"}
3 | (16,8292) | 616 | f | f | 25 00 00 00
00 00 00 00 | f | (1,18) | {"(1,18)", "(4,22)"}
4 | (16,8292) | 616 | f | f | 26 00 00 00
00 00 00 00 | f | (4,18) | {"(4,18)", "(6,17)"}
5 | (16,8292) | 616 | f | f | 27 00 00 00
00 00 00 00 | f | (1,2) | {"(1,2)", "(1,19)"}
6 | (16,8292) | 616 | f | f | 28 00 00 00
00 00 00 00 | f | (2,24) | {"(2,24)", "(4,11)"}
7 | (16,8292) | 616 | f | f | 29 00 00 00
00 00 00 00 | f | (2,17) | {"(2,17)", "(11,2)"}

```

```

      8 | (16,8292) |      616 | f      | f      | 2a 00 00 00
00 00 00 00 | f      | (0,25) | {"(0,25)", "(3,20)"}
      9 | (16,8292) |      616 | f      | f      | 2b 00 00 00
00 00 00 00 | f      | (0,10) | {"(0,10)", "(0,14)"}
     10 | (16,8292) |      616 | f      | f      | 2c 00 00 00
00 00 00 00 | f      | (1,3)  | {"(1,3)", "(3,9)"}
     11 | (16,8292) |      616 | f      | f      | 2d 00 00 00
00 00 00 00 | f      | (6,28) | {"(6,28)", "(11,1)"}
     12 | (16,8292) |      616 | f      | f      | 2e 00 00 00
00 00 00 00 | f      | (0,27) | {"(0,27)", "(1,13)"}
     13 | (16,8292) |      616 | f      | f      | 2f 00 00 00
00 00 00 00 | f      | (4,17) | {"(4,17)", "(4,21)"}
(13 rows)

```

This is a B-tree leaf page. All tuples that point to the table happen to be posting list tuples (all of which store a total of 100 6 byte TIDs). There is also a “high key” tuple at `itemoffset` number 1. `ctid` is used to store encoded information about each tuple in this example, though leaf page tuples often store a heap TID directly in the `ctid` field instead. `tids` is the list of TIDs stored as a posting list.

In an internal page (not shown), the block number part of `ctid` is a “downlink”, which is a block number of another page in the index itself. The offset part (the second number) of `ctid` stores encoded information about the tuple, such as the number of columns present (suffix truncation may have removed unneeded suffix columns). Truncated columns are treated as having the value “minus infinity”.

`htid` shows a heap TID for the tuple, regardless of the underlying tuple representation. This value may match `ctid`, or may be decoded from the alternative representations used by posting list tuples and tuples from internal pages. Tuples in internal pages usually have the implementation level heap TID column truncated away, which is represented as a NULL `htid` value.

Note that the first item on any non-rightmost page (any page with a non-zero value in the `btpo_next` field) is the page’s “high key”, meaning its data serves as an upper bound on all items appearing on the page, while its `ctid` field does not point to another block. Also, on internal pages, the first real data item (the first item that is not a high key) reliably has every column truncated away, leaving no actual value in its `data` field. Such an item does have a valid downlink in its `ctid` field, however.

For more details about the structure of B-tree indexes, see Section 60.4.1. For more details about deduplication and posting lists, see Section 60.4.2.

`bt_page_items(page bytea)` returns `setof record`

It is also possible to pass a page to `bt_page_items` as a `bytea` value. A page image obtained with `get_raw_page` should be passed as argument. So the last example could also be rewritten like this:

```

test=# SELECT itemoffset, ctid, itemlen, nulls, vars, data,
       dead, htid, tids[0:2] AS some_tids
       FROM bt_page_items(get_raw_page('tenk2_hundred', 5));
 itemoffset | ctid      | itemlen | nulls | vars | data
            | dead | htid | some_tids
-----+-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----+-----
      1 | (16,1)   |      16 | f     | f     | 30 00 00 00
00 00 00 00 |      |      |
      2 | (16,8292) |     616 | f     | f     | 24 00 00 00
00 00 00 00 | f     | (1,6) | {"(1,6)", "(10,22)"}

```

```

      3 | (16,8292) |      616 | f      | f      | 25 00 00 00
00 00 00 00 | f      | (1,18) | {"(1,18)","(4,22)"}
      4 | (16,8292) |      616 | f      | f      | 26 00 00 00
00 00 00 00 | f      | (4,18) | {"(4,18)","(6,17)"}
      5 | (16,8292) |      616 | f      | f      | 27 00 00 00
00 00 00 00 | f      | (1,2)  | {"(1,2)","(1,19)"}
      6 | (16,8292) |      616 | f      | f      | 28 00 00 00
00 00 00 00 | f      | (2,24) | {"(2,24)","(4,11)"}
      7 | (16,8292) |      616 | f      | f      | 29 00 00 00
00 00 00 00 | f      | (2,17) | {"(2,17)","(11,2)"}
      8 | (16,8292) |      616 | f      | f      | 2a 00 00 00
00 00 00 00 | f      | (0,25) | {"(0,25)","(3,20)"}
      9 | (16,8292) |      616 | f      | f      | 2b 00 00 00
00 00 00 00 | f      | (0,10) | {"(0,10)","(0,14)"}
     10 | (16,8292) |      616 | f      | f      | 2c 00 00 00
00 00 00 00 | f      | (1,3)  | {"(1,3)","(3,9)"}
     11 | (16,8292) |      616 | f      | f      | 2d 00 00 00
00 00 00 00 | f      | (6,28) | {"(6,28)","(11,1)"}
     12 | (16,8292) |      616 | f      | f      | 2e 00 00 00
00 00 00 00 | f      | (0,27) | {"(0,27)","(1,13)"}
     13 | (16,8292) |      616 | f      | f      | 2f 00 00 00
00 00 00 00 | f      | (4,17) | {"(4,17)","(4,21)"}
(13 rows)

```

All the other details are the same as explained in the previous item.

## F.57.4. GIN Functions

`gin_metapage_info(page bytea)` returns record

`gin_metapage_info` returns information about a GIN index metapage. For example:

```

test=# SELECT * FROM gin_metapage_info(get_raw_page('gin_index',
0));
-[ RECORD 1 ]-----+-----
pending_head      | 4294967295
pending_tail      | 4294967295
tail_free_size    | 0
n_pending_pages   | 0
n_pending_tuples  | 0
n_total_pages     | 7
n_entry_pages     | 6
n_data_pages      | 0
n_entries         | 693
version           | 2

```

`gin_page_opaque_info(page bytea)` returns record

`gin_page_opaque_info` returns information about a GIN index opaque area, like the page type. For example:

```

test=# SELECT * FROM
  gin_page_opaque_info(get_raw_page('gin_index', 2));
rightlink | maxoff | flags
-----+-----+-----
          5 |      0 | {data,leaf,compressed}
(1 row)

```

`gin_leafpage_items(page bytea)` returns setof record

`gin_leafpage_items` returns information about the data stored in a GIN leaf page. For example:

```
test=# SELECT first_tid, nbytes, tids[0:5] AS some_tids
        FROM gin_leafpage_items(get_raw_page('gin_test_idx',
        2));
 first_tid | nbytes |                               some_tids
-----+-----+-----
(8,41)    |    244 | {"(8,41)","(8,43)","(8,44)","(8,45)","(8,46)"}
(10,45)   |    248 | {"(10,45)","(10,46)","(10,47)","(10,48)","(10,49)"}
(12,52)   |    248 | {"(12,52)","(12,53)","(12,54)","(12,55)","(12,56)"}
(14,59)   |    320 | {"(14,59)","(14,60)","(14,61)","(14,62)","(14,63)"}
(167,16)  |    376 | {"(167,16)","(167,17)","(167,18)","(167,19)","(167,20)"}
(170,30)  |    376 | {"(170,30)","(170,31)","(170,32)","(170,33)","(170,34)"}
(173,44)  |    197 | {"(173,44)","(173,45)","(173,46)","(173,47)","(173,48)"}
(7 rows)
```

## F.57.5. Hash Functions

`hash_page_type(page bytea)` returns text

`hash_page_type` returns page type of the given HASH index page. For example:

```
test=# SELECT hash_page_type(get_raw_page('con_hash_index', 0));
 hash_page_type
-----
metapage
```

`hash_page_stats(page bytea)` returns setof record

`hash_page_stats` returns information about a bucket or overflow page of a HASH index. For example:

```
test=# SELECT * FROM
 hash_page_stats(get_raw_page('con_hash_index', 1));
-[ RECORD 1 ]-----+-----
live_items          | 407
dead_items          | 0
page_size           | 8192
free_size           | 8
hasho_prevblkno    | 4096
hasho_nextblkno    | 8474
hasho_bucket        | 0
hasho_flag          | 66
hasho_page_id       | 65408
```

hash\_page\_items(page bytea) returns setof record

hash\_page\_items returns information about the data stored in a bucket or overflow page of a HASH index page. For example:

```
test=# SELECT * FROM
  hash_page_items(get_raw_page('con_hash_index', 1)) LIMIT 5;
 itemoffset |   ctid   |   data
-----+-----+-----
          1 | (899,77) | 1053474816
          2 | (897,29) | 1053474816
          3 | (894,207)| 1053474816
          4 | (892,159)| 1053474816
          5 | (890,111)| 1053474816
```

hash\_bitmap\_info(index oid, blkno int) returns record

hash\_bitmap\_info shows the status of a bit in the bitmap page for a particular overflow page of HASH index. For example:

```
test=# SELECT * FROM hash_bitmap_info('con_hash_index', 2052);
 bitmapblkno | bitmapbit | bitstatus
-----+-----+-----
           65 |          3 | t
```

hash\_metapage\_info(page bytea) returns record

hash\_metapage\_info returns information stored in the meta page of a HASH index. For example:

```
test=# SELECT magic, version, ntuples, ffactor, bsize, bmsize,
  bmshift,
test-#      maxbucket, highmask, lowmask, ovflpoint, firstfree,
  nmaps, procid,
test-#      regexp_replace(spares::text, '(,0)*}', '}') as
  spares,
test-#      regexp_replace(mapp::text, '(,0)*}', '}') as mapp
test-# FROM hash_metapage_info(get_raw_page('con_hash_index',
  0));
-[ RECORD 1 ]-----
 magic      | 105121344
 version    | 4
 ntuples    | 500500
 ffactor    | 40
 bsize      | 8152
 bmsize     | 4096
 bmshift    | 15
 maxbucket  | 12512
 highmask   | 16383
 lowmask    | 8191
 ovflpoint  | 28
 firstfree  | 1204
 nmaps      | 1
 procid     | 450
 spares     | {0,0,0,0,0,0,1,1,1,1,1,1,1,1,3,4,4,4,45,55,58,59,
 508,567,628,704,1193,1202,1204}
```

mapp | {65}

## F.58. passwordcheck

The `passwordcheck` module checks users' passwords whenever they are set with `CREATE ROLE` or `ALTER ROLE`. If a password is considered too weak, it will be rejected and the command will terminate with an error.

To enable this module, add `'$libdir/passwordcheck'` to `shared_preload_libraries` in `lightdb.conf`, then restart the server.

You can adapt this module to your needs by changing the source code. For example, you can use `CrackLib`<sup>10</sup> to check passwords — this only requires uncommenting two lines in the `Makefile` and rebuilding the module. (We cannot include `CrackLib` by default for license reasons.) Without `CrackLib`, the module enforces a few simple rules for password strength, which you can modify or extend as you see fit.

### Caution

To prevent unencrypted passwords from being sent across the network, written to the server log or otherwise stolen by a database administrator, LightDB allows the user to supply pre-encrypted passwords. Many client programs make use of this functionality and encrypt the password before sending it to the server.

This limits the usefulness of the `passwordcheck` module, because in that case it can only try to guess the password. For this reason, `passwordcheck` is not recommended if your security requirements are high. It is more secure to use an external authentication method such as GSSAPI (see Chapter 18) than to rely on passwords within the database.

Alternatively, you could modify `passwordcheck` to reject pre-encrypted passwords, but forcing users to set their passwords in clear text carries its own security risks.

## F.59. postgres\_fdw

The `postgres_fdw` module provides the foreign-data wrapper `postgres_fdw`, which can be used to access data stored in external LightDB servers.

The functionality provided by this module overlaps substantially with the functionality of the older `dblink` module. But `postgres_fdw` provides more transparent and standards-compliant syntax for accessing remote tables, and can give better performance in many cases.

To prepare for remote access using `postgres_fdw`:

1. Install the `postgres_fdw` extension using `CREATE EXTENSION`.
2. Create a foreign server object, using `CREATE SERVER`, to represent each remote database you want to connect to. Specify connection information, except `user` and `password`, as options of the server object.
3. Create a user mapping, using `CREATE USER MAPPING`, for each database user you want to allow to access each foreign server. Specify the remote user name and password to use as `user` and `password` options of the user mapping.
4. Create a foreign table, using `CREATE FOREIGN TABLE` or `IMPORT FOREIGN SCHEMA`, for each remote table you want to access. The columns of the foreign table must match the referenced

<sup>10</sup> <https://sourceforge.net/projects/cracklib/>



remote table. You can, however, use table and/or column names different from the remote table's, if you specify the correct remote names as options of the foreign table object.

Now you need only `SELECT` from a foreign table to access the data stored in its underlying remote table. You can also modify the remote table using `INSERT`, `UPDATE`, `DELETE`, or `COPY`. (Of course, the remote user you have specified in your user mapping must have privileges to do these things.)

Note that `postgres_fdw` currently lacks support for `INSERT` statements with an `ON CONFLICT DO UPDATE` clause. However, the `ON CONFLICT DO NOTHING` clause is supported, provided a unique index inference specification is omitted. Note also that `postgres_fdw` supports row movement invoked by `UPDATE` statements executed on partitioned tables, but it currently does not handle the case where a remote partition chosen to insert a moved row into is also an `UPDATE` target partition that will be updated later.

It is generally recommended that the columns of a foreign table be declared with exactly the same data types, and collations if applicable, as the referenced columns of the remote table. Although `postgres_fdw` is currently rather forgiving about performing data type conversions at need, surprising semantic anomalies may arise when types or collations do not match, due to the remote server interpreting query conditions differently from the local server.

Note that a foreign table can be declared with fewer columns, or with a different column order, than its underlying remote table has. Matching of columns to the remote table is by name, not position.

## F.59.1. FDW Options of `postgres_fdw`

### F.59.1.1. Connection Options

A foreign server using the `postgres_fdw` foreign data wrapper can have the same options that `libpq` accepts in connection strings, as described in Section 32.1.2, except that these options are not allowed or have special handling:

- `user`, `password` and `sslpassword` (specify these in a user mapping, instead, or use a service file)
- `client_encoding` (this is automatically set from the local server encoding)
- `fallback_application_name` (always set to `postgres_fdw`)
- `sslkey` and `sslcert` - these may appear in *either or both* a connection and a user mapping. If both are present, the user mapping setting overrides the connection setting.

Only superusers may create or modify user mappings with the `sslcert` or `sslkey` settings.

Only superusers may connect to foreign servers without password authentication, so always specify the `password` option for user mappings belonging to non-superusers.

A superuser may override this check on a per-user-mapping basis by setting the user mapping option `password_required 'false'`, e.g.,

```
ALTER USER MAPPING FOR some_non_superuser SERVER loopback_nopw
OPTIONS (ADD password_required 'false');
```

To prevent unprivileged users from exploiting the authentication rights of the unix user the `lightdb` server is running as to escalate to superuser rights, only the superuser may set this option on a user mapping.

Care is required to ensure that this does not allow the mapped user the ability to connect as superuser to the mapped database per CVE-2007-3278 and CVE-2007-6601. Don't set `password_required=false` on the `public` role. Keep in mind that the mapped user can potentially use any client certificates, `.pgpass`, `.pg_service.conf` etc in the unix home directory of the system user the `lightdb` server runs as. They can also use any trust relationship granted by authentication modes like `peer` or `ident` authentication.

### F.59.1.2. Object Name Options

These options can be used to control the names used in SQL statements sent to the remote LightDB server. These options are needed when a foreign table is created with names different from the underlying remote table's names.

`schema_name`

This option, which can be specified for a foreign table, gives the schema name to use for the foreign table on the remote server. If this option is omitted, the name of the foreign table's schema is used.

`table_name`

This option, which can be specified for a foreign table, gives the table name to use for the foreign table on the remote server. If this option is omitted, the foreign table's name is used.

`column_name`

This option, which can be specified for a column of a foreign table, gives the column name to use for the column on the remote server. If this option is omitted, the column's name is used.

### F.59.1.3. Cost Estimation Options

`postgres_fdw` retrieves remote data by executing queries against remote servers, so ideally the estimated cost of scanning a foreign table should be whatever it costs to be done on the remote server, plus some overhead for communication. The most reliable way to get such an estimate is to ask the remote server and then add something for overhead — but for simple queries, it may not be worth the cost of an additional remote query to get a cost estimate. So `postgres_fdw` provides the following options to control how cost estimation is done:

`use_remote_estimate`

This option, which can be specified for a foreign table or a foreign server, controls whether `postgres_fdw` issues remote `EXPLAIN` commands to obtain cost estimates. A setting for a foreign table overrides any setting for its server, but only for that table. The default is `false`.

`fdw_startup_cost`

This option, which can be specified for a foreign server, is a numeric value that is added to the estimated startup cost of any foreign-table scan on that server. This represents the additional overhead of establishing a connection, parsing and planning the query on the remote side, etc. The default value is 100.

`fdw_tuple_cost`

This option, which can be specified for a foreign server, is a numeric value that is used as extra cost per-tuple for foreign-table scans on that server. This represents the additional overhead of data transfer between servers. You might increase or decrease this number to reflect higher or lower network delay to the remote server. The default value is 0.01.

When `use_remote_estimate` is `true`, `postgres_fdw` obtains row count and cost estimates from the remote server and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. When `use_remote_estimate` is `false`, `postgres_fdw` performs local row count and cost estimation and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. This local estimation is unlikely to be very accurate unless local copies of the remote table's statistics are available. Running `ANALYZE` on the foreign table is the way to update the local statistics; this will perform a scan of the remote table and then calculate and store statistics just as though the table were local. Keeping local statistics can be a useful way to reduce per-query planning overhead for a remote table — but if the remote table is frequently updated, the local statistics will soon be obsolete.

### F.59.1.4. Remote Execution Options

By default, only `WHERE` clauses using built-in operators and functions will be considered for execution on the remote server. Clauses involving non-built-in functions are checked locally after rows are fetched. If such functions are available on the remote server and can be relied on to produce the same results as they do locally, performance can be improved by sending such `WHERE` clauses for remote execution. This behavior can be controlled using the following option:

`extensions`

This option is a comma-separated list of names of LightDB extensions that are installed, in compatible versions, on both the local and remote servers. Functions and operators that are immutable and belong to a listed extension will be considered shippable to the remote server. This option can only be specified for foreign servers, not per-table.

When using the `extensions` option, *it is the user's responsibility* that the listed extensions exist and behave identically on both the local and remote servers. Otherwise, remote queries may fail or behave unexpectedly.

`fetch_size`

This option specifies the number of rows `postgres_fdw` should get in each fetch operation. It can be specified for a foreign table or a foreign server. The option specified on a table overrides an option specified for the server. The default is 100.

### F.59.1.5. Updatability Options

By default all foreign tables using `postgres_fdw` are assumed to be updatable. This may be overridden using the following option:

`updatable`

This option controls whether `postgres_fdw` allows foreign tables to be modified using `INSERT`, `UPDATE` and `DELETE` commands. It can be specified for a foreign table or a foreign server. A table-level option overrides a server-level option. The default is `true`.

Of course, if the remote table is not in fact updatable, an error would occur anyway. Use of this option primarily allows the error to be thrown locally without querying the remote server. Note however that the `information_schema` views will report a `postgres_fdw` foreign table to be updatable (or not) according to the setting of this option, without any check of the remote server.

### F.59.1.6. Importing Options

`postgres_fdw` is able to import foreign table definitions using `IMPORT FOREIGN SCHEMA`. This command creates foreign table definitions on the local server that match tables or views present on the remote server. If the remote tables to be imported have columns of user-defined data types, the local server must have compatible types of the same names.

Importing behavior can be customized with the following options (given in the `IMPORT FOREIGN SCHEMA` command):

`import_collate`

This option controls whether column `COLLATE` options are included in the definitions of foreign tables imported from a foreign server. The default is `true`. You might need to turn this off if the remote server has a different set of collation names than the local server does, which is likely to be the case if it's running on a different operating system. If you do so, however, there is a very severe risk that the imported table columns' collations will not match the underlying data, resulting in anomalous query behavior.

Even when this parameter is set to `true`, importing columns whose collation is the remote server's default can be risky. They will be imported with `COLLATE "default"`, which will select the local server's default collation, which could be different.

`import_default`

This option controls whether column `DEFAULT` expressions are included in the definitions of foreign tables imported from a foreign server. The default is `false`. If you enable this option, be wary of defaults that might get computed differently on the local server than they would be on the remote server; `nextval()` is a common source of problems. The `IMPORT` will fail altogether if an imported default expression uses a function or operator that does not exist locally.

`import_generated`

This option controls whether column `GENERATED` expressions are included in the definitions of foreign tables imported from a foreign server. The default is `true`. The `IMPORT` will fail altogether if an imported generated expression uses a function or operator that does not exist locally.

`import_not_null`

This option controls whether column `NOT NULL` constraints are included in the definitions of foreign tables imported from a foreign server. The default is `true`.

Note that constraints other than `NOT NULL` will never be imported from the remote tables. Although LightDB does support `CHECK` constraints on foreign tables, there is no provision for importing them automatically, because of the risk that a constraint expression could evaluate differently on the local and remote servers. Any such inconsistency in the behavior of a `CHECK` constraint could lead to hard-to-detect errors in query optimization. So if you wish to import `CHECK` constraints, you must do so manually, and you should verify the semantics of each one carefully. For more detail about the treatment of `CHECK` constraints on foreign tables, see `CREATE FOREIGN TABLE`.

Tables or foreign tables which are partitions of some other table are automatically excluded. Partitioned tables are imported, unless they are a partition of some other table. Since all data can be accessed through the partitioned table which is the root of the partitioning hierarchy, this approach should allow access to all the data without creating extra objects.

## F.59.2. Connection Management

`postgres_fdw` establishes a connection to a foreign server during the first query that uses a foreign table associated with the foreign server. This connection is kept and re-used for subsequent queries in the same session. However, if multiple user identities (user mappings) are used to access the foreign server, a connection is established for each user mapping.

## F.59.3. Transaction Management

During a query that references any remote tables on a foreign server, `postgres_fdw` opens a transaction on the remote server if one is not already open corresponding to the current local transaction. The remote transaction is committed or aborted when the local transaction commits or aborts. Savepoints are similarly managed by creating corresponding remote savepoints.

The remote transaction uses `SERIALIZABLE` isolation level when the local transaction has `SERIALIZABLE` isolation level; otherwise it uses `REPEATABLE READ` isolation level. This choice ensures that if a query performs multiple table scans on the remote server, it will get snapshot-consistent results for all the scans. A consequence is that successive queries within a single transaction will see the same data from the remote server, even if concurrent updates are occurring on the remote server due to other activities. That behavior would be expected anyway if the local transaction uses `SERIALIZABLE` or `REPEATABLE READ` isolation level, but it might be surprising for a `READ COMMITTED` local transaction. A future LightDB release might modify these rules.

Note that it is currently not supported by `postgres_fdw` to prepare the remote transaction for two-phase commit.

## F.59.4. Remote Query Optimization

`postgres_fdw` attempts to optimize remote queries to reduce the amount of data transferred from foreign servers. This is done by sending query `WHERE` clauses to the remote server for execution, and by not retrieving table columns that are not needed for the current query. To reduce the risk of misexecution of queries, `WHERE` clauses are not sent to the remote server unless they use only data types, operators, and functions that are built-in or belong to an extension that's listed in the foreign server's `extensions` option. Operators and functions in such clauses must be `IMMUTABLE` as well. For an `UPDATE` or `DELETE` query, `postgres_fdw` attempts to optimize the query execution by sending the whole query to the remote server if there are no query `WHERE` clauses that cannot be sent to the remote server, no local joins for the query, no row-level local `BEFORE` or `AFTER` triggers or stored generated columns on the target table, and no `CHECK OPTION` constraints from parent views. In `UPDATE`, expressions to assign to target columns must use only built-in data types, `IMMUTABLE` operators, or `IMMUTABLE` functions, to reduce the risk of misexecution of the query.

When `postgres_fdw` encounters a join between foreign tables on the same foreign server, it sends the entire join to the foreign server, unless for some reason it believes that it will be more efficient to fetch rows from each table individually, or unless the table references involved are subject to different user mappings. While sending the `JOIN` clauses, it takes the same precautions as mentioned above for the `WHERE` clauses.

The query that is actually sent to the remote server for execution can be examined using `EXPLAIN VERBOSE`.

## F.59.5. Remote Query Execution Environment

In the remote sessions opened by `postgres_fdw`, the `search_path` parameter is set to just `pg_catalog`, so that only built-in objects are visible without schema qualification. This is not an issue for queries generated by `postgres_fdw` itself, because it always supplies such qualification. However, this can pose a hazard for functions that are executed on the remote server via triggers or rules on remote tables. For example, if a remote table is actually a view, any functions used in that view will be executed with the restricted search path. It is recommended to schema-qualify all names in such functions, or else attach `SET search_path` options (see `CREATE FUNCTION`) to such functions to establish their expected search path environment.

`postgres_fdw` likewise establishes remote session settings for various parameters:

- `TimeZone` is set to `UTC`
- `DateStyle` is set to `ISO`
- `IntervalStyle` is set to `postgres`
- `extra_float_digits` is set to 3 for remote servers 9.0 and newer and is set to 2 for older versions

These are less likely to be problematic than `search_path`, but can be handled with function `SET` options if the need arises.

It is *not* recommended that you override this behavior by changing the session-level settings of these parameters; that is likely to cause `postgres_fdw` to malfunction.

## F.59.6. Cross-Version Compatibility

`postgres_fdw` can be used with remote servers dating back to LightDB 8.3. Read-only capability is available back to 8.1. A limitation however is that `postgres_fdw` generally assumes that immutable built-in functions and operators are safe to send to the remote server for execution, if they appear in a `WHERE` clause for a foreign table. Thus, a built-in function that was added since the remote server's release might be sent to it for execution, resulting in “function does not exist” or a similar error.

This type of failure can be worked around by rewriting the query, for example by embedding the foreign table reference in a sub-SELECT with `OFFSET 0` as an optimization fence, and placing the problematic function or operator outside the sub-SELECT.

## F.59.7. Examples

Here is an example of creating a foreign table with `postgres_fdw`. First install the extension:

```
CREATE EXTENSION postgres_fdw;
```

Then create a foreign server using `CREATE SERVER`. In this example we wish to connect to a LightDB server on host `192.83.123.89` listening on port `5432`. The database to which the connection is made is named `foreign_db` on the remote server:

```
CREATE SERVER foreign_server
    FOREIGN DATA WRAPPER postgres_fdw
    OPTIONS (host '192.83.123.89', port '5432', dbname
'foreign_db');
```

A user mapping, defined with `CREATE USER MAPPING`, is needed as well to identify the role that will be used on the remote server:

```
CREATE USER MAPPING FOR local_user
    SERVER foreign_server
    OPTIONS (user 'foreign_user', password 'password');
```

Now it is possible to create a foreign table with `CREATE FOREIGN TABLE`. In this example we wish to access the table named `some_schema.some_table` on the remote server. The local name for it will be `foreign_table`:

```
CREATE FOREIGN TABLE foreign_table (
    id integer NOT NULL,
    data text
)
    SERVER foreign_server
    OPTIONS (schema_name 'some_schema', table_name
'some_table');
```

It's essential that the data types and other properties of the columns declared in `CREATE FOREIGN TABLE` match the actual remote table. Column names must match as well, unless you attach `column_name` options to the individual columns to show how they are named in the remote table. In many cases, use of `IMPORT FOREIGN SCHEMA` is preferable to constructing foreign table definitions manually.

## F.59.8. Author

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## F.60. rum

### F.60.1. Introduction

The **rum** module provides access method to work with RUM index. It is based on the GIN access methods code.

GIN index allows to perform fast full text search using `tsvector` and `tsquery` types. But full text search with GIN index has several problems:

- Slow ranking. It is need position information about lexemes to ranking. GIN index doesn't store positions of lexemes. So after index scan we need additional heap scan to retrieve lexemes positions.
- Slow phrase search with GIN index. This problem relates with previous problem. It is need position information to perform phrase search.
- Slow ordering by timestamp. GIN index can't store some related information in index with lexemes. So it is necessary to perform additional heap scan.

RUM solves this problems by storing additional information in posting tree. For example, positional information of lexemes or timestamps.

Drawback of RUM is that it has slower build and insert time than GIN. It is because we need to store additional information besides keys and because RUM uses generic WAL records.

## F.60.2. Common operators and functions

`rum` module provides next operators.

Operator	Returns	Description
<code>tsvector &lt;=&gt; tsquery</code>	float4	Returns distance between <code>tsvector</code> and <code>tsquery</code> .
<code>timestamp &lt;=&gt; timestamp</code>	float8	Returns distance between two timestamps.
<code>timestamp &lt;=  timestamp</code>	float8	Returns distance only for left timestamps.
<code>timestamp  =&gt; timestamp</code>	float8	Returns distance only for right timestamps.

Last three operations also works for types `timestampz`, `int2`, `int4`, `int8`, `float4`, `float8`, `money` and `oid`.

## F.60.3. Operator classes

`rum` provides next operator classes.

### F.60.3.1. `rum_tsvector_ops`

For type: `tsvector`

This operator class stores `tsvector` lexemes with positional information. Supports ordering by `<=>` operator and prefix search. There is the example.

Let us assume we have the table:

```
CREATE TABLE test_rum(t text, a tsvector);

CREATE TRIGGER tsvectorupdate
BEFORE UPDATE OR INSERT ON test_rum
FOR EACH ROW EXECUTE PROCEDURE tsvector_update_trigger('a',
'pg_catalog.english', 't');

INSERT INTO test_rum(t) VALUES ('The situation is most beautiful');
INSERT INTO test_rum(t) VALUES ('It is a beautiful');
INSERT INTO test_rum(t) VALUES ('It looks like a beautiful place');
```

To create the `rum` index we need create an extension:

```
CREATE EXTENSION rum;
```

Then we can create new index:

```
CREATE INDEX rumidx ON test_rum USING rum (a rum_tsvector_ops);
```

And we can execute the following queries:

```
SELECT t, a <=> to_tsquery('english', 'beautiful | place') AS rank
FROM test_rum
WHERE a @@ to_tsquery('english', 'beautiful | place')
ORDER BY a <=> to_tsquery('english', 'beautiful | place');
```

t	rank
It looks like a beautiful place	8.22467
The situation is most beautiful	16.4493
It is a beautiful	16.4493

(3 rows)

```
SELECT t, a <=> to_tsquery('english', 'place | situation') AS rank
FROM test_rum
WHERE a @@ to_tsquery('english', 'place | situation')
ORDER BY a <=> to_tsquery('english', 'place | situation');
```

t	rank
The situation is most beautiful	16.4493
It looks like a beautiful place	16.4493

(2 rows)

### F.60.3.2. rum\_tsvector\_hash\_ops

For type: tsvector

This operator class stores hash of tsvector lexemes with positional information. Supports ordering by <=> operator. But **doesn't** support prefix search.

### F.60.3.3. rum\_TYPE\_ops

For types: int2, int4, int8, float4, float8, money, oid, time, timetz, date, interval, macaddr, inet, cidr, text, varchar, char, bytea, bit, varbit, numeric, timestamp, timestamptz

Supported operations: <, <=, =, >=, > for all types and <=>, <=| and |=> for int2, int4, int8, float4, float8, money, oid, timestamp and timestamptz types.

Supports ordering by <=>, <=| and |=> operators. Can be used with rum\_tsvector\_addon\_ops, rum\_tsvector\_hash\_addon\_ops` andrum\_anyarray\_addon\_ops` operator classes.

### F.60.3.4. rum\_tsvector\_addon\_ops

For type: tsvector

This operator class stores tsvector lexemes with any supported by module field. There is the example.

Let us assume we have the table:

```
CREATE TABLE tsts (id int, t tsvector, d timestamp);
```



```
\copy tstts from 'rum/data/tstts.data'
```

```
CREATE INDEX tstts_idx ON tstts USING rum (t rum_tsvector_addon_ops,
d)
WITH (attach = 'd', to = 't');
```

Now we can execute the following queries:

```
EXPLAIN (costs off)
SELECT id, d, d <=> '2016-05-16 14:21:25' FROM tstts WHERE t @@
'wr&qh' ORDER BY d <=> '2016-05-16 14:21:25' LIMIT 5;
QUERY PLAN
```

```
-----
Limit
->  Index Scan using tstts_idx on tstts
      Index Cond: (t @@ ''wr'' & ''qh''::tsquery)
      Order By: (d <=> 'Mon May 16 14:21:25 2016'::timestamp
without time zone)
(4 rows)
```

```
SELECT id, d, d <=> '2016-05-16 14:21:25' FROM tstts WHERE t @@
'wr&qh' ORDER BY d <=> '2016-05-16 14:21:25' LIMIT 5;
```

```
id | d | ?column?
-----+-----+-----
355 | Mon May 16 14:21:22.326724 2016 | 2.673276
354 | Mon May 16 13:21:22.326724 2016 | 3602.673276
371 | Tue May 17 06:21:22.326724 2016 | 57597.326724
406 | Wed May 18 17:21:22.326724 2016 | 183597.326724
415 | Thu May 19 02:21:22.326724 2016 | 215997.326724
(5 rows)
```

**Warning:** Currently RUM has bogus behaviour when one creates an index using ordering over pass-by-reference additional information. This is due to the fact that posting trees have fixed length right bound and fixed length non-leaf posting items. It isn't allowed to create such indexes.

### F.60.3.5. rum\_tsvector\_hash\_addon\_ops

For type: tsvector

This operator class stores hash of tsvector lexems with any supported by module field.

**Doesn't** support prefix search.

### F.60.3.6. rum\_tsquery\_ops

For type: tsquery

Stores branches of query tree in additional information. For example we have the table:

```
CREATE TABLE query (q tsquery, tag text);

INSERT INTO query VALUES ('supernova & star', 'sn'),
('black', 'color'),
('big & bang & black & hole', 'bang'),
('spiral & galaxy', 'shape'),
('black & hole', 'color');
```

```
CREATE INDEX query_idx ON query USING rum(q);
```

Now we can execute the following fast query:

```
SELECT * FROM query
  WHERE to_tsvector('black holes never exists before we think
about them') @@ q;
   q          | tag
-----+-----
 'black'      | color
 'black' & 'hole' | color
(2 rows)
```

### F.60.3.7. rum\_anyarray\_ops

For type: anyarray

This operator class stores anyarray elements with length of the array. Supports operators &&, @>, <@, =, % operators. Supports ordering by <=> operator. For example we have the table:

```
CREATE TABLE test_array (i int2[]);

INSERT INTO test_array VALUES ('{}'), ('{0}'), ('{1,2,3,4}'),
 ('{1,2,3}'), ('{1,2}'), ('{1}');

CREATE INDEX idx_array ON test_array USING rum (i
rum_anyarray_ops);
```

Now we can execute the query using index scan:

```
SET enable_seqscan TO off;

EXPLAIN (COSTS OFF) SELECT * FROM test_array WHERE i && '{1}' ORDER
BY i <=> '{1}' ASC;
      QUERY PLAN
-----
Index Scan using idx_array on test_array
  Index Cond: (i && '{1}'::smallint[])
  Order By: (i <=> '{1}'::smallint[])
(3 rows)

SELECT * FROM test_array WHERE i && '{1}' ORDER BY i <=> '{1}' ASC;
   i
-----
 {1}
 {1,2}
 {1,2,3}
 {1,2,3,4}
(4 rows)
```

### F.60.3.8. rum\_anyarray\_addon\_ops

For type: anyarray

This operator class stores anyarray elements with any supported by module field.

## F.61. seg

This module implements a data type `seg` for representing line segments, or floating point intervals. `seg` can represent uncertainty in the interval endpoints, making it especially useful for representing laboratory measurements.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.61.1. Rationale

The geometry of measurements is usually more complex than that of a point in a numeric continuum. A measurement is usually a segment of that continuum with somewhat fuzzy limits. The measurements come out as intervals because of uncertainty and randomness, as well as because the value being measured may naturally be an interval indicating some condition, such as the temperature range of stability of a protein.

Using just common sense, it appears more convenient to store such data as intervals, rather than pairs of numbers. In practice, it even turns out more efficient in most applications.

Further along the line of common sense, the fuzziness of the limits suggests that the use of traditional numeric data types leads to a certain loss of information. Consider this: your instrument reads 6.50, and you input this reading into the database. What do you get when you fetch it? Watch:

```
test=> select 6.50 :: float8 as "pH";
      pH
-----
6.5
(1 row)
```

In the world of measurements, 6.50 is not the same as 6.5. It may sometimes be critically different. The experimenters usually write down (and publish) the digits they trust. 6.50 is actually a fuzzy interval contained within a bigger and even fuzzier interval, 6.5, with their center points being (probably) the only common feature they share. We definitely do not want such different data items to appear the same.

Conclusion? It is nice to have a special data type that can record the limits of an interval with arbitrarily variable precision. Variable in the sense that each data element records its own precision.

Check this out:

```
test=> select '6.25 .. 6.50'::seg as "pH";
      pH
-----
6.25 .. 6.50
(1 row)
```

### F.61.2. Syntax

The external representation of an interval is formed using one or two floating-point numbers joined by the range operator (`..` or `...`). Alternatively, it can be specified as a center point plus or minus a deviation. Optional certainty indicators (`<`, `>` or `~`) can be stored as well. (Certainty indicators are ignored by all the built-in operators, however.) Table F.184 gives an overview of allowed representations; Table F.185 shows some examples.

In Table F.184, `x`, `y`, and `delta` denote floating-point numbers. `x` and `y`, but not `delta`, can be preceded by a certainty indicator.

**Table F.184. `seg` External Representations**

<code>x</code>	Single value (zero-length interval)
<code>x .. y</code>	Interval from <code>x</code> to <code>y</code>
<code>x (+-) delta</code>	Interval from <code>x - delta</code> to <code>x + delta</code>
<code>x ..</code>	Open interval with lower bound <code>x</code>
<code>.. x</code>	Open interval with upper bound <code>x</code>

**Table F.185. Examples of Valid `seg` Input**

<code>5.0</code>	Creates a zero-length segment (a point, if you will)
<code>~5.0</code>	Creates a zero-length segment and records <code>~</code> in the data. <code>~</code> is ignored by <code>seg</code> operations, but is preserved as a comment.
<code>&lt;5.0</code>	Creates a point at 5.0. <code>&lt;</code> is ignored but is preserved as a comment.
<code>&gt;5.0</code>	Creates a point at 5.0. <code>&gt;</code> is ignored but is preserved as a comment.
<code>5 (+-) 0.3</code>	Creates an interval <code>4.7 .. 5.3</code> . Note that the <code>(+-)</code> notation isn't preserved.
<code>50 ..</code>	Everything that is greater than or equal to 50
<code>.. 0</code>	Everything that is less than or equal to 0
<code>1.5e-2 .. 2E-2</code>	Creates an interval <code>0.015 .. 0.02</code>
<code>1 ... 2</code>	The same as <code>1...2</code> , or <code>1 .. 2</code> , or <code>1..2</code> (spaces around the range operator are ignored)

Because the `...` operator is widely used in data sources, it is allowed as an alternative spelling of the `..` operator. Unfortunately, this creates a parsing ambiguity: it is not clear whether the upper bound in `0...23` is meant to be 23 or 0.23. This is resolved by requiring at least one digit before the decimal point in all numbers in `seg` input.

As a sanity check, `seg` rejects intervals with the lower bound greater than the upper, for example `5 .. 2`.

### F.61.3. Precision

`seg` values are stored internally as pairs of 32-bit floating point numbers. This means that numbers with more than 7 significant digits will be truncated.

Numbers with 7 or fewer significant digits retain their original precision. That is, if your query returns 0.00, you will be sure that the trailing zeroes are not the artifacts of formatting: they reflect the precision of the original data. The number of leading zeroes does not affect precision: the value 0.0067 is considered to have just 2 significant digits.

### F.61.4. Usage

The `seg` module includes a GiST index operator class for `seg` values. The operators supported by the GiST operator class are shown in Table F.186.

**Table F.186. Seg GiST Operators**

Operator	Description
<code>seg &lt;&lt; seg</code>	<code>→ boolean</code>

Operator	Description
	Is the first <code>seg</code> entirely to the left of the second? <code>[a, b] &lt;&lt; [c, d]</code> is true if <code>b &lt; c</code> .
<code>seg &gt;&gt; seg</code> → boolean	Is the first <code>seg</code> entirely to the right of the second? <code>[a, b] &gt;&gt; [c, d]</code> is true if <code>a &gt; d</code> .
<code>seg &amp;&lt; seg</code> → boolean	Does the first <code>seg</code> not extend to the right of the second? <code>[a, b] &amp;&lt; [c, d]</code> is true if <code>b &lt;= d</code> .
<code>seg &amp;&gt; seg</code> → boolean	Does the first <code>seg</code> not extend to the left of the second? <code>[a, b] &amp;&gt; [c, d]</code> is true if <code>a &gt;= c</code> .
<code>seg = seg</code> → boolean	Are the two <code>segs</code> equal?
<code>seg &amp;&amp; seg</code> → boolean	Do the two <code>segs</code> overlap?
<code>seg @&gt; seg</code> → boolean	Does the first <code>seg</code> contain the second?
<code>seg &lt;@ seg</code> → boolean	Is the first <code>seg</code> contained in the second?

(Before LightDB 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

In addition to the above operators, the usual comparison operators shown in Table 9.1 are available for type `seg`. These operators first compare (a) to (c), and if these are equal, compare (b) to (d). That results in reasonably good sorting in most cases, which is useful if you want to use `ORDER BY` with this type.

## F.61.5. Notes

For examples of usage, see the regression test `sql/seg.sql`.

The mechanism that converts `(+-)` to regular ranges isn't completely accurate in determining the number of significant digits for the boundaries. For example, it adds an extra digit to the lower boundary if the resulting interval includes a power of ten:

```
lightdb@postgres=> select '10(+-)1'::seg as seg;
      seg
-----
9.0 .. 11          -- should be: 9 .. 11
```

The performance of an R-tree index can largely depend on the initial order of input values. It may be very helpful to sort the input table on the `seg` column; see the script `sort-segments.pl` for an example.

## F.61.6. Credits

Original author: Gene Selkov, Jr. <selkovjr@mcs.anl.gov>, Mathematics and Computer Science Division, Argonne National Laboratory.

My thanks are primarily to Prof. Joe Hellerstein (<https://dsf.berkeley.edu/jmh/>) for elucidating the gist of the GiST (<http://gist.cs.berkeley.edu/>). I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like

to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

## F.62. sepgsql

`sepgsql` is a loadable module that supports label-based mandatory access control (MAC) based on SELinux security policy.

### Warning

The current implementation has significant limitations, and does not enforce mandatory access control for all actions. See Section F.62.7.

### F.62.1. Overview

This module integrates with SELinux to provide an additional layer of security checking above and beyond what is normally provided by LightDB. From the perspective of SELinux, this module allows LightDB to function as a user-space object manager. Each table or function access initiated by a DML query will be checked against the system security policy. This check is in addition to the usual SQL permissions checking performed by LightDB.

SELinux access control decisions are made using security labels, which are represented by strings such as `system_u:object_r:sepgsql_table_t:s0`. Each access control decision involves two labels: the label of the subject attempting to perform the action, and the label of the object on which the operation is to be performed. Since these labels can be applied to any sort of object, access control decisions for objects stored within the database can be (and, with this module, are) subjected to the same general criteria used for objects of any other type, such as files. This design is intended to allow a centralized security policy to protect information assets independent of the particulars of how those assets are stored.

The `SECURITY LABEL` statement allows assignment of a security label to a database object.

### F.62.2. Installation

`sepgsql` can only be used on Linux 2.6.28 or higher with SELinux enabled. It is not available on any other platform. You will also need `libselinux 2.1.10` or higher and `selinux-policy 3.9.13` or higher (although some distributions may backport the necessary rules into older policy versions).

The `sestatus` command allows you to check the status of SELinux. A typical display is:

```
$ sestatus
SELinux status:                enabled
SELinuxfs mount:              /selinux
Current mode:                  enforcing
Mode from config file:        enforcing
Policy version:                24
Policy from config file:      targeted
```

If SELinux is disabled or not installed, you must set that product up first before installing this module.

To build this module, include the option `--with-selinux` in your LightDB configure command. Be sure that the `libselinux-devel` RPM is installed at build time.

To use this module, you must include `sepgsql` in the `shared_preload_libraries` parameter in `lightdb.conf`. The module will not function correctly if loaded in any other manner. Once the

module is loaded, you should execute `sepgsql.sql` in each database. This will install functions needed for security label management, and assign initial security labels.

Here is an example showing how to initialize a fresh database cluster with `sepgsql` functions and security labels installed. Adjust the paths shown as appropriate for your installation:

```
$ export LTDATA=/path/to/data/directory
$ initdb
$ vi $LTDATA/lightdb.conf
  change
    #shared_preload_libraries = ''           # (change
requires restart)
  to
    shared_preload_libraries = 'sepgsql'     # (change
requires restart)
$ for DBNAME in template0 template1 postgres; do
  lightdb --single -F -c exit_on_error=true $DBNAME \
    </usr/local/lightdb-x/share/contrib/sepgsql.sql >/dev/null
done
```

Please note that you may see some or all of the following notifications depending on the particular versions you have of `libselenium` and `selinux-policy`:

```
/etc/selinux/targeted/contexts/sepgsql_contexts: line 33 has
invalid object type db_blobs
/etc/selinux/targeted/contexts/sepgsql_contexts: line 36 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 37 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 38 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 39 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 40 has
invalid object type db_language
```

These messages are harmless and should be ignored.

If the installation process completes without error, you can now start the server normally.

## F.62.3. Regression Tests

Due to the nature of SELinux, running the regression tests for `sepgsql` requires several extra configuration steps, some of which must be done as root. The regression tests will not be run by an ordinary `make check` or `make installcheck` command; you must set up the configuration and then invoke the test script manually. The tests must be run in the `contrib/sepgsql` directory of a configured LightDB build tree. Although they require a build tree, the tests are designed to be executed against an installed server, that is they are comparable to `make installcheck` not `make check`.

First, set up `sepgsql` in a working database according to the instructions in Section F.62.2. Note that the current operating system user must be able to connect to the database as superuser without password authentication.

Second, build and install the policy package for the regression test. The `sepgsql-regtest` policy is a special purpose policy package which provides a set of rules to be allowed during the regression tests. It should be built from the policy source file `sepgsql-regtest.te`, which is done using `make` with a Makefile supplied by SELinux. You will need to locate the appropriate Makefile on

your system; the path shown below is only an example. (This Makefile is usually supplied by the `selinux-policy-devel` or `selinux-policy` RPM.) Once built, install this policy package using the `semodule` command, which loads supplied policy packages into the kernel. If the package is correctly installed, `semodule -l` should list `sepgsql-regtest` as an available policy package:

```
$ cd .../contrib/sepgsql
$ make -f /usr/share/selinux/devel/Makefile
$ sudo semodule -u sepgsql-regtest.pp
$ sudo semodule -l | grep sepgsql
sepgsql-regtest 1.07
```

Third, turn on `sepgsql_regression_test_mode`. For security reasons, the rules in `sepgsql-regtest` are not enabled by default; the `sepgsql_regression_test_mode` parameter enables the rules needed to launch the regression tests. It can be turned on using the `setsebool` command:

```
$ sudo setsebool sepgsql_regression_test_mode on
$ getsebool sepgsql_regression_test_mode
sepgsql_regression_test_mode --> on
```

Fourth, verify your shell is operating in the `unconfined_t` domain:

```
$ id -z
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
```

See Section F.62.8 for details on adjusting your working domain, if necessary.

Finally, run the regression test script:

```
$ ./test_sepgsql
```

This script will attempt to verify that you have done all the configuration steps correctly, and then it will run the regression tests for the `sepgsql` module.

After completing the tests, it's recommended you disable the `sepgsql_regression_test_mode` parameter:

```
$ sudo setsebool sepgsql_regression_test_mode off
```

You might prefer to remove the `sepgsql-regtest` policy entirely:

```
$ sudo semodule -r sepgsql-regtest
```

## F.62.4. GUC Parameters

`sepgsql.permissive` (boolean)

This parameter enables `sepgsql` to function in permissive mode, regardless of the system setting. The default is off. This parameter can only be set in the `lightdb.conf` file or on the server command line.

When this parameter is on, `sepgsql` functions in permissive mode, even if SELinux in general is working in enforcing mode. This parameter is primarily useful for testing purposes.



`sepgsql.debug_audit` (boolean)

This parameter enables the printing of audit messages regardless of the system policy settings. The default is off, which means that messages will be printed according to the system settings.

The security policy of SELinux also has rules to control whether or not particular accesses are logged. By default, access violations are logged, but allowed accesses are not.

This parameter forces all possible logging to be turned on, regardless of the system policy.

## F.62.5. Features

### F.62.5.1. Controlled Object Classes

The security model of SELinux describes all the access control rules as relationships between a subject entity (typically, a client of the database) and an object entity (such as a database object), each of which is identified by a security label. If access to an unlabeled object is attempted, the object is treated as if it were assigned the label `unlabeled_t`.

Currently, `sepgsql` allows security labels to be assigned to schemas, tables, columns, sequences, views, and functions. When `sepgsql` is in use, security labels are automatically assigned to supported database objects at creation time. This label is called a default security label, and is decided according to the system security policy, which takes as input the creator's label, the label assigned to the new object's parent object and optionally name of the constructed object.

A new database object basically inherits the security label of the parent object, except when the security policy has special rules known as type-transition rules, in which case a different label may be applied. For schemas, the parent object is the current database; for tables, sequences, views, and functions, it is the containing schema; for columns, it is the containing table.

### F.62.5.2. DML Permissions

For tables, `db_table:select`, `db_table:insert`, `db_table:update` or `db_table:delete` are checked for all the referenced target tables depending on the kind of statement; in addition, `db_table:select` is also checked for all the tables that contain columns referenced in the `WHERE` or `RETURNING` clause, as a data source for `UPDATE`, and so on.

Column-level permissions will also be checked for each referenced column. `db_column:select` is checked on not only the columns being read using `SELECT`, but those being referenced in other DML statements; `db_column:update` or `db_column:insert` will also be checked for columns being modified by `UPDATE` or `INSERT`.

For example, consider:

```
UPDATE t1 SET x = 2, y = func1(y) WHERE z = 100;
```

Here, `db_column:update` will be checked for `t1.x`, since it is being updated, `db_column:{select update}` will be checked for `t1.y`, since it is both updated and referenced, and `db_column:select` will be checked for `t1.z`, since it is only referenced. `db_table:{select update}` will also be checked at the table level.

For sequences, `db_sequence:get_value` is checked when we reference a sequence object using `SELECT`; however, note that we do not currently check permissions on execution of corresponding functions such as `lastval()`.

For views, `db_view:expand` will be checked, then any other required permissions will be checked on the objects being expanded from the view, individually.

For functions, `db_procedure: {execute}` will be checked when user tries to execute a function as a part of query, or using fast-path invocation. If this function is a trusted procedure, it also checks `db_procedure: {entrypoint}` permission to check whether it can perform as entry point of trusted procedure.

In order to access any schema object, `db_schema: search` permission is required on the containing schema. When an object is referenced without schema qualification, schemas on which this permission is not present will not be searched (just as if the user did not have `USAGE` privilege on the schema). If an explicit schema qualification is present, an error will occur if the user does not have the requisite permission on the named schema.

The client must be allowed to access all referenced tables and columns, even if they originated from views which were then expanded, so that we apply consistent access control rules independent of the manner in which the table contents are referenced.

The default database privilege system allows database superusers to modify system catalogs using DML commands, and reference or modify toast tables. These operations are prohibited when `sepgsql` is enabled.

### F.62.5.3. DDL Permissions

SELinux defines several permissions to control common operations for each object type; such as creation, alter, drop and relabel of security label. In addition, several object types have special permissions to control their characteristic operations; such as addition or deletion of name entries within a particular schema.

Creating a new database object requires `create` permission. SELinux will grant or deny this permission based on the client's security label and the proposed security label for the new object. In some cases, additional privileges are required:

- `CREATE DATABASE` additionally requires `getattr` permission for the source or template database.
- Creating a schema object additionally requires `add_name` permission on the parent schema.
- Creating a table additionally requires permission to create each individual table column, just as if each table column were a separate top-level object.
- Creating a function marked as `LEAKPROOF` additionally requires `install` permission. (This permission is also checked when `LEAKPROOF` is set for an existing function.)

When `DROP` command is executed, `drop` will be checked on the object being removed. Permissions will be also checked for objects dropped indirectly via `CASCADE`. Deletion of objects contained within a particular schema (tables, views, sequences and procedures) additionally requires `remove_name` on the schema.

When `ALTER` command is executed, `setattr` will be checked on the object being modified for each object types, except for subsidiary objects such as the indexes or triggers of a table, where permissions are instead checked on the parent object. In some cases, additional permissions are required:

- Moving an object to a new schema additionally requires `remove_name` permission on the old schema and `add_name` permission on the new one.
- Setting the `LEAKPROOF` attribute on a function requires `install` permission.
- Using `SECURITY LABEL` on an object additionally requires `relabelfrom` permission for the object in conjunction with its old security label and `relabelto` permission for the object in conjunction with its new security label. (In cases where multiple label providers are installed and the user tries to set a security label, but it is not managed by SELinux, only `setattr` should be checked here. This is currently not done due to implementation restrictions.)

## F.62.5.4. Trusted Procedures

Trusted procedures are similar to security definer functions or setuid commands. SELinux provides a feature to allow trusted code to run using a security label different from that of the client, generally for the purpose of providing highly controlled access to sensitive data (e.g., rows might be omitted, or the precision of stored values might be reduced). Whether or not a function acts as a trusted procedure is controlled by its security label and the operating system security policy. For example:

```
lightdb@postgres=# CREATE TABLE customer (
                    cid      int primary key,
                    cname    text,
                    credit   text
                    );
CREATE TABLE
lightdb@postgres=# SECURITY LABEL ON COLUMN customer.credit
                   IS 'system_u:object_r:sepgsql_secret_table_t:s0';
SECURITY LABEL
lightdb@postgres=# CREATE FUNCTION show_credit(int) RETURNS text
                   AS 'SELECT regexp_replace(credit, ''-[0-9]+$'', ''-
xxxx'', 'g')
                   FROM customer WHERE cid = $1'
                   LANGUAGE sql;
CREATE FUNCTION
lightdb@postgres=# SECURITY LABEL ON FUNCTION show_credit(int)
                   IS
                   'system_u:object_r:sepgsql_trusted_proc_exec_t:s0';
SECURITY LABEL
```

The above operations should be performed by an administrative user.

```
lightdb@postgres=# SELECT * FROM customer;
ERROR:  SELinux: security policy violation
lightdb@postgres=# SELECT cid, cname, show_credit(cid) FROM
customer;
cid | cname | show_credit
-----+-----+-----
  1 | taro  | 1111-2222-3333-xxxx
  2 | hanako | 5555-6666-7777-xxxx
(2 rows)
```

In this case, a regular user cannot reference `customer.credit` directly, but a trusted procedure `show_credit` allows the user to print the credit card numbers of customers with some of the digits masked out.

## F.62.5.5. Dynamic Domain Transitions

It is possible to use SELinux's dynamic domain transition feature to switch the security label of the client process, the client domain, to a new context, if that is allowed by the security policy. The client domain needs the `setcurrent` permission and also `dyntransition` from the old to the new domain.

Dynamic domain transitions should be considered carefully, because they allow users to switch their label, and therefore their privileges, at their option, rather than (as in the case of a trusted procedure) as mandated by the system. Thus, the `dyntransition` permission is only considered safe when used to switch to a domain with a smaller set of privileges than the original one. For example:

```

regression=# select sepysql_getcon();
                sepysql_getcon
-----
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
(1 row)

regression=# SELECT
  sepysql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-
s0:c1.c4');
  sepysql_setcon
-----
t
(1 row)

regression=# SELECT
  sepysql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-
s0:c1.c1023');
ERROR:  SELinux: security policy violation

```

In this example above we were allowed to switch from the larger MCS range `c1 . c1023` to the smaller range `c1 . c4`, but switching back was denied.

A combination of dynamic domain transition and trusted procedure enables an interesting use case that fits the typical process life-cycle of connection pooling software. Even if your connection pooling software is not allowed to run most of SQL commands, you can allow it to switch the security label of the client using the `sepysql_setcon()` function from within a trusted procedure; that should take some credential to authorize the request to switch the client label. After that, this session will have the privileges of the target user, rather than the connection pooler. The connection pooler can later revert the security label change by again using `sepysql_setcon()` with `NULL` argument, again invoked from within a trusted procedure with appropriate permissions checks. The point here is that only the trusted procedure actually has permission to change the effective security label, and only does so when given proper credentials. Of course, for secure operation, the credential store (table, procedure definition, or whatever) must be protected from unauthorized access.

### F.62.5.6. Miscellaneous

We reject the `LOAD` command across the board, because any module loaded could easily circumvent security policy enforcement.

## F.62.6. Sepysql Functions

Table F.187 shows the available functions.

**Table F.187. Sepysql Functions**

Function	Description
<code>sepysql_getcon()</code> → text	Returns the client domain, the current security label of the client.
<code>sepysql_setcon(text)</code> → boolean	Switches the client domain of the current session to the new domain, if allowed by the security policy. It also accepts <code>NULL</code> input as a request to transition to the client's original domain.
<code>sepysql_mcstrans_in(text)</code> → text	Translates the given qualified MLS/MCS range into raw format if the <code>mcstrans</code> daemon is running.

Function	Description
<code>sepgsql_mcstrans_out ( text ) → text</code>	Translates the given raw MLS/MCS range into qualified format if the mcstrans daemon is running.
<code>sepgsql_restorecon ( text ) → boolean</code>	Sets up initial security labels for all objects within the current database. The argument may be NULL, or the name of a specfile to be used as alternative of the system default.

## F.62.7. Limitations

### Data Definition Language (DDL) Permissions

Due to implementation restrictions, some DDL operations do not check permissions.

### Data Control Language (DCL) Permissions

Due to implementation restrictions, DCL operations do not check permissions.

### Row-level access control

LightDB supports row-level access, but `sepgsql` does not.

### Covert channels

`sepgsql` does not try to hide the existence of a certain object, even if the user is not allowed to reference it. For example, we can infer the existence of an invisible object as a result of primary key conflicts, foreign key violations, and so on, even if we cannot obtain the contents of the object. The existence of a top secret table cannot be hidden; we only hope to conceal its contents.

## F.62.8. External Resources

### SE-LightDB Introduction<sup>11</sup>

This wiki page provides a brief overview, security design, architecture, administration and upcoming features.

### SELinux User's and Administrator's Guide<sup>12</sup>

This document provides a wide spectrum of knowledge to administer SELinux on your systems. It focuses primarily on Red Hat operating systems, but is not limited to them.

### Fedora SELinux FAQ<sup>13</sup>

This document answers frequently asked questions about SELinux. It focuses primarily on Fedora, but is not limited to Fedora.

## F.62.9. Author

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## F.63. spi

<sup>11</sup> <https://wiki.postgresql.org/wiki/SEPostgreSQL>

<sup>12</sup> [https://access.redhat.com/documentation/en-us/red\\_hat\\_enterprise\\_linux/7/html/selinux\\_users\\_and\\_administrators\\_guide/index](https://access.redhat.com/documentation/en-us/red_hat_enterprise_linux/7/html/selinux_users_and_administrators_guide/index)

<sup>13</sup> [https://fedoraproject.org/wiki/SELinux\\_FAQ](https://fedoraproject.org/wiki/SELinux_FAQ)

The `spi` module provides several workable examples of using the Server Programming Interface (SPI) and triggers. While these functions are of some value in their own right, they are even more useful as examples to modify for your own purposes. The functions are general enough to be used with any table, but you have to specify table and field names (as described below) while creating a trigger.

Each of the groups of functions described below is provided as a separately-installable extension.

## F.63.1. `refint` — Functions for Implementing Referential Integrity

`check_primary_key()` and `check_foreign_key()` are used to check foreign key constraints. (This functionality is long since superseded by the built-in foreign key mechanism, of course, but the module is still useful as an example.)

`check_primary_key()` checks the referencing table. To use, create a `BEFORE INSERT OR UPDATE` trigger using this function on a table referencing another table. Specify as the trigger arguments: the referencing table's column name(s) which form the foreign key, the referenced table name, and the column names in the referenced table which form the primary/unique key. To handle multiple foreign keys, create a trigger for each reference.

`check_foreign_key()` checks the referenced table. To use, create a `BEFORE DELETE OR UPDATE` trigger using this function on a table referenced by other table(s). Specify as the trigger arguments: the number of referencing tables for which the function has to perform checking, the action if a referencing key is found (`cascade` — to delete the referencing row, `restrict` — to abort transaction if referencing keys exist, `setnull` — to set referencing key fields to null), the triggered table's column names which form the primary/unique key, then the referencing table name and column names (repeated for as many referencing tables as were specified by first argument). Note that the primary/unique key columns should be marked `NOT NULL` and should have a unique index.

There are examples in `refint.example`.

## F.63.2. `autoinc` — Functions for Autoincrementing Fields

`autoinc()` is a trigger that stores the next value of a sequence into an integer field. This has some overlap with the built-in “serial column” feature, but it is not the same: `autoinc()` will override attempts to substitute a different field value during inserts, and optionally it can be used to increment the field during updates, too.

To use, create a `BEFORE INSERT` (or optionally `BEFORE INSERT OR UPDATE`) trigger using this function. Specify two trigger arguments: the name of the integer column to be modified, and the name of the sequence object that will supply values. (Actually, you can specify any number of pairs of such names, if you'd like to update more than one autoincrementing column.)

There is an example in `autoinc.example`.

## F.63.3. `insert_username` — Functions for Tracking Who Changed a Table

`insert_username()` is a trigger that stores the current user's name into a text field. This can be useful for tracking who last modified a particular row within a table.

To use, create a `BEFORE INSERT` and/or `UPDATE` trigger using this function. Specify a single trigger argument: the name of the text column to be modified.

There is an example in `insert_username.example`.

## F.63.4. `moddatetime` — Functions for Tracking Last Modification Time

`moddatetime()` is a trigger that stores the current time into a `timestamp` field. This can be useful for tracking the last modification time of a particular row within a table.

To use, create a `BEFORE UPDATE` trigger using this function. Specify a single trigger argument: the name of the column to be modified. The column must be of type `timestamp` or `timestamp with time zone`.

There is an example in `moddatetime.example`.

## F.64. `sslinfo`

The `sslinfo` module provides information about the SSL certificate that the current client provided when connecting to LightDB. The module is useless (most functions will return `NULL`) if the current connection does not use SSL.

Some of the information available through this module can also be obtained using the built-in system view `pg_stat_ssl`.

This extension won't build at all unless the installation was configured with `--with-openssl`.

### F.64.1. Functions Provided

`ssl_is_used()` returns `boolean`

Returns true if current connection to server uses SSL, and false otherwise.

`ssl_version()` returns `text`

Returns the name of the protocol used for the SSL connection (e.g., `TLSv1.0`, `TLSv1.1`, or `TLSv1.2`).

`ssl_cipher()` returns `text`

Returns the name of the cipher used for the SSL connection (e.g., `DHE-RSA-AES256-SHA`).

`ssl_client_cert_present()` returns `boolean`

Returns true if current client has presented a valid SSL client certificate to the server, and false otherwise. (The server might or might not be configured to require a client certificate.)

`ssl_client_serial()` returns `numeric`

Returns serial number of current client certificate. The combination of certificate serial number and certificate issuer is guaranteed to uniquely identify a certificate (but not its owner — the owner ought to regularly change their keys, and get new certificates from the issuer).

So, if you run your own CA and allow only certificates from this CA to be accepted by the server, the serial number is the most reliable (albeit not very mnemonic) means to identify a user.

`ssl_client_dn()` returns `text`

Returns the full subject of the current client certificate, converting character data into the current database encoding. It is assumed that if you use non-ASCII characters in the certificate names, your database is able to represent these characters, too. If your database uses the `SQL_ASCII` encoding, non-ASCII characters in the name will be represented as UTF-8 sequences.

The result looks like `/CN=Somebody /C=Some country/O=Some organization`.

`ssl_issuer_dn()` returns text

Returns the full issuer name of the current client certificate, converting character data into the current database encoding. Encoding conversions are handled the same as for `ssl_client_dn`.

The combination of the return value of this function with the certificate serial number uniquely identifies the certificate.

This function is really useful only if you have more than one trusted CA certificate in your server's certificate authority file, or if this CA has issued some intermediate certificate authority certificates.

`ssl_client_dn_field(fieldname text)` returns text

This function returns the value of the specified field in the certificate subject, or NULL if the field is not present. Field names are string constants that are converted into ASN1 object identifiers using the OpenSSL object database. The following values are acceptable:

```
commonName (alias CN)
surname (alias SN)
name
givenName (alias GN)
countryName (alias C)
localityName (alias L)
stateOrProvinceName (alias ST)
organizationName (alias O)
organizationalUnitName (alias OU)
title
description
initials
postalCode
streetAddress
generationQualifier
description
dnQualifier
x500UniqueIdentifier
pseudonym
role
emailAddress
```

All of these fields are optional, except `commonName`. It depends entirely on your CA's policy which of them would be included and which wouldn't. The meaning of these fields, however, is strictly defined by the X.500 and X.509 standards, so you cannot just assign arbitrary meaning to them.

`ssl_issuer_field(fieldname text)` returns text

Same as `ssl_client_dn_field`, but for the certificate issuer rather than the certificate subject.

`ssl_extension_info()` returns setof record

Provide information about extensions of client certificate: extension name, extension value, and if it is a critical extension.

## F.64.2. Author

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## F.65. system\_stats

*system\_stats* is a LightDB extension that provides functions to access system level statistics that can be used for monitoring.

### F.65.1. Security

Due to the nature of the information returned by these functions, access is restricted to superusers and members of the `monitor_system_stats` role which will be created when the extension is installed. To allow users to access the functions without granting them superuser access, add them to the `monitor_system_stats` role. For example:

```
GRANT monitor_system_stats to nagios;
```

### F.65.2. Functions

The following functions are provided to fetch system level statistics for all platforms.

#### F.65.2.1. pg\_sys\_os\_info

This interface allows the user to get operating system statistics.

#### F.65.2.2. pg\_sys\_cpu\_info

This interface allows the user to get CPU information.

#### F.65.2.3. pg\_sys\_cpu\_usage\_info

This interface allows the user to get CPU usage information. Values are a percentage of time spent by CPUs for all operations.

#### F.65.2.4. pg\_sys\_memory\_info

This interface allows the user to get memory usage information. All the values are in bytes.

#### F.65.2.5. pg\_sys\_io\_analysis\_info

This interface allows the user to get an I/O analysis of block devices.

#### F.65.2.6. pg\_sys\_disk\_info

This interface allows the user to get the disk information.

#### F.65.2.7. pg\_sys\_load\_avg\_info

This interface allows the user to get the average load of the system over 1, 5, 10 and 15 minute intervals.

#### F.65.2.8. pg\_sys\_process\_info

This interface allows the user to get process information.

#### F.65.2.9. pg\_sys\_network\_info

This interface allows the user to get network interface information.

## **F.65.2.10. pg\_sys\_cpu\_memory\_by\_process**

This interface allows the user to get the CPU and memory information for each process ID.

## **F.65.3. Detailed output of each functions**

### **F.65.3.1. pg\_sys\_os\_info**

- Name
- Version
- Host name
- Domain name
- Handle count
- Process count
- Thread count
- Architecture
- Last bootup time
- Uptime in seconds

### **F.65.3.2. pg\_sys\_cpu\_info**

- Vendor
- Description
- Model name
- Processor type
- Logical processor
- Physical processor
- Number of cores
- Architecture
- Clock speed in hz
- CPU type
- CPU family
- Byte order
- L1d cache size
- L1i cache size
- L2 cache size
- L3 cache size

### **F.65.3.3. pg\_sys\_cpu\_usage\_info**

- Percent time spent in processing usermode normal process
- Percent time spent in processing usermode niced process
- Percent time spent in kernel mode process
- Percent time spent in idle mode
- Percent time spent in io completion
- Percent time spent in servicing interrupt
- Percent time spent in servicing software interrupt
- Percent user time spent
- Percent processor time spent
- Percent privileged time spent
- Percent interrupt time spent

### **F.65.3.4. pg\_sys\_memory\_info**

- Total memory
- Used memory
- Free memory

- Total swap memory
- Used swap memory
- Free swap memory
- Total cache memory
- Total kernel memory
- Kernel paged memory
- Kernel non paged memory
- Total page file
- Available page file

### **F.65.3.5. pg\_sys\_io\_analysis\_info**

- Block device name
- Total number of reads
- Total number of writes
- Read bytes
- Written bytes
- Time spent in milliseconds for reading
- Time spent in milliseconds for writing

### **F.65.3.6. pg\_sys\_disk\_info**

- File system of the disk
- File system type
- Mount point for the file system
- Drive letter
- Drive type
- Total space in bytes
- Used space in bytes
- Available space in bytes
- Number of total inodes
- Number of used inodes
- Number of free inodes

### **F.65.3.7. pg\_sys\_load\_avg\_info**

- 1 minute load average
- 5 minute load average
- 10 minute load average
- 15 minute load average

### **F.65.3.8. pg\_sys\_process\_info**

- Number of total processes
- Number of running processes
- Number of sleeping processes
- Number of stopped processes
- Number of zombie processes

### **F.65.3.9. pg\_sys\_network\_info**

- Name of the interface\_name
- ipv4 address of the interface
- Number of total bytes transmitted
- Number of total packets transmitted
- Number of transmit errors by this network device
- Number of packets dropped during transmission
- Number of total bytes received

- Number of total packets received
- Number of receive errors by this network device
- Number of packets dropped by this network device
- Interface speed in mbps

### F.65.3.10. pg\_sys\_cpu\_memory\_by\_process

- PID of the process
- Process name
- CPU usage in bytes
- Memory usage in bytes
- Total memory used in bytes

## F.66. tablefunc

The `tablefunc` module includes various functions that return tables (that is, multiple rows). These functions are useful both in their own right and as examples of how to write C functions that return multiple rows.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.66.1. Functions Provided

Table F.188 summarizes the functions provided by the `tablefunc` module.

**Table F.188. tablefunc Functions**

Function	Description
<code>normal_rand ( numvals integer, mean float8, stddev float8 )</code>	<code>→ setof float8</code> Produces a set of normally distributed random values.
<code>crosstab ( sql text )</code>	<code>→ setof record</code> Produces a “pivot table” containing row names plus <i>N</i> value columns, where <i>N</i> is determined by the row type specified in the calling query.
<code>crosstabN ( sql text )</code>	<code>→ setof table_crosstab_N</code> Produces a “pivot table” containing row names plus <i>N</i> value columns. <code>crosstab2</code> , <code>crosstab3</code> , and <code>crosstab4</code> are predefined, but you can create additional <code>crosstabN</code> functions as described below.
<code>crosstab ( source_sql text, category_sql text )</code>	<code>→ setof record</code> Produces a “pivot table” with the value columns specified by a second query.
<code>crosstab ( sql text, N integer )</code>	<code>→ setof record</code> Obsolete version of <code>crosstab ( text )</code> . The parameter <i>N</i> is now ignored, since the number of value columns is always determined by the calling query.
<code>connectby ( relname text, keyid_fld text, parent_keyid_fld text [, orderby_fld text ], start_with text, max_depth integer [, branch_delim text ] )</code>	<code>→ setof record</code> Produces a representation of a hierarchical tree structure.

#### F.66.1.1. normal\_rand

`normal_rand(int numvals, float8 mean, float8 stddev)` returns set of float8

`normal_rand` produces a set of normally distributed random values (Gaussian distribution).

*numvals* is the number of values to be returned from the function. *mean* is the mean of the normal distribution of values and *stddev* is the standard deviation of the normal distribution of values.

For example, this call requests 1000 values with a mean of 5 and a standard deviation of 3:

```
test=# SELECT * FROM normal_rand(1000, 5, 3);
      normal_rand
-----
 1.56556322244898
 9.10040991424657
 5.36957140345079
-0.369151492880995
 0.283600703686639
      .
      .
      .
 4.82992125404908
 9.71308014517282
 2.49639286969028
(1000 rows)
```

### F.66.1.2. `crosstab(text)`

```
crosstab(text sql)
crosstab(text sql, int N)
```

The `crosstab` function is used to produce “pivot” displays, wherein data is listed across the page rather than down. For example, we might have data like

```
row1  val11
row1  val12
row1  val13
...
row2  val21
row2  val22
row2  val23
...
```

which we wish to display like

```
row1  val11  val12  val13  ...
row2  val21  val22  val23  ...
...
```

The `crosstab` function takes a text parameter that is a SQL query producing raw data formatted in the first way, and produces a table formatted in the second way.

The *sql* parameter is a SQL statement that produces the source set of data. This statement must return one *row\_name* column, one *category* column, and one *value* column. *N* is an obsolete parameter, ignored if supplied (formerly this had to match the number of output value columns, but now that is determined by the calling query).

For example, the provided query might produce a set something like:

row_name	cat	value
row1	cat1	val1
row1	cat2	val2
row1	cat3	val3
row1	cat4	val4
row2	cat1	val5
row2	cat2	val6
row2	cat3	val7
row2	cat4	val8

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM crosstab('...') AS ct(row_name text, category_1 text,
category_2 text);
```

This example produces a set something like:

row_name	<= value columns ==>	
	category_1	category_2
row1	val1	val2
row2	val5	val6

The `FROM` clause must define the output as one `row_name` column (of the same data type as the first result column of the SQL query) followed by `N` `value` columns (all of the same data type as the third result column of the SQL query). You can set up as many output value columns as you wish. The names of the output columns are up to you.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. It fills the output `value` columns, left to right, with the `value` fields from these rows. If there are fewer rows in a group than there are output `value` columns, the extra output columns are filled with nulls; if there are more rows, the extra input rows are skipped.

In practice the SQL query should always specify `ORDER BY 1, 2` to ensure that the input rows are properly ordered, that is, values with the same `row_name` are brought together and correctly ordered within the row. Notice that `crosstab` itself does not pay any attention to the second column of the query result; it's just there to be ordered by, to control the order in which the third-column values appear across the page.

Here is a complete example:

```
CREATE TABLE ct(id SERIAL, rowid TEXT, attribute TEXT, value TEXT);
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att1','val1');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att2','val2');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att3','val3');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att4','val4');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att1','val5');
```

```

INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att2','val6');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att3','val7');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att4','val8');

SELECT *
FROM crosstab(
  'select rowid, attribute, value
   from ct
   where attribute = 'att2' or attribute = 'att3'
   order by 1,2')
AS ct(row_name text, category_1 text, category_2 text, category_3
text);

 row_name | category_1 | category_2 | category_3
-----+-----+-----+-----
 test1   | val2       | val3       |
 test2   | val6       | val7       |
(2 rows)

```

You can avoid always having to write out a FROM clause to define the output columns, by setting up a custom crosstab function that has the desired output row type wired into its definition. This is described in the next section. Another possibility is to embed the required FROM clause in a view definition.

### Note

See also the `\crosstabview` command in `ltsql`, which provides functionality similar to `crosstab()`.

## F.66.1.3. `crosstabN(text)`

```
crosstabN(text sql)
```

The `crosstabN` functions are examples of how to set up custom wrappers for the general `crosstab` function, so that you need not write out column names and types in the calling `SELECT` query. The `tablefunc` module includes `crosstab2`, `crosstab3`, and `crosstab4`, whose output row types are defined as

```

CREATE TYPE tablefunc_crosstab_N AS (
  row_name TEXT,
  category_1 TEXT,
  category_2 TEXT,
  .
  .
  .
  category_N TEXT
);

```

Thus, these functions can be used directly when the input query produces `row_name` and value columns of type `text`, and you want 2, 3, or 4 output values columns. In all other ways they behave exactly as described above for the general `crosstab` function.

For instance, the example given in the previous section would also work as

```

SELECT *
FROM crosstab3(
  'select rowid, attribute, value
   from ct
   where attribute = 'att2' or attribute = 'att3'
   order by 1,2');

```

These functions are provided mostly for illustration purposes. You can create your own return types and functions based on the underlying `crosstab()` function. There are two ways to do it:

- Create a composite type describing the desired output columns, similar to the examples in `contrib/tablefunc/tablefunc--1.0.sql`. Then define a unique function name accepting one text parameter and returning setof `your_type_name`, but linking to the same underlying `crosstab C` function. For example, if your source data produces row names that are text, and values that are float8, and you want 5 value columns:

```

CREATE TYPE my_crosstab_float8_5_cols AS (
  my_row_name text,
  my_category_1 float8,
  my_category_2 float8,
  my_category_3 float8,
  my_category_4 float8,
  my_category_5 float8
);

CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(text)
  RETURNS setof my_crosstab_float8_5_cols
  AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;

```

- Use OUT parameters to define the return type implicitly. The same example could also be done this way:

```

CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(
  IN text,
  OUT my_row_name text,
  OUT my_category_1 float8,
  OUT my_category_2 float8,
  OUT my_category_3 float8,
  OUT my_category_4 float8,
  OUT my_category_5 float8)
  RETURNS setof record
  AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;

```

### F.66.1.4. `crosstab(text, text)`

```
crosstab(text source_sql, text category_sql)
```

The main limitation of the single-parameter form of `crosstab` is that it treats all values in a group alike, inserting each value into the first available column. If you want the value columns to correspond to specific categories of data, and some groups might not have data for some of the categories, that doesn't work well. The two-parameter form of `crosstab` handles this case by providing an explicit list of the categories corresponding to the output columns.

`source_sql` is a SQL statement that produces the source set of data. This statement must return one `row_name` column, one `category` column, and one `value` column. It may also have one or more



“extra” columns. The `row_name` column must be first. The `category` and `value` columns must be the last two columns, in that order. Any columns between `row_name` and `category` are treated as “extra”. The “extra” columns are expected to be the same for all rows with the same `row_name` value.

For example, `source_sql` might produce a set something like:

```
SELECT row_name, extra_col, cat, value FROM foo ORDER BY 1;
```

row_name	extra_col	cat	value
row1	extra1	cat1	val1
row1	extra1	cat2	val2
row1	extra1	cat4	val4
row2	extra2	cat1	val5
row2	extra2	cat2	val6
row2	extra2	cat3	val7
row2	extra2	cat4	val8

`category_sql` is a SQL statement that produces the set of categories. This statement must return only one column. It must produce at least one row, or an error will be generated. Also, it must not produce duplicate values, or an error will be generated. `category_sql` might be something like:

```
SELECT DISTINCT cat FROM foo ORDER BY 1;
```

```
cat
-----
cat1
cat2
cat3
cat4
```

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM crosstab('...', '...')
AS ct(row_name text, extra text, cat1 text, cat2 text, cat3
text, cat4 text);
```

This will produce a result something like:

row_name	extra	<== value columns ==>	cat1	cat2	cat3	cat4
row1	extra1	val1	val2			val4
row2	extra2	val5	val6	val7		val8

The `FROM` clause must define the proper number of output columns of the proper data types. If there are  $N$  columns in the `source_sql` query's result, the first  $N-2$  of them must match up with the first  $N-2$  output columns. The remaining output columns must have the type of the last column of the `source_sql` query's result, and there must be exactly as many of them as there are rows in the `category_sql` query's result.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. The output `row_name` column, plus any “extra” columns, are copied from the first row of the group. The output `value` columns are filled with the `value` fields from rows having matching `category` values. If a row's `category` does not match any output of the

*category\_sql* query, its value is ignored. Output columns whose matching category is not present in any input row of the group are filled with nulls.

In practice the *source\_sql* query should always specify `ORDER BY 1` to ensure that values with the same *row\_name* are brought together. However, ordering of the categories within a group is not important. Also, it is essential to be sure that the order of the *category\_sql* query's output matches the specified output column order.

Here are two complete examples:

```
create table sales(year int, month int, qty int);
insert into sales values(2007, 1, 1000);
insert into sales values(2007, 2, 1500);
insert into sales values(2007, 7, 500);
insert into sales values(2007, 11, 1500);
insert into sales values(2007, 12, 2000);
insert into sales values(2008, 1, 1000);

select * from crosstab(
  'select year, month, qty from sales order by 1',
  'select m from generate_series(1,12) m'
) as (
  year int,
  "Jan" int,
  "Feb" int,
  "Mar" int,
  "Apr" int,
  "May" int,
  "Jun" int,
  "Jul" int,
  "Aug" int,
  "Sep" int,
  "Oct" int,
  "Nov" int,
  "Dec" int
);

```

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2007	1000	1500					500			
	1500	2000								
2008	1000									

(2 rows)

```
CREATE TABLE cth(rowid text, rowdt timestamp, attribute text, val
text);
INSERT INTO cth VALUES('test1','01 March 2003','temperature','42');
INSERT INTO cth VALUES('test1','01 March
2003','test_result','PASS');
INSERT INTO cth VALUES('test1','01 March 2003','volts','2.6987');
INSERT INTO cth VALUES('test2','02 March 2003','temperature','53');
INSERT INTO cth VALUES('test2','02 March
2003','test_result','FAIL');
INSERT INTO cth VALUES('test2','02 March 2003','test_startdate','01
March 2003');
```

```

INSERT INTO cth VALUES('test2','02 March 2003','volts','3.1234');

SELECT * FROM crosstab
(
  'SELECT rowid, rowdt, attribute, val FROM cth ORDER BY 1',
  'SELECT DISTINCT attribute FROM cth ORDER BY 1'
)
AS
(
  rowid text,
  rowdt timestamp,
  temperature int4,
  test_result text,
  test_startdate timestamp,
  volts float8
);
rowid |          rowdt          | temperature | test_result |
test_startdate | volts
-----+-----+-----+-----+-----
test1 | Sat Mar 01 00:00:00 2003 |          42 | PASS        |
          |          2.6987
test2 | Sun Mar 02 00:00:00 2003 |          53 | FAIL        | Sat
Mar 01 00:00:00 2003 |          3.1234
(2 rows)

```

You can create predefined functions to avoid having to write out the result column names and types in each query. See the examples in the previous section. The underlying C function for this form of crosstab is named `crosstab_hash`.

### F.66.1.5. connectby

```

connectby(text relname, text keyid_fld, text parent_keyid_fld
          [, text orderby_fld ], text start_with, int max_depth
          [, text branch_delim ])

```

The `connectby` function produces a display of hierarchical data that is stored in a table. The table must have a key field that uniquely identifies rows, and a parent-key field that references the parent (if any) of each row. `connectby` can display the sub-tree descending from any row.

Table F.189 explains the parameters.

**Table F.189. connectby Parameters**

Parameter	Description
<i>relname</i>	Name of the source relation
<i>keyid_fld</i>	Name of the key field
<i>parent_keyid_fld</i>	Name of the parent-key field
<i>orderby_fld</i>	Name of the field to order siblings by (optional)
<i>start_with</i>	Key value of the row to start at
<i>max_depth</i>	Maximum depth to descend to, or zero for unlimited depth
<i>branch_delim</i>	String to separate keys with in branch output (optional)

The key and parent-key fields can be any data type, but they must be the same type. Note that the *start\_with* value must be entered as a text string, regardless of the type of the key field.

The *connectby* function is declared to return *setof record*, so the actual names and types of the output columns must be defined in the FROM clause of the calling SELECT statement, for example:

```
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
    'pos', 'row2', 0, '~')
    AS t(keyid text, parent_keyid text, level int, branch text, pos
    int);
```

The first two output columns are used for the current row's key and its parent row's key; they must match the type of the table's key field. The third output column is the depth in the tree and must be of type *integer*. If a *branch\_delim* parameter was given, the next output column is the branch display and must be of type *text*. Finally, if an *orderby\_fld* parameter was given, the last output column is a serial number, and must be of type *integer*.

The “branch” output column shows the path of keys taken to reach the current row. The keys are separated by the specified *branch\_delim* string. If no branch display is wanted, omit both the *branch\_delim* parameter and the branch column in the output column list.

If the ordering of siblings of the same parent is important, include the *orderby\_fld* parameter to specify which field to order siblings by. This field can be of any sortable data type. The output column list must include a final integer serial-number column, if and only if *orderby\_fld* is specified.

The parameters representing table and field names are copied as-is into the SQL queries that *connectby* generates internally. Therefore, include double quotes if the names are mixed-case or contain special characters. You may also need to schema-qualify the table name.

In large tables, performance will be poor unless there is an index on the parent-key field.

It is important that the *branch\_delim* string not appear in any key values, else *connectby* may incorrectly report an infinite-recursion error. Note that if *branch\_delim* is not provided, a default value of ~ is used for recursion detection purposes.

Here is an example:

```
CREATE TABLE connectby_tree(keyid text, parent_keyid text, pos
    int);

INSERT INTO connectby_tree VALUES('row1',NULL, 0);
INSERT INTO connectby_tree VALUES('row2','row1', 0);
INSERT INTO connectby_tree VALUES('row3','row1', 0);
INSERT INTO connectby_tree VALUES('row4','row2', 1);
INSERT INTO connectby_tree VALUES('row5','row2', 0);
INSERT INTO connectby_tree VALUES('row6','row4', 0);
INSERT INTO connectby_tree VALUES('row7','row3', 0);
INSERT INTO connectby_tree VALUES('row8','row6', 0);
INSERT INTO connectby_tree VALUES('row9','row5', 0);

-- with branch, without orderby_fld (order of results is not
-- guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
    'row2', 0, '~')
    AS t(keyid text, parent_keyid text, level int, branch text);
keyid | parent_keyid | level |          branch
-----+-----+-----+-----
row2  |              |      0 | row2
row4  | row2         |      1 | row2~row4
```

```

row6 | row4          |      2 | row2~row4~row6
row8 | row6          |      3 | row2~row4~row6~row8
row5 | row2          |      1 | row2~row5
row9 | row5          |      2 | row2~row5~row9
(6 rows)

```

```

-- without branch, without orderby_fld (order of results is not
guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'row2', 0)

```

```

AS t(keyid text, parent_keyid text, level int);

```

```

keyid | parent_keyid | level
-----+-----+-----

```

```

row2 |          |      0
row4 | row2     |      1
row6 | row4     |      2
row8 | row6     |      3
row5 | row2     |      1
row9 | row5     |      2
(6 rows)

```

```

-- with branch, with orderby_fld (notice that row5 comes before
row4)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'pos', 'row2', 0, '~')

```

```

AS t(keyid text, parent_keyid text, level int, branch text, pos
int);

```

```

keyid | parent_keyid | level |          branch          | pos
-----+-----+-----+-----+-----

```

```

row2 |          |      0 | row2                    | 1
row5 | row2     |      1 | row2~row5               | 2
row9 | row5     |      2 | row2~row5~row9         | 3
row4 | row2     |      1 | row2~row4               | 4
row6 | row4     |      2 | row2~row4~row6         | 5
row8 | row6     |      3 | row2~row4~row6~row8    | 6
(6 rows)

```

```

-- without branch, with orderby_fld (notice that row5 comes before
row4)

```

```

SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'pos', 'row2', 0)

```

```

AS t(keyid text, parent_keyid text, level int, pos int);

```

```

keyid | parent_keyid | level | pos
-----+-----+-----+-----

```

```

row2 |          |      0 | 1
row5 | row2     |      1 | 2
row9 | row5     |      2 | 3
row4 | row2     |      1 | 4
row6 | row4     |      2 | 5
row8 | row6     |      3 | 6
(6 rows)

```

## F.66.2. Author

Joe Conway

## F.67. tcn

The `tcn` module provides a trigger function that notifies listeners of changes to any table on which it is attached. It must be used as an `AFTER trigger FOR EACH ROW`.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

Only one parameter may be supplied to the function in a `CREATE TRIGGER` statement, and that is optional. If supplied it will be used for the channel name for the notifications. If omitted `tcn` will be used for the channel name.

The payload of the notifications consists of the table name, a letter to indicate which type of operation was performed, and column name/value pairs for primary key columns. Each part is separated from the next by a comma. For ease of parsing using regular expressions, table and column names are always wrapped in double quotes, and data values are always wrapped in single quotes. Embedded quotes are doubled.

A brief example of using the extension follows.

```
test=# create table tcndata
test=# (
test(#   a int not null,
test(#   b date not null,
test(#   c text,
test(#   primary key (a, b)
test(# );
CREATE TABLE
test=# create trigger tcndata_tcn_trigger
test=# after insert or update or delete on tcndata
test=# for each row execute function
  triggered_change_notification();
CREATE TRIGGER
test=# listen tcn;
LISTEN
test=# insert into tcndata values (1, date '2012-12-22', 'one'),
test=#                               (1, date '2012-12-23',
  'another'),
test=#                               (2, date '2012-12-23', 'two');
INSERT 0 3
Asynchronous notification "tcn" with payload
  ""tcndata",I,"a"='1',"b"='2012-12-22'" received from server
  process with PID 22770.
Asynchronous notification "tcn" with payload
  ""tcndata",I,"a"='1',"b"='2012-12-23'" received from server
  process with PID 22770.
Asynchronous notification "tcn" with payload
  ""tcndata",I,"a"='2',"b"='2012-12-23'" received from server
  process with PID 22770.
test=# update tcndata set c = 'uno' where a = 1;
UPDATE 2
Asynchronous notification "tcn" with payload
  ""tcndata",U,"a"='1',"b"='2012-12-22'" received from server
  process with PID 22770.
Asynchronous notification "tcn" with payload
  ""tcndata",U,"a"='1',"b"='2012-12-23'" received from server
  process with PID 22770.
test=# delete from tcndata where a = 1 and b = date '2012-12-22';
DELETE 1
```

```
Asynchronous notification "tcn" with payload
""tcndata",D,"a"='1',"b"='2012-12-22'" received from server
process with PID 22770.
```

## F.68. test\_decoding

`test_decoding` is an example of a logical decoding output plugin. It doesn't do anything especially useful, but can serve as a starting point for developing your own output plugin.

`test_decoding` receives WAL through the logical decoding mechanism and decodes it into text representations of the operations performed.

Typical output from this plugin, used over the SQL logical decoding interface, might be:

```
lightdb@postgres=# SELECT * FROM
pg_logical_slot_get_changes('test_slot', NULL, NULL, 'include-
xids', '0');
   lsn   | xid | data
-----+-----
0/16D30F8 | 691 | BEGIN
0/16D32A0 | 691 | table public.data: INSERT: id[int4]:2
data[text]: 'arg'
0/16D32A0 | 691 | table public.data: INSERT: id[int4]:3
data[text]: 'demo'
0/16D32A0 | 691 | COMMIT
0/16D32D8 | 692 | BEGIN
0/16D3398 | 692 | table public.data: DELETE: id[int4]:2
0/16D3398 | 692 | table public.data: DELETE: id[int4]:3
0/16D3398 | 692 | COMMIT
(8 rows)
```

## F.69. tsm\_system\_rows

The `tsm_system_rows` module provides the table sampling method `SYSTEM_ROWS`, which can be used in the `TABLESAMPLE` clause of a `SELECT` command.

This table sampling method accepts a single integer argument that is the maximum number of rows to read. The resulting sample will always contain exactly that many rows, unless the table does not contain enough rows, in which case the whole table is selected.

Like the built-in `SYSTEM` sampling method, `SYSTEM_ROWS` performs block-level sampling, so that the sample is not completely random but may be subject to clustering effects, especially if only a small number of rows are requested.

`SYSTEM_ROWS` does not support the `REPEATABLE` clause.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.69.1. Examples

Here is an example of selecting a sample of a table with `SYSTEM_ROWS`. First install the extension:

```
CREATE EXTENSION tsm_system_rows;
```

Then you can use it in a `SELECT` command, for instance:

```
SELECT * FROM my_table TABLESAMPLE SYSTEM_ROWS(100);
```

This command will return a sample of 100 rows from the table `my_table` (unless the table does not have 100 visible rows, in which case all its rows are returned).

## F.70. `tsm_system_time`

The `tsm_system_time` module provides the table sampling method `SYSTEM_TIME`, which can be used in the `TABLESAMPLE` clause of a `SELECT` command.

This table sampling method accepts a single floating-point argument that is the maximum number of milliseconds to spend reading the table. This gives you direct control over how long the query takes, at the price that the size of the sample becomes hard to predict. The resulting sample will contain as many rows as could be read in the specified time, unless the whole table has been read first.

Like the built-in `SYSTEM` sampling method, `SYSTEM_TIME` performs block-level sampling, so that the sample is not completely random but may be subject to clustering effects, especially if only a small number of rows are selected.

`SYSTEM_TIME` does not support the `REPEATABLE` clause.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.70.1. Examples

Here is an example of selecting a sample of a table with `SYSTEM_TIME`. First install the extension:

```
CREATE EXTENSION tsm_system_time;
```

Then you can use it in a `SELECT` command, for instance:

```
SELECT * FROM my_table TABLESAMPLE SYSTEM_TIME(1000);
```

This command will return as large a sample of `my_table` as it can read in 1 second (1000 milliseconds). Of course, if the whole table can be read in under 1 second, all its rows will be returned.

## F.71. `tsvector2`

Extended `tsvector` type for LightDB. It was implemented to provide better compression and to remove 1MB size limitation of original `tsvector` type.

It could be used as transparent replacement of original `tsvector` and supports all its functions, operators and index types. Functions that contain `tsvector` in their names have been changed to `tsvector2`. Full list of these functions specified below.

Refer to LightDB documentation to get details about `tsvector`. They can be also applied to `tsvector2`.

### F.71.1. `tsvector2` specific functions

- `to_tsvector2` (from `text`, `json`, `jsonb` types)
- `array_to_tsvector2`
- `tsvector2_to_array`



- `tsvector2_stat` (should be used instead of `ts_stat`)
- `jsonb_to_tsvector2`
- `json_to_tsvector2`
- `tsvector2_update_trigger`
- `tsvector2_update_trigger_column`

## F.71.2. Common functions that could be safely used on both types

- `strip`
- `unnest`
- `length`
- `setweight`
- `ts_rank`
- `ts_rank_cd`
- `ts_delete`
- `ts_filter`

## F.72. unaccent

`unaccent` is a text search dictionary that removes accents (diacritic signs) from lexemes. It's a filtering dictionary, which means its output is always passed to the next dictionary (if any), unlike the normal behavior of dictionaries. This allows accent-insensitive processing for full text search.

The current implementation of `unaccent` cannot be used as a normalizing dictionary for the thesaurus dictionary.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.72.1. Configuration

An `unaccent` dictionary accepts the following options:

- `RULES` is the base name of the file containing the list of translation rules. This file must be stored in `$_SHAREDIR/tsearch_data/` (where `$_SHAREDIR` means the LightDB installation's shared-data directory). Its name must end in `.rules` (which is not to be included in the `RULES` parameter).

The rules file has the following format:

- Each line represents one translation rule, consisting of a character with accent followed by a character without accent. The first is translated into the second. For example,

```
À      A
Á      A
Â      A
Ã      A
Ä      A
Å      A
Æ      AE
```

The two characters must be separated by whitespace, and any leading or trailing whitespace on a line is ignored.

- Alternatively, if only one character is given on a line, instances of that character are deleted; this is useful in languages where accents are represented by separate characters.

- Actually, each “character” can be any string not containing whitespace, so unaccent dictionaries could be used for other sorts of substring substitutions besides diacritic removal.
- As with other LightDB text search configuration files, the rules file must be stored in UTF-8 encoding. The data is automatically translated into the current database's encoding when loaded. Any lines containing untranslatable characters are silently ignored, so that rules files can contain rules that are not applicable in the current encoding.

A more complete example, which is directly useful for most European languages, can be found in `unaccent.rules`, which is installed in `$SHAREDIR/tsearch_data/` when the unaccent module is installed. This rules file translates characters with accents to the same characters without accents, and it also expands ligatures into the equivalent series of simple characters (for example, `Æ` to `AE`).

## F.72.2. Usage

Installing the unaccent extension creates a text search template unaccent and a dictionary unaccent based on it. The unaccent dictionary has the default parameter setting `RULES='unaccent'`, which makes it immediately usable with the standard `unaccent.rules` file. If you wish, you can alter the parameter, for example

```
mydb=# ALTER TEXT SEARCH DICTIONARY unaccent (RULES='my_rules');
```

or create new dictionaries based on the template.

To test the dictionary, you can try:

```
mydb=# select ts_lexize('unaccent','Hôtel');
 ts_lexize
-----
 {Hotel}
(1 row)
```

Here is an example showing how to insert the unaccent dictionary into a text search configuration:

```
mydb=# CREATE TEXT SEARCH CONFIGURATION fr ( COPY = french );
mydb=# ALTER TEXT SEARCH CONFIGURATION fr
        ALTER MAPPING FOR hword, hword_part, word
        WITH unaccent, french_stem;
mydb=# select to_tsvector('fr','Hôtels de la Mer');
 to_tsvector
-----
 'hotel':1 'mer':4
(1 row)

mydb=# select to_tsvector('fr','Hôtel de la Mer') @@
 to_tsquery('fr','Hotels');
 ?column?
-----
 t
(1 row)

mydb=# select ts_headline('fr','Hôtel de la
 Mer',to_tsquery('fr','Hotels'));
 ts_headline
-----
 <b>Hôtel</b> de la Mer
```

(1 row)

## F.72.3. Functions

The `unaccent()` function removes accents (diacritic signs) from a given string. Basically, it's a wrapper around `unaccent`-type dictionaries, but it can be used outside normal text search contexts.

`unaccent([dictionary regdictionary, ] string text)` returns `text`

If the `dictionary` argument is omitted, the text search dictionary named `unaccent` and appearing in the same schema as the `unaccent()` function itself is used.

For example:

```
SELECT unaccent('unaccent', 'Hôtel');
SELECT unaccent('Hôtel');
```

## F.73. uuid-oss

The `uuid-oss` module provides functions to generate universally unique identifiers (UUIDs) using one of several standard algorithms. There are also functions to produce certain special UUID constants. This module is only necessary for special requirements beyond what is available in core LightDB. See Section 9.14 for built-in ways to generate UUIDs.

This module is considered “trusted”, that is, it can be installed by non-superusers who have `CREATE` privilege on the current database.

### F.73.1. uuid-oss Functions

Table F.190 shows the functions available to generate UUIDs. The relevant standards ITU-T Rec. X.667, ISO/IEC 9834-8:2005, and RFC 4122 specify four algorithms for generating UUIDs, identified by the version numbers 1, 3, 4, and 5. (There is no version 2 algorithm.) Each of these algorithms could be suitable for a different set of applications.

**Table F.190. Functions for UUID Generation**

Function	Description
<code>uuid_generate_v1()</code> → <code>uuid</code>	Generates a version 1 UUID. This involves the MAC address of the computer and a time stamp. Note that UUIDs of this kind reveal the identity of the computer that created the identifier and the time at which it did so, which might make it unsuitable for certain security-sensitive applications.
<code>uuid_generate_v1mc()</code> → <code>uuid</code>	Generates a version 1 UUID, but uses a random multicast MAC address instead of the real MAC address of the computer.
<code>uuid_generate_v3(namespace uuid, name text)</code> → <code>uuid</code>	Generates a version 3 UUID in the given namespace using the specified input name. The namespace should be one of the special constants produced by the <code>uuid_ns_*</code> () functions shown in Table F.191. (It could be any UUID in theory.) The name is an identifier in the selected namespace. For example:

Function	Description
	<pre>SELECT uuid_generate_v3(uuid_ns_url(), 'www.hs.net/lightdb');</pre> <p>The name parameter will be MD5-hashed, so the cleartext cannot be derived from the generated UUID. The generation of UUIDs by this method has no random or environment-dependent element and is therefore reproducible.</p>
<code>uuid_generate_v4 ()</code> → <code>uuid</code>	Generates a version 4 UUID, which is derived entirely from random numbers.
<code>sys_guid ()</code> → <code>uuid</code>	Generates a version 4 UUID, which is derived entirely from random numbers. Equivalent with function <code>uuid_generate_v4</code> .
<code>uuid_generate_v5 ( namespace uuid, name text )</code> → <code>uuid</code>	Generates a version 5 UUID, which works like a version 3 UUID except that SHA-1 is used as a hashing method. Version 5 should be preferred over version 3 because SHA-1 is thought to be more secure than MD5.

**Table F.191. Functions Returning UUID Constants**

Function	Description
<code>uuid_nil ()</code> → <code>uuid</code>	Returns a “nil” UUID constant, which does not occur as a real UUID.
<code>uuid_ns_dns ()</code> → <code>uuid</code>	Returns a constant designating the DNS namespace for UUIDs.
<code>uuid_ns_url ()</code> → <code>uuid</code>	Returns a constant designating the URL namespace for UUIDs.
<code>uuid_ns_oid ()</code> → <code>uuid</code>	Returns a constant designating the ISO object identifier (OID) namespace for UUIDs. (This pertains to ASN.1 OIDs, which are unrelated to the OIDs used in LightDB.)
<code>uuid_ns_x500 ()</code> → <code>uuid</code>	Returns a constant designating the X.500 distinguished name (DN) namespace for UUIDs.

## F.73.2. Author

Peter Eisentraut <peter\_e@gmx.net>

## F.74. wal2sql

The `wal2sql` is an output extension for logical decoding. It means that the extension have access to tuples produced by INSERT and UPDATE. Also, UPDATE/DELETE old row versions can be accessed depending on the configured replica identity. Changes can be consumed using the streaming protocol (logical replication slots) or by a special SQL API.

format version 1 produces a JSON object per transaction. All of the new/old tuples are available in the JSON object. Also, there are options to include properties such as transaction timestamp, schema-qualified, data types, and transaction ids.

format version 2 produces a JSON object per tuple. Optional JSON object for beginning and end of transaction. Also, there are a variety of options to include properties.

## F.74.1. Configuration

You need to set up at least parameters at `lightdb.conf`

```
# lightdb.conf
wal_level = logical
```

## F.74.2. Configuration Parameters

`include-transaction` (boolean)

emit records denoting the start and end of each transaction. Default is true.

`include-xids` (boolean)

add xid to each changeset. Default is false.

`include-timestamp` (boolean)

add timestamp to each changeset. Default is false.

`include-pk` (boolean)

add primary key information as pk. Column name and data type is included. Default is false.

`include-origin` (boolean)

add origin of a piece of data. Default is false.

`include-schemas` (boolean)

add schema to each change. Default is true.

`include-types` (boolean)

add type to each change. Default is true.

`include-type-oids` (boolean)

add type oids. Default is false.

`include-typmod` (boolean)

add modifier to types that have it (eg. `varchar(20)` instead of `varchar`). Default is true.

`include-domain-data-type` (boolean)

replace domain name with the underlying data type. Default is false.

`include-column-positions` (boolean)

add column position (`pg_attribute.attnum`). Default is false.

`include-not-null` (boolean)

add not null information as `columnoptionals`. Default is false.

`include-default` (boolean)

add default expression. Default is false.

`pretty-print` (boolean)

add spaces and indentation to JSON structures. Default is false.

`write-in-chunks` (boolean)

write after every change instead of every changeset. Only used when `format-version` is 1. Default is false.

`include-lsn` (boolean)

add nextlsn to each changeset. Default is false.

`actions` (boolean)

define which operations will be sent. Default is all actions (insert, update, delete, and truncate). However, if you are using `format-version` 1, truncate is not enabled (backward compatibility).

`filter-origins` (boolean)

exclude changes from the specified origins. Default is empty which means that no origin will be filtered. It is a comma separated value.

`filter-tables` (boolean)

exclude rows from the specified tables. Default is empty which means that no table will be filtered. It is a comma separated value. The tables should be schema-qualified. `*.foo` means table foo in all schemas and `bar.*` means all tables in schema bar. Special characters (space, single quote, comma, period, asterisk) must be escaped with backslash. Schema and table are case-sensitive. Table "public"."Foo bar" should be specified as `public.Foo\ bar`.

`add-tables` (boolean)

include only rows from the specified tables. Default is all tables from all schemas. It has the same rules from `filter-tables`.

`filter-msg-prefixes` (boolean)

exclude messages if prefix is in the list. Default is empty which means that no message will be filtered. It is a comma separated value.

`add-msg-prefixes` (boolean)

include only messages if prefix is in the list. Default is all prefixes. It is a comma separated value. `wal2sql` applies `filter-msg-prefixes` before this parameter.

`format-version` (integer)

defines which format to use. Default is 1.

## F.74.3. Examples of Parameters

There are two ways to obtain the changes (JSON objects) from `wal2sql` plugin: calling functions via `ltdts_recvlogical` or SQL.

### F.74.3.1. `ltdts_recvlogical`

Besides the configuration above, it is necessary to configure a replication connection to use `ltdts_recvlogical`.

Add a replication connection rule at `lt_hba.conf`

```
                local    mydatabase    myuser
trust
```

Also, set `max_wal_senders` at `lightdb.conf`:

```
max_wal_senders = 1
```

A restart is necessary if you changed `max_wal_senders`. You are ready to try `wal2sql`. In one terminal:

```
                # create a logical replication slot name as
test_oracle_slot
                ltdts_recvlogical -d postgres --slot=test_oracle_slot
--create-slot -P wal2sql

                # delete a logical replication slot
                ltdts_recvlogical -d postgres --slot=test_oracle_slot
--drop-slot

                # print output in the first terminal
                ltdts_recvlogical -d postgres --slot test_oracle_slot
--start -o pretty-print=1 -o add-msg-prefixes=wal2sql -f -

                # forward output to oracle#
                ltdts_recvlogical --tnsname=TEST --oracle-
username=scott --oracle-password=tiger --start --
slot=test_oracle_slot -o include-types=false
                -o include-type-oids=true -d postgres -h 10.20.30.193 -
p 9999 -f debug.dat
```

## F.74.3.2. SQL

Save the following code and execute it

```
                CREATE TABLE table3_with_pk (a SERIAL, b VARCHAR(30), c
TIMESTAMP NOT NULL, PRIMARY KEY(a, c));
                CREATE TABLE table3_without_pk (a SERIAL, b
NUMERIC(5,2), c TEXT);

                SELECT 'init' FROM
pg_create_logical_replication_slot('test_slot', 'wal2sql');

                BEGIN;
                INSERT INTO table3_with_pk (b, c) VALUES('Backup and
Restore', now());
                INSERT INTO table3_with_pk (b, c) VALUES('Tuning',
now());
                INSERT INTO table3_with_pk (b, c) VALUES('Replication',
now());
                SELECT pg_logical_emit_message(true, 'wal2sql', 'this
message will be delivered');
```

```

DELETE FROM table3_with_pk WHERE a < 3;
SELECT pg_logical_emit_message(false, 'wal2sql', 'this
non-transactional message will be delivered even if you rollback
the transaction');

INSERT INTO table3_without_pk (b, c) VALUES(2.34,
'Tapir');
-- it is not added to stream because there isn't a pk
or a replica identity
UPDATE table3_without_pk SET c = 'Anta' WHERE c =
'Tapir';
COMMIT;

SELECT data FROM
pg_logical_slot_get_changes('test_slot', NULL, NULL, 'format-
version', '2', 'add-msg-prefixes', 'wal2sql');
SELECT 'stop' FROM
pg_drop_replication_slot('test_slot');

DROP TABLE table3_with_pk;
DROP TABLE table3_without_pk;

```

## F.74.4. Note

1. wal2sql is not supported on LoongArch<sup>14</sup>.
2. In high availability please start `ltdts_logicalrepl_copier.sh` to copy slot from primary to standby.
3. In high availability when failover occur, please restart new primary LightDB to let slot work.

## F.75. xml2

The `xml2` module provides XPath querying and XSLT functionality.

### F.75.1. Deprecation Notice

From LightDB 8.3 on, there is XML-related functionality based on the SQL/XML standard in the core server. That functionality covers XML syntax checking and XPath queries, which is what this module does, and more, but the API is not at all compatible. It is planned that this module will be removed in a future version of LightDB in favor of the newer standard API, so you are encouraged to try converting your applications. If you find that some of the functionality of this module is not available in an adequate form with the newer API, please explain your issue to [pgsql-hackers@lists.postgresql.org](mailto:pgsql-hackers@lists.postgresql.org) so that the deficiency can be addressed.

### F.75.2. Description of Functions

Table F.192 shows the functions provided by this module. These functions provide straightforward XML parsing and XPath queries.

**Table F.192. `xml2` Functions**

Function	Description
<code>xml_valid</code>	<code>( document text ) → boolean</code>

<sup>14</sup> <https://www.loongson.cn/>



Function	Description
	Parses the given document and returns true if the document is well-formed XML. (Note: this is an alias for the standard LightDB function <code>xml_is_well_formed()</code> . The name <code>xml_valid()</code> is technically incorrect since validity and well-formedness have different meanings in XML.)
<code>xpath_string ( document text, query text ) → text</code>	Evaluates the XPath query on the supplied document, and casts the result to <code>text</code> .
<code>xpath_number ( document text, query text ) → real</code>	Evaluates the XPath query on the supplied document, and casts the result to <code>real</code> .
<code>xpath_bool ( document text, query text ) → boolean</code>	Evaluates the XPath query on the supplied document, and casts the result to <code>boolean</code> .
<code>xpath_nodeSet ( document text, query text, toptag text, itemtag text ) → text</code>	Evaluates the query on the document and wraps the result in XML tags. If the result is multivalued, the output will look like:  <pre>&lt;toptag&gt; &lt;itemtag&gt;Value 1 which could be an XML fragment&lt;/itemtag&gt; &lt;itemtag&gt;Value 2....&lt;/itemtag&gt; &lt;/toptag&gt;</pre> <p>If either <code>toptag</code> or <code>itemtag</code> is an empty string, the relevant tag is omitted.</p>
<code>xpath_nodeSet ( document text, query text, itemtag text ) → text</code>	Like <code>xpath_nodeSet ( document, query, toptag, itemtag )</code> but result omits <code>toptag</code> .
<code>xpath_nodeSet ( document text, query text ) → text</code>	Like <code>xpath_nodeSet ( document, query, toptag, itemtag )</code> but result omits both tags.
<code>xpath_list ( document text, query text, separator text ) → text</code>	Evaluates the query on the document and returns multiple values separated by the specified separator, for example <code>Value 1, Value 2, Value 3</code> if <code>separator</code> is <code>,</code> .
<code>xpath_list ( document text, query text ) → text</code>	This is a wrapper for the above function that uses <code>,</code> as the separator.

### F.75.3. `xpath_table`

`xpath_table ( text key, text document, text relation, text xpaths, text criteria )` returns `setof record`

`xpath_table` is a table function that evaluates a set of XPath queries on each of a set of documents and returns the results as a table. The primary key field from the original document table is returned as the first column of the result so that the result set can readily be used in joins. The parameters are described in Table F.193.

**Table F.193. `xpath_table` Parameters**

Parameter	Description
<code>key</code>	the name of the “key” field — this is just a field to be used as the first column of the output table, i.e., it identifies the record

Parameter	Description
	from which each output row came (see note below about multiple values)
<i>document</i>	the name of the field containing the XML document
<i>relation</i>	the name of the table or view containing the documents
<i>xpaths</i>	one or more XPath expressions, separated by
<i>criteria</i>	the contents of the WHERE clause. This cannot be omitted, so use <code>true</code> or <code>1=1</code> if you want to process all the rows in the relation

These parameters (except the XPath strings) are just substituted into a plain SQL `SELECT` statement, so you have some flexibility — the statement is

```
SELECT <key>, <document> FROM <relation> WHERE <criteria>
```

so those parameters can be *anything* valid in those particular locations. The result from this `SELECT` needs to return exactly two columns (which it will unless you try to list multiple fields for key or document). Beware that this simplistic approach requires that you validate any user-supplied values to avoid SQL injection attacks.

The function has to be used in a `FROM` expression, with an `AS` clause to specify the output columns; for example

```
SELECT * FROM
xpath_table('article_id',
            'article_xml',
            'articles',
            '/article/author|/article/pages|/article/title',
            'date_entered > ''2003-01-01'' ')
AS t(article_id integer, author text, page_count integer, title
text);
```

The `AS` clause defines the names and types of the columns in the output table. The first is the “key” field and the rest correspond to the XPath queries. If there are more XPath queries than result columns, the extra queries will be ignored. If there are more result columns than XPath queries, the extra columns will be `NULL`.

Notice that this example defines the `page_count` result column as an integer. The function deals internally with string representations, so when you say you want an integer in the output, it will take the string representation of the XPath result and use `LightDB` input functions to transform it into an integer (or whatever type the `AS` clause requests). An error will result if it can't do this — for example if the result is empty — so you may wish to just stick to `text` as the column type if you think your data has any problems.

The calling `SELECT` statement doesn't necessarily have to be just `SELECT *` — it can reference the output columns by name or join them to other tables. The function produces a virtual table with which you can perform any operation you wish (e.g., aggregation, joining, sorting etc). So we could also have:

```
SELECT t.title, p.fullname, p.email
FROM xpath_table('article_id', 'article_xml', 'articles',
                '/article/title|/article/author/@id',
                'xpath_string(article_xml, '/article/@date') >
                ''2003-03-20'' ')
AS t(article_id integer, title text, author_id integer),
tblPeopleInfo AS p
WHERE t.author_id = p.person_id;
```

as a more complicated example. Of course, you could wrap all of this in a view for convenience.

### F.75.3.1. Multivalued Results

The `xpath_table` function assumes that the results of each XPath query might be multivalued, so the number of rows returned by the function may not be the same as the number of input documents. The first row returned contains the first result from each query, the second row the second result from each query. If one of the queries has fewer values than the others, null values will be returned instead.

In some cases, a user will know that a given XPath query will return only a single result (perhaps a unique document identifier) — if used alongside an XPath query returning multiple results, the single-valued result will appear only on the first row of the result. The solution to this is to use the `key` field as part of a join against a simpler XPath query. As an example:

```
CREATE TABLE test (
  id int PRIMARY KEY,
  xml text
);

INSERT INTO test VALUES (1, '<doc num="C1">
<line num="L1"><a>1</a><b>2</b><c>3</c></line>
<line num="L2"><a>11</a><b>22</b><c>33</c></line>
</doc>');

INSERT INTO test VALUES (2, '<doc num="C2">
<line num="L1"><a>111</a><b>222</b><c>333</c></line>
<line num="L2"><a>111</a><b>222</b><c>333</c></line>
</doc>');

SELECT * FROM
  xpath_table('id','xml','test',
    '/doc/@num|/doc/line/@num|/doc/line/a|/doc/line/b|/
doc/line/c',
    'true')
  AS t(id int, doc_num varchar(10), line_num varchar(10), val1 int,
    val2 int, val3 int)
WHERE id = 1 ORDER BY doc_num, line_num
```

id	doc_num	line_num	val1	val2	val3
1	C1	L1	1	2	3
1		L2	11	22	33

To get `doc_num` on every line, the solution is to use two invocations of `xpath_table` and join the results:

```
SELECT t.*,i.doc_num FROM
  xpath_table('id', 'xml', 'test',
    '/doc/line/@num|/doc/line/a|/doc/line/b|/doc/line/c',
    'true')
  AS t(id int, line_num varchar(10), val1 int, val2 int, val3
int),
  xpath_table('id', 'xml', 'test', '/doc/@num', 'true')
  AS i(id int, doc_num varchar(10))
WHERE i.id=t.id AND i.id=1
ORDER BY doc_num, line_num;
```

id	line_num	val1	val2	val3	doc_num
1	L1	1	2	3	C1
1	L2	11	22	33	C1

(2 rows)

## F.75.4. XSLT Functions

The following functions are available if libxslt is installed:

### F.75.4.1. `xslt_process`

```
xslt_process(text document, text stylesheet, text paramlist)
returns text
```

This function applies the XSL stylesheet to the document and returns the transformed result. The `paramlist` is a list of parameter assignments to be used in the transformation, specified in the form `a=1,b=2`. Note that the parameter parsing is very simple-minded: parameter values cannot contain commas!

There is also a two-parameter version of `xslt_process` which does not pass any parameters to the transformation.

## F.75.5. Author

John Gray <jgray@azuli.co.uk>

Development of this module was sponsored by Torchbox Ltd. ([www.torchbox.com](http://www.torchbox.com)). It has the same BSD license as LightDB.

## F.76. zhparser

`zhparser` is a LightDB extension for full-text search of Chinese language (Mandarin Chinese). It implements a Chinese language parser base on the Simple Chinese Word Segmentation (SCWS).

### F.76.1. CONFIGURATION

These options are used to control dictionary loading behavior and word segmentation behavior. None of these options is required and are false by default (that is, if these options are not set in the configuration file, `zhparser` behaves the same as setting the following options to false).

Ignore all special symbols such as punctuation: `zhparser.punctuation_ignore = f`

Idle words are automatically grouped in two-word word segmentation: `zhparser.seg_with_duality = f`

Load all dictionaries into memory: `zhparser.dict_in_memory = f`

Short word compound: `zhparser.multi_short = f`

Hash binary compound: `zhparser.multi_duality = f`

Important word compound: `zhparser.multi_zmain = f`

Set `zhparser` non stop words: See `lightdb_tsearch_non_stopwords` for more information

In addition to the dictionaries shipped with `zhparser`, you can add custom dictionaries, which take precedence over native dictionaries. The file must be stored in the `share/postgresql/tsearch_data`

directory. zhparser determines the dictionary format based on the file extension. The.txt extension means that the dictionary is in text format, and the.xdb extension means that the dictionary is in XDB format. Multiple files are separated by commas, and dictionaries are categorized in descending order of priority, such as:

```
zhparser.extra_dicts = 'dict_extra.txt,mydict.xdb'
```

Note: The zhparser.extra\_dicts and zhparser.dict\_in\_memory options need to be set before backend starts (can be changed in configuration file and reload, after which a new connection takes effect), other options can be set to take effect at any time in session.

## F.76.2. EXAMPLE

```
-- make test configuration using parser

CREATE TEXT SEARCH CONFIGURATION testzhcfg (PARSER =
zhparser);

-- add token mapping

ALTER TEXT SEARCH CONFIGURATION testzhcfg ADD MAPPING
FOR n,v,a,i,e,l WITH simple;

-- ts_parse

SELECT * FROM ts_parse('zhparser', 'hello world! 2010##
##### #2011#####
#####');

-- test to_tsvector

SELECT to_tsvector('testzhcfg', '#####
#####>#####"#####2011#####2012#####
#####');

-- test to_tsquery

SELECT to_tsquery('testzhcfg', '#####');

-- test lightdb_tsearch_non_stopwords

SET lightdb_tsearch_non_stopwords = '1';
ERROR:  invalid value for parameter
"lightdb_tsearch_non_stopwords": "1"
DETAIL:  lightdb_tsearch_non_stopwords not support '1'
as non stopword.

SET lightdb_tsearch_non_stopwords = '@:_-';
SELECT to_tsvector('testzhcfg', '#####this is from
lt_hs_tab table #####logged at 2020-12-21 ##### 00:22:32,
username=zjh&pwd=balabala');

to_tsvector
```

```

'00:22:32':16 '2020-12-21':13 'at':12 'from':5 'is':4
'logged':11 'lt_hs_tab':6 'pwd=balabala':18 'table':7 'this':3
'username=zjh':17 '##':10 '##':14 '###':2 '##':9 '###':1 '###':8
'##':15
(1 row)

SET lightdb_tsearch_non_stopwords = '';
SELECT to_tsvector('testzhcfg', 'this is from lt_hs_tab
table logged at 2020-12-21 00:22:32, username=zjh&pwd=balabala');

to_tsvector

```

```

-----
'00':11 '12':9 '2020':8 '21':10 '22':12 '32':13 'at':7
'balabala':17 'from':3 'is':2 'logged':6 'lt_hs_tab':4 'pwd':16
'table':5 'this':1 'username':14 'zjh':15
(1 row)

```

## F.76.3. Custom dictionary

\*\* TXT dictionary is currently compatible with CLI/SCws\_gen\_dict used text dictionary) \*\*

- One entry per line, Comments starting with a # or semicolon are ignored and skipped

Each line consists of 4 fields, which are successively "word "(composed of Chinese characters or less than 3 letters), "TF", "IDF" and" part of speech ". The fields are separated by Spaces or tabs. There is no limit on the number of fields, and they can be aligned to beautify themselves

Except for "word", other fields can be ignored. If omitted, TF and IDF default to 1.0 and the part of speech is "@"

TXT library dynamic loading (internal monitoring file modification time is automatically converted into XDB stored in the system temporary directory), it is recommended that TXT dictionary not too large

To delete words, please set the part of speech to "!", the word is set to invalid, even if it exists in other core libraries

Note: 1. The format of the custom dictionary can be TXT or binary XDB format. The XDB format is more efficient and suitable for large dictionaries. You can use the built-in SCWS tool scWS-Gen-dict to convert text dictionaries to XDB format. 2. The default zhparser dictionary is Simplified Chinese.

## F.76.4. Custom dictionary 2.1

\*\* Custom dictionary 2.1 adds the portability of custom dictionary and is compatible with features provided by 1.0 \*\*

Custom dictionary require superuser privileges. Custom dictionary are database-level (not instance). Each database has its own custom participle and is stored under the data directory base/ database ID (version 2.0 is stored under share/tsearch\_data).

```

test=# SELECT * FROM ts_parse('zhparser', '#####');
 tokid | token
-----+-----
    118 | ##
    110 | #

```

```

110 | ##
110 | ##

test=# insert into zhparser.zhprs_custom_word values('#
###');
--Delete the word insert into zhprs_custom_word(word,
attr) values('word', '!');
--\d zhprs_custom_word view its table structure,
supported TD, IDF
test=# select sync_zhprs_custom_word();
sync_zhprs_custom_word
-----

(1 row)

test=# \q --sync then re-establish the connection
[lzzhang@lzzhang-pc bin]$ ./psql -U lzzhang -d test -p
1600
test=# SELECT * FROM ts_parse('zhparser', '#####');
 tokid | token
-----+-----
  118 | ##
  110 | #
  120 | #####

```

## F.77. pldebugger

LightDB pl/pgsql Debugger API. This module is a set of shared libraries which implement an API for debugging pl/pgsql functions on LightDB lightDB 13.8-23.2 and above.

### F.77.1. Installation

Edit your lightdb.conf file, and modify the shared\_preload\_libraries config option to look like:

```
shared_preload_libraries = '$libdir/plugin_debugger'
```

- plugin\_debugger must be the last extension, or debug may not be effect. - Restart LightDB for the new setting to take effect.

- Run the following command in the database or databases that you wish to debug functions in:

```
CREATE EXTENSION pldbgapi;
```

### F.77.2. Usage

Connect navicat to the database containing the functions you wish to debug. Right-click the function to debug, and select Debugging->Debug to execute and debug the function immediately, or select Debugging->Set Global Breakpoint to set a breakpoint on the function. This will cause the debugger to wait for another session (such as a backend servicing a web app) to execute the function and allow you to debug in-context. For further information, please see the navicat documentation.

### F.77.3. Architecture

The debugger consists of three parts: 1. The client. This is typically a GUI displays the source code, current stack frame, variables etc, and allows the user to set breakpoints and step through the code. The client can reside on a different host than the database server. 2. The target backend. This is the backend that runs the code being debugged. The plugin\_debugger.so library must be loaded into the

target backend. 3. Debugging proxy. This is another backend process that the client is connected to. The API functions, `pldbg_*` in `pldbgapi.so` library, are run in this backend. The client is to connected to the debugging proxy using a regular `libpq` connection. When a debugging session is active, the proxy is connected to the target via a socket. The protocol between the proxy and the target backend is not visible to others, and is subject to change. The `pldbg_*` API functions form the public interface to the debugging facility. debugger client \*----- libpq -----\* Proxy backend (navicat) \* | pldebugger socket connection | \* application client \*----- libpq -----\* Target backend

## F.78. It\_t3sdk

This LightDB extension implements JRES's T3 requests.

### F.78.1. Installation

To install the `t3sdk`, CRES's C client library is needed, and the default version is CRES2.0.V202302.00.000. This library can be downloaded from HUNDSUN

Download CRES's SDK and unzip, directory such as :

```
acm/
dev/
  client_demo/T3SDK/c++/linux.x64/lib/libt3sdk.so
  client_demo/T3SDK_C/linux.x64/lib/libt3sdk_c.so
docker/
instance/
tools/
```

The CRES's SDK `libt3sdk.so` and `libt3sdk_c.so` must add to `LD_LIBRARY_PATH`.

If you first install, use `CREATE EXTENSION t3sdk`.

If you already installed a previous version and you just want to upgrade, then `ALTER EXTENSION t3sdk UPDATE`.

### F.78.2. Concepts

Every T3 call is a made up of list of `VARCHAR` and an response of `t3sdk_response`.

Every times request to T3's service, the backend process hold on connection until that process exit. The key is server's address and port, and the value is connection handle.

		List of functions	
Schema	Name	Result data type	Argument
data types			
	Type		
public	<code>t3sdk_send</code>	<code>t3sdk_response</code>	<code>t_address</code>
	character varying, groups character varying, version character varying, function_id character varying, function_args character varying		func



Column	Type	Collation	Nullable
content	character varying		

### F.78.3. Functions

- `t3sdk_send(t_address VARCHAR, groups VARCHAR, service VARCHAR, version VARCHAR, function_id VARCHAR, function_args VARCHAR)` returns `t3sdk_response`

By default a 60 second timeout is set for the send of a request. If a different timeout is desired the following GUC variable can be used to set it in milliseconds:

```
t3sdk.t3_send_timeout_msec = 60000
```

By default a 60 second timeout is set for the rcv of a request. If a different timeout is desired the following GUC variable can be used to set it in milliseconds:

```
t3sdk.t3_rcv_timeout_msec = 60000
```

If a different T3's license is desired the following GUC variable can be used to set:

```
t3sdk.t3_license_no = 'HS-HUNDSUN001-FBASE2-0000-4ePWxzscBVtY9ZKdgDKhSyk2'
```

### F.78.4. Examples

```
-- send t3 request
select * from t3sdk_send('10.20.30.193:18082', 'g',
'repo-app', 'v', 'getExpressInfoNdb', '');
```

content

```
-----
{"result":
[{"express_id":"a","order_id":"1","express_no":"123456789","company":"#
###1","create_datetime":"20230407010201","status":"0"},
{"express_id":"b","order_id":"2","express_no":"123456789","company":"#
###2","create_dat
etime":"20230407010201","status":"0"}]}
(1 row)
```

### F.79. It\_http

This LightDB extension implements http requests.

## F.79.1. Installation

If you first install, use `CREATE EXTENSION http`.

If you already installed a previous version and you just want to upgrade, then `ALTER EXTENSION http UPDATE`.

## F.79.2. Concepts

Every HTTP call is a made up of an `http_request` and an `http_response`.

```
Composite type "public.http_request"
```

Column	Type	Modifiers
method	http_method	
uri	character varying	
headers	http_header[]	
content_type	character varying	
content	character varying	

```
Composite type "public.http_response"
```

Column	Type	Modifiers
status	integer	
content_type	character varying	
headers	http_header[]	
content	character varying	

The utility functions, `http_get()`, `http_post()`, `http_put()`, `http_delete()` and `http_head()` are just wrappers around a master function, `http(http_request)` that returns `http_response`.

The `headers` field for requests and response is a LightDB array of type `http_header` which is just a simple tuple.

```
Composite type "public.http_header"
```

Column	Type	Modifiers
field	character varying	
value	character varying	

As seen in the examples, you can unspool the array of `http_header` tuples into a result set using the LightDB `unnest()` function on the array. From there you select out the particular header you are interested in.

## F.79.3. Functions

- `http_header(field VARCHAR, value VARCHAR)` returns `http_header`
- `http(request http_request)` returns `http_response`
- `http_get(uri VARCHAR)` returns `http_response`

- `http_get(uri VARCHAR, data JSONB)` returns `http_response`
- `http_post(uri VARCHAR, content VARCHAR, content_type VARCHAR)` returns `http_response`
- `http_post(uri VARCHAR, data JSONB)` returns `http_response`
- `http_put(uri VARCHAR, content VARCHAR, content_type VARCHAR)` returns `http_response`
- `http_patch(uri VARCHAR, content VARCHAR, content_type VARCHAR)` returns `http_response`
- `http_delete(uri VARCHAR, content VARCHAR, content_type VARCHAR)` returns `http_response`
- `http_head(uri VARCHAR)` returns `http_response`
- `http_set_curlopt(curlopt VARCHAR, value varchar)` returns `boolean`
- `http_reset_curlopt()` returns `boolean`
- `http_list_curlopt()` returns `setof(curlopt text, value text)`
- `urlencode(string VARCHAR)` returns `text`
- `urlencode(data JSONB)` returns `text`

## F.79.4. CURL Options

Select CURL options<sup>15</sup> are available to set using the `http_set_curlopt(curlopt VARCHAR, value varchar)` function.

- `CURLOPT_DNS_SERVERS`<sup>16</sup>
- `CURLOPT_PROXY`<sup>17</sup>
- `CURLOPT_PRE_PROXY`<sup>18</sup>
- `CURLOPT_PROXYPORT`<sup>19</sup>
- `CURLOPT_PROXYUSERPWD`<sup>20</sup>
- `CURLOPT_PROXYUSERNAME`<sup>21</sup>
- `CURLOPT_PROXYPASSWORD`<sup>22</sup>
- `CURLOPT_PROXY_TLSAUTH_USERNAME`<sup>23</sup>
- `CURLOPT_PROXY_TLSAUTH_PASSWORD`<sup>24</sup>
- `CURLOPT_PROXY_TLSAUTH_TYPE`<sup>25</sup>
- `CURLOPT_TLSAUTH_USERNAME`<sup>26</sup>

---

<sup>15</sup> [https://curl.haxx.se/libcurl/c/curl\\_easy\\_setopt.html](https://curl.haxx.se/libcurl/c/curl_easy_setopt.html)

<sup>16</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_DNS\\_SERVERS.html](https://curl.haxx.se/libcurl/c/CURLOPT_DNS_SERVERS.html)

<sup>17</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXY.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXY.html)

<sup>18</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PRE\\_PROXY.html](https://curl.haxx.se/libcurl/c/CURLOPT_PRE_PROXY.html)

<sup>19</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXYPORT.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXYPORT.html)

<sup>20</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXYUSERPWD.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXYUSERPWD.html)

<sup>21</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXYUSERNAME.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXYUSERNAME.html)

<sup>22</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXYPASSWORD.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXYPASSWORD.html)

<sup>23</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXY\\_TLSAUTH\\_USERNAME.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXY_TLSAUTH_USERNAME.html)

<sup>24</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXY\\_TLSAUTH\\_PASSWORD.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXY_TLSAUTH_PASSWORD.html)

<sup>25</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_PROXY\\_TLSAUTH\\_TYPE.html](https://curl.haxx.se/libcurl/c/CURLOPT_PROXY_TLSAUTH_TYPE.html)

<sup>26</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TLSAUTH\\_USERNAME.html](https://curl.haxx.se/libcurl/c/CURLOPT_TLSAUTH_USERNAME.html)

- CURLOPT\_TLSAUTH\_PASSWORD<sup>27</sup>
- CURLOPT\_TLSAUTH\_TYPE<sup>28</sup>
- CURLOPT\_SSL\_VERIFYHOST<sup>29</sup>
- CURLOPT\_SSL\_VERIFYPEER<sup>30</sup>
- CURLOPT\_SSLCERT<sup>31</sup>
- CURLOPT\_SSLKEY<sup>32</sup>
- CURLOPT\_SSLCERTTYPE<sup>33</sup>
- CURLOPT\_CAINFO<sup>34</sup>
- CURLOPT\_TIMEOUT<sup>35</sup>
- CURLOPT\_TIMEOUT\_MS<sup>36</sup>
- CURLOPT\_TCP\_KEEPALIVE<sup>37</sup>
- CURLOPT\_TCP\_KEEPIDLE<sup>38</sup>
- CURLOPT\_CONNECTTIMEOUT<sup>39</sup>
- CURLOPT\_USERAGENT<sup>40</sup>

## F.79.5. Keep-Alive and Timeouts

The `http_reset_curlopt()` approach described above is recommended. The global variables below will be deprecated and removed over time.

By default each request uses a fresh connection and assures that the connection is closed when the request is done. This behavior reduces the chance of consuming system resources (sockets) as the extension runs over extended periods of time.

High-performance applications may wish to enable keep-alive and connection persistence to reduce latency and enhance throughput. The following GUC variable changes the behavior of the `http` extension to maintain connections as long as possible:

```
http.keepalive = 'on'
```

By default a 60 second timeout is set for the completion of a request. If a different timeout is desired the following GUC variable can be used to set it in milliseconds:

```
http.timeout_msec = 60000
```

---

<sup>27</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TLSAUTH\\_PASSWORD.html](https://curl.haxx.se/libcurl/c/CURLOPT_TLSAUTH_PASSWORD.html)

<sup>28</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TLSAUTH\\_TYPE.html](https://curl.haxx.se/libcurl/c/CURLOPT_TLSAUTH_TYPE.html)

<sup>29</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_SSL\\_VERIFYHOST.html](https://curl.haxx.se/libcurl/c/CURLOPT_SSL_VERIFYHOST.html)

<sup>30</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_SSL\\_VERIFYPEER.html](https://curl.haxx.se/libcurl/c/CURLOPT_SSL_VERIFYPEER.html)

<sup>31</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_SSLCERT.html](https://curl.haxx.se/libcurl/c/CURLOPT_SSLCERT.html)

<sup>32</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_SSLKEY.html](https://curl.haxx.se/libcurl/c/CURLOPT_SSLKEY.html)

<sup>33</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_SSLCERTTYPE.html](https://curl.haxx.se/libcurl/c/CURLOPT_SSLCERTTYPE.html)

<sup>34</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_CAINFO.html](https://curl.haxx.se/libcurl/c/CURLOPT_CAINFO.html)

<sup>35</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TIMEOUT.html](https://curl.haxx.se/libcurl/c/CURLOPT_TIMEOUT.html)

<sup>36</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TIMEOUT\\_MS.html](https://curl.haxx.se/libcurl/c/CURLOPT_TIMEOUT_MS.html)

<sup>37</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TCP\\_KEEPALIVE.html](https://curl.haxx.se/libcurl/c/CURLOPT_TCP_KEEPALIVE.html)

<sup>38</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_TCP\\_KEEPIDLE.html](https://curl.haxx.se/libcurl/c/CURLOPT_TCP_KEEPIDLE.html)

<sup>39</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_CONNECTTIMEOUT.html](https://curl.haxx.se/libcurl/c/CURLOPT_CONNECTTIMEOUT.html)

<sup>40</sup> [https://curl.haxx.se/libcurl/c/CURLOPT\\_USERAGENT.html](https://curl.haxx.se/libcurl/c/CURLOPT_USERAGENT.html)

## F.79.6. Examples

```

-- URL encode a string.

SELECT urlencode('my special string's and things?');

          urlencode
-----
my+special+string%27s+and+things%3F
(1 row)

-- URL encode a JSON associative array.

SELECT urlencode(jsonb_build_object('name', 'Colin and
James')));

          urlencode
-----
name=Colin+and+James
(1 row)

-- Run a GET request and see the content.

SELECT content
FROM http_get('http://httpbin.org/ip');

          content
-----
{"origin": "24.69.186.43"}
(1 row)

-- Run a GET request with an Authorization header.

SELECT content::json->'headers'->'Authorization'
FROM http((
    'GET',
    'http://httpbin.org/headers',
    ARRAY[http_header('Authorization', 'Bearer
eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9')],
    NULL,
    NULL
)::http_request);

          content
-----
Bearer eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9
(1 row)

```

-- Read the status and content fields out of a http\_response object.

```
SELECT status, content_type
FROM http_get('http://httpbin.org/');
```

```
status | content_type
-----+-----
200 | text/html; charset=utf-8
(1 row)
```

-- Show all the http\_header in an http\_response object.

```
SELECT (unnest(headers)).*
FROM http_get('http://httpbin.org/');
```

```

              field              | value
-----+-----
Connection              | close
Server                   | meinheld/0.6.1
Date                     | Tue, 09 Jan 2018
18:40:30 GMT
Content-Type             | text/html;
charset=utf-8
Content-Length           | 13011
Access-Control-Allow-Origin | *
Access-Control-Allow-Credentials | true
X-Powered-By            | Flask
X-Processed-Time        | 0.0208520889282
Via                      | 1.1 vegur
```

-- Use the PUT command to send a simple text document to a server.

```
SELECT status, content_type, content::json->>'data' AS
data
FROM http_put('http://httpbin.org/put', 'some text',
'text/plain');
```

```
status | content_type | data
-----+-----+-----
200 | application/json | some text
```

-- Use the PATCH command to send a simple JSON document to a server.

```
SELECT status, content_type, content::json->>'data' AS
data
FROM http_patch('http://httpbin.org/patch',
'{"this":"that"}', 'application/json');
```

```
status | content_type | data
-----+-----+-----
```

```

200 | application/json | '{"this":"that"}'

-- Use the DELETE command to request resource deletion.
SELECT status, content_type, content::json->>'url' AS
url
    FROM http_delete('http://httpbin.org/delete');

    status | content_type | url
-----+-----+-----
    200 | application/json | http://httpbin.org/delete

-- As a shortcut to send data to a GET request, pass a
JSONB data argument.

SELECT status, content::json->'args' AS args
    FROM http_get('http://httpbin.org/get',

jsonb_build_object('myvar', 'myval', 'foo', 'bar'));

-- To POST to a URL using a data payload instead of
parameters embedded in the URL, encode the data in a JSONB as a
data payload.

SELECT status, content::json->'form' AS form
    FROM http_post('http://httpbin.org/post',

jsonb_build_object('myvar', 'myval', 'foo', 'bar'));

-- To access binary content, you must coerce
the content from the default varchar representation to
a bytea representation using the textsend function. Using the
default varchar::bytea cast will not work, as the cast will stop
the first time it hits a zero-valued byte (common in binary data).

WITH
    http AS (
        SELECT * FROM http_get('http://httpbin.org/image/
png')
    ),
    headers AS (
        SELECT (unnest(headers)).* FROM http
    )
SELECT
    http.content_type,
    length(textsend(http.content)) AS length_binary,
    headers.value AS length_headers
FROM http, headers
WHERE field = 'Content-Length';

    content_type | length_binary | length_headers
-----+-----+-----
image/png      |          8090 |          8090

```

---

# Appendix G. Additional Supplied Programs

This appendix and the previous one contain information regarding the modules that can be found in the `contrib` directory of the LightDB distribution. See Appendix F for more information about the `contrib` section in general and server extensions and plug-ins found in `contrib` specifically.

This appendix covers utility programs found in `contrib`. Once installed, either from source or a packaging system, they are found in the `bin` directory of the LightDB installation and can be used like any other program.

## G.1. Client Applications

This section covers LightDB client applications in `contrib`. They can be run from anywhere, independent of where the database server resides. See also [LightDB Client Applications](#) for information about client applications that are part of the core LightDB distribution.



## oid2name

oid2name — resolve OIDs and file nodes in a LightDB data directory

## Synopsis

oid2name [*option...*]

## Description

oid2name is a utility program that helps administrators to examine the file structure used by LightDB. To make use of it, you need to be familiar with the database file structure, which is described in Chapter 64.

### Note

The name “oid2name” is historical, and is actually rather misleading, since most of the time when you use it, you will really be concerned with tables' filenode numbers (which are the file names visible in the database directories). Be sure you understand the difference between table OIDs and table filenodes!

oid2name connects to a target database and extracts OID, filenode, and/or table name information. You can also have it show database OIDs or tablespace OIDs.

## Options

oid2name accepts the following command-line arguments:

`-f filenode`

`--filenode=filenode`

show info for table with filenode *filenode*.

`-i`

`--indexes`

include indexes and sequences in the listing.

`-o oid`

`--oid=oid`

show info for table with OID *oid*.

`-q`

`--quiet`

omit headers (useful for scripting).

`-s`

`--tablespaces`

show tablespace OIDs.

`-S`

`--system-objects`

include system objects (those in `information_schema`, `pg_toast` and `pg_catalog` schemas).

`-t tablename_pattern`  
`--table=tablename_pattern`

show info for table(s) matching *tablename\_pattern*.

`-V`  
`--version`

Print the oid2name version and exit.

`-x`  
`--extended`

display more information about each object shown: tablespace name, schema name, and OID.

`-?`  
`--help`

Show help about oid2name command line arguments, and exit.

oid2name also accepts the following command-line arguments for connection parameters:

`-d database`  
`--dbname=database`

database to connect to.

`-h host`  
`--host=host`

database server's host.

`-H host`

database server's host. Use of this parameter is *deprecated* as of LightDB 12.

`-p port`  
`--port=port`

database server's port.

`-U username`  
`--username=username`

user name to connect as.

To display specific tables, select which tables to show by using `-o`, `-f` and/or `-t`. `-o` takes an OID, `-f` takes a filenode, and `-t` takes a table name (actually, it's a LIKE pattern, so you can use things like `f00%`). You can use as many of these options as you like, and the listing will include all objects matched by any of the options. But note that these options can only show objects in the database given by `-d`.

If you don't give any of `-o`, `-f` or `-t`, but do give `-d`, it will list all tables in the database named by `-d`. In this mode, the `-S` and `-i` options control what gets listed.

If you don't give `-d` either, it will show a listing of database OIDs. Alternatively you can give `-s` to get a tablespace listing.

## Environment

LTHOST  
LTPORT  
LTUSER

Default connection parameters.

This utility, like most other LightDB utilities, also uses the environment variables supported by libpq (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are always, auto and never.

## Notes

`oid2name` requires a running database server with non-corrupt system catalogs. It is therefore of only limited use for recovering from catastrophic database corruption situations.

## Examples

```
$ # what's in this database server, anyway?
$ oid2name
All databases:
  Oid Database Name Tablespace
-----
 17228      alvherre  pg_default
 17255      regression pg_default
 17227      template0  pg_default
 1          templatel pg_default

$ oid2name -s
All tablespaces:
  Oid Tablespace Name
-----
 1663      pg_default
 1664      pg_global
 155151    fastdisk
 155152    bigdisk

$ # OK, let's look into database alvherre
$ cd $LTDATA/base/17228

$ # get top 10 db objects in the default tablespace, ordered by
size
$ ls -lS * | head -10
-rw----- 1 alvherre alvherre 136536064 sep 14 09:51 155173
-rw----- 1 alvherre alvherre 17965056  sep 14 09:51 1155291
-rw----- 1 alvherre alvherre 1204224  sep 14 09:51 16717
-rw----- 1 alvherre alvherre 581632  sep 6 17:51 1255
-rw----- 1 alvherre alvherre 237568  sep 14 09:50 16674
-rw----- 1 alvherre alvherre 212992  sep 14 09:51 1249
-rw----- 1 alvherre alvherre 204800  sep 14 09:51 16684
-rw----- 1 alvherre alvherre 196608  sep 14 09:50 16700
-rw----- 1 alvherre alvherre 163840  sep 14 09:50 16699
-rw----- 1 alvherre alvherre 122880  sep 6 17:51 16751

$ # I wonder what file 155173 is ...
$ oid2name -d alvherre -f 155173
From database "alvherre":
  Filenode Table Name
-----
 155173    accounts

$ # you can ask for more than one object
```

```

$ oid2name -d alvherre -f 155173 -f 1155291
From database "alvherre":
  Filenode      Table Name
-----
    155173      accounts
    1155291     accounts_pkey

$ # you can mix the options, and get more details with -x
$ oid2name -d alvherre -t accounts -f 1155291 -x
From database "alvherre":
  Filenode      Table Name      Oid  Schema  Tablespace
-----
    155173      accounts      155173  public  pg_default
    1155291     accounts_pkey 1155291  public  pg_default

$ # show disk space for every db object
$ du [0-9]* |
> while read SIZE FILENODE
> do
>   echo "$SIZE      `oid2name -q -d alvherre -i -f $FILENODE`"
> done
16              1155287  branches_pkey
16              1155289  tellers_pkey
17561           1155291  accounts_pkey
...

$ # same, but sort by size
$ du [0-9]* | sort -rn | while read SIZE FN
> do
>   echo "$SIZE      `oid2name -q -d alvherre -f $FN`"
> done
133466          155173   accounts
17561           1155291  accounts_pkey
1177            16717   pg_proc_proname_args_nsp_index
...

$ # If you want to see what's in tablespaces, use the lt_tblspc
directory
$ cd $LTDATA/lt_tblspc
$ oid2name -s
All tablespaces:
  Oid  Tablespace Name
-----
    1663      pg_default
    1664      pg_global
    155151     fastdisk
    155152     bigdisk

$ # what databases have objects in tablespace "fastdisk"?
$ ls -d 155151/*
155151/17228/ 155151/LT_VERSION

$ # Oh, what was database 17228 again?
$ oid2name
All databases:
  Oid  Database Name  Tablespace
-----
    17228      alvherre        pg_default

```

```
17255 regression pg_default
17227 template0 pg_default
1 template1 pg_default
```

```
$ # Let's see what objects does this database have in the
tablespace.
```

```
$ cd 155151/17228
```

```
$ ls -l
```

```
total 0
```

```
-rw----- 1 lightdb lightdb 0 sep 13 23:20 155156
```

```
$ # OK, this is a pretty small table ... but which one is it?
```

```
$ oid2name -d alvherre -f 155156
```

```
From database "alvherre":
```

```
Filenode Table Name
-----
155156      foo
```

## Author

B. Palmer <bpalmer@crimelabs.net>

## vacuumlo

vacuumlo — remove orphaned large objects from a LightDB database

## Synopsis

```
vacuumlo [option...] dbname...
```

## Description

vacuumlo is a simple utility program that will remove any “orphaned” large objects from a LightDB database. An orphaned large object (LO) is considered to be any LO whose OID does not appear in any `oid` or `lo` data column of the database.

If you use this, you may also be interested in the `lo_manage` trigger in the `lo` module. `lo_manage` is useful to try to avoid creating orphaned LOs in the first place.

All databases named on the command line are processed.

## Options

vacuumlo accepts the following command-line arguments:

```
-l limit  
--limit=limit
```

Remove no more than *limit* large objects per transaction (default 1000). Since the server acquires a lock per LO removed, removing too many LOs in one transaction risks exceeding `max_locks_per_transaction`. Set the limit to zero if you want all removals done in a single transaction.

```
-n  
--dry-run
```

Don't remove anything, just show what would be done.

```
-v  
--verbose
```

Write a lot of progress messages.

```
-V  
--version
```

Print the vacuumlo version and exit.

```
-?  
--help
```

Show help about vacuumlo command line arguments, and exit.

vacuumlo also accepts the following command-line arguments for connection parameters:

```
-h host  
--host=host
```

Database server's host.

`-p port`  
`--port=port`

Database server's port.

`-U username`  
`--username=username`

User name to connect as.

`-w`  
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`  
`--password`

Force `vacuumlo` to prompt for a password before connecting to a database.

This option is never essential, since `vacuumlo` will automatically prompt for a password if the server demands password authentication. However, `vacuumlo` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

## Environment

`LTHOST`  
`LTPORT`  
`LTUSER`

Default connection parameters.

This utility, like most other LightDB utilities, also uses the environment variables supported by `libpq` (see Section 32.14).

The environment variable `LT_COLOR` specifies whether to use color in diagnostic messages. Possible values are `always`, `auto` and `never`.

## Notes

`vacuumlo` works by the following method: First, `vacuumlo` builds a temporary table which contains all of the OIDs of the large objects in the selected database. It then scans through all columns in the database that are of type `oid` or `lo`, and removes matching entries from the temporary table. (Note: Only types with these names are considered; in particular, domains over them are not considered.) The remaining entries in the temporary table identify orphaned LOs. These are removed.

## Author

Peter Mount <[peter@retep.org.uk](mailto:peter@retep.org.uk)>

## G.2. Server Applications

This section covers LightDB server-related applications in `contrib`. They are typically run on the host where the database server resides. See also `LightDB Server Applications` for information about server applications that are part of the core LightDB distribution.

## lt\_standby

lt\_standby — supports the creation of a LightDB warm standby server

## Synopsis

```
lt_standby [option...] archiveLocation nextwalfile walfilepath  
[restartwalfile]
```

## Description

lt\_standby supports creation of a “warm standby” database server. It is designed to be a production-ready program, as well as a customizable template should you require specific modifications.

lt\_standby is designed to be a waiting `restore_command`, which is needed to turn a standard archive recovery into a warm standby operation. Other configuration is required as well, all of which is described in the main server manual (see Section 24.2).

To configure a standby server to use lt\_standby, put this into its `lightdb.conf` configuration file:

```
restore_command = 'lt_standby archiveDir %f %p %r'
```

where `archiveDir` is the directory from which WAL segment files should be restored.

If `restartwalfile` is specified, normally by using the `%r` macro, then all WAL files logically preceding this file will be removed from `archiveLocation`. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the `archiveLocation` is a transient staging area for this particular standby server, but *not* when the `archiveLocation` is intended as a long-term WAL archive area.

lt\_standby assumes that `archiveLocation` is a directory readable by the server-owning user. If `restartwalfile` (or `-k`) is specified, the `archiveLocation` directory must be writable too.

There are two ways to fail over to a “warm standby” database server when the master server fails:

### Smart Failover

In smart failover, the server is brought up after applying all WAL files available in the archive. This results in zero data loss, even if the standby server has fallen behind, but if there is a lot of unapplied WAL it can be a long time before the standby server becomes ready. To trigger a smart failover, create a trigger file containing the word `smart`, or just create it and leave it empty.

### Fast Failover

In fast failover, the server is brought up immediately. Any WAL files in the archive that have not yet been applied will be ignored, and all transactions in those files are lost. To trigger a fast failover, create a trigger file and write the word `fast` into it. lt\_standby can also be configured to execute a fast failover automatically if no new WAL file appears within a defined interval.

## Options

lt\_standby accepts the following command-line arguments:

`-c`

Use `cp` or `copy` command to restore WAL files from archive. This is the only supported behavior so this option is useless.



-d

Print lots of debug logging output on `stderr`.

-k

Remove files from *archive\_location* so that no more than this many WAL files before the current one are kept in the archive. Zero (the default) means not to remove any files from *archive\_location*. This parameter will be silently ignored if *restartwalfile* is specified, since that specification method is more accurate in determining the correct archive cut-off point. Use of this parameter is *deprecated* as of LightDB 8.3; it is safer and more efficient to specify a *restartwalfile* parameter. A too small setting could result in removal of files that are still needed for a restart of the standby server, while a too large setting wastes archive space.

-r *maxretries*

Set the maximum number of times to retry the copy command if it fails (default 3). After each failure, we wait for *sleeptime* \* *num\_retries* so that the wait time increases progressively. So by default, we will wait 5 secs, 10 secs, then 15 secs before reporting the failure back to the standby server. This will be interpreted as end of recovery and the standby will come up fully as a result.

-s *sleeptime*

Set the number of seconds (up to 60, default 5) to sleep between tests to see if the WAL file to be restored is available in the archive yet. The default setting is not necessarily recommended; consult Section 24.2 for discussion.

-t *triggerfile*

Specify a trigger file whose presence should cause failover. It is recommended that you use a structured file name to avoid confusion as to which server is being triggered when multiple servers exist on the same system; for example `/tmp/pgsql.trigger.5432`.

-V

--version

Print the `lt_standby` version and exit.

-w *maxwaittime*

Set the maximum number of seconds to wait for the next WAL file, after which a fast failover will be performed. A setting of zero (the default) means wait forever. The default setting is not necessarily recommended; consult Section 24.2 for discussion.

-?

--help

Show help about `lt_standby` command line arguments, and exit.

## Notes

`lt_standby` is designed to work with LightDB 8.2 and later.

LightDB 8.3 provides the `%r` macro, which is designed to let `lt_standby` know the last file it needs to keep. With LightDB 8.2, the `-k` option must be used if archive cleanup is required. This option remains available in 8.3, but its use is deprecated.

LightDB 8.4 provides the `recovery_end_command` option. Without this option a leftover trigger file can be hazardous.

`lt_standby` is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

## Examples

On Linux or Unix systems, you might use:

```
archive_command = 'cp %p ../archive/%f'

restore_command = 'lt_standby -d -s 2 -t /tmp/
pgsql.trigger.5442 ../archive %f %p %r 2>>standby.log'

recovery_end_command = 'rm -f /tmp/pgsql.trigger.5442'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby (enabling use of `ln`). This will:

- produce debugging output in `standby.log`
- sleep for 2 seconds between checks for next WAL file availability
- stop waiting only when a trigger file called `/tmp/pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

On Windows, you might use:

```
archive_command = 'copy %p ...\\archive\\%f'

restore_command = 'lt_standby -d -s 5 -t C:\pgsql.trigger.5442 ...
\archive %f %p %r 2>>standby.log'

recovery_end_command = 'del C:\pgsql.trigger.5442'
```

Note that backslashes need to be doubled in the `archive_command`, but *not* in the `restore_command` or `recovery_end_command`. This will:

- use the `copy` command to restore WAL files from archive
- produce debugging output in `standby.log`
- sleep for 5 seconds between checks for next WAL file availability
- stop waiting only when a trigger file called `C:\pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

The `copy` command on Windows sets the final file size before the file is completely copied, which would ordinarily confuse `lt_standby`. Therefore `lt_standby` waits `sleep_time` seconds once it sees the proper file size. GNUWin32's `cp` sets the file size only after the file copy is complete.

Since the Windows example uses `copy` at both ends, either or both servers might be accessing the archive directory across the network.

## **Author**

Simon Riggs <simon@2ndquadrant.com>

## **See Also**

lt\_archivecleanup

---

# Appendix H. External Projects

LightDB is a complex software project, and managing the project is difficult. We have found that many enhancements to LightDB can be more efficiently developed separately from the core project.

## H.1. Client Interfaces

There are only two client interfaces included in the base LightDB distribution:

- libpq is included because it is the primary C language interface, and because many other client interfaces are built on top of it.
- ECPG is included because it depends on the server-side SQL grammar, and is therefore sensitive to changes in LightDB itself.

All other language interfaces are external projects and are distributed separately. Table H.1 includes a list of some of these projects. Note that some of these packages might not be released under the same license as LightDB. For more information on each language interface, including licensing terms, refer to its website and documentation.

**Table H.1. Externally Maintained Client Interfaces**

Name	Language	Comments	Website
DBD::Pg	Perl	Perl DBI driver	<a href="https://metacpan.org/release/DBD-Pg">https://metacpan.org/release/DBD-Pg</a>
JDBC	Java	Type 4 JDBC driver	<a href="https://www.light-pg.com/docs/LTJDBC/current/index.html">https://www.light-pg.com/docs/LTJDBC/current/index.html</a>
libpqxx	C++	C++ interface	<a href="https://pqxx.org/">https://pqxx.org/</a>
node-postgres	JavaScript	Node.js driver	<a href="https://node-postgres.com/">https://node-postgres.com/</a>
Npgsql	.NET	.NET data provider	<a href="https://www.npgsql.org/">https://www.npgsql.org/</a>
pgtcl	Tcl		<a href="https://github.com/flightaware/Pgtcl">https://github.com/flightaware/Pgtcl</a>
pgtclng	Tcl		<a href="https://sourceforge.net/projects/pgtclng/">https://sourceforge.net/projects/pgtclng/</a>
pq	Go	Pure Go driver for Go's database/sql	<a href="https://github.com/lib/pq">https://github.com/lib/pq</a>
psqlODBC	ODBC	ODBC driver	<a href="https://odbc.postgresql.org/">https://odbc.postgresql.org/</a>
psycopg	Python	DB API 2.0-compliant	<a href="https://www.psycopg.org/">https://www.psycopg.org/</a>

## H.2. Administration Tools

There are several administration tools available for LightDB. The most popular is pgAdmin<sup>1</sup>, and there are several commercially available ones as well.

## H.3. Procedural Languages

---

<sup>1</sup> <https://www.pgadmin.org/>

LightDB includes several procedural languages with the base distribution: PL/pgSQL, PL/oraSQL.

In addition, there are a number of procedural languages that are developed and maintained outside the core LightDB distribution. Table H.2 lists some of these packages. Note that some of these projects might not be released under the same license as LightDB. For more information on each procedural language, including licensing information, refer to its website and documentation.

**Table H.2. Externally Maintained Procedural Languages**

Name	Language	Website
PL/Java	Java	<a href="https://tada.github.io/pljava/">https://tada.github.io/pljava/</a>
PL/Lua	Lua	<a href="https://github.com/pllua/pllua-ng">https://github.com/pllua/pllua-ng</a>
PL/R	R	<a href="https://github.com/postgres-plr/plr">https://github.com/postgres-plr/plr</a>
PL/sh	Unix shell	<a href="https://github.com/petere/plsh">https://github.com/petere/plsh</a>
PL/v8	JavaScript	<a href="https://github.com/plv8/plv8">https://github.com/plv8/plv8</a>

## H.4. Extensions

LightDB is designed to be easily extensible. For this reason, extensions loaded into the database can function just like features that are built in. The `contrib/` directory shipped with the source code contains several extensions, which are described in Appendix F. Other extensions are developed independently, like PostGIS<sup>2</sup>. Even LightDB replication solutions can be developed externally. For example, Slony-I<sup>3</sup> is a popular master/standby replication solution that is developed independently from the core project.

<sup>2</sup> <https://postgis.net/>

<sup>3</sup> <https://www.slony.info>

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# Appendix I. LightDB Limits

Table I.1 describes various hard limits of LightDB. However, practical limits, such as performance limitations or available disk space may apply before absolute hard limits are reached.

**Table I.1. LightDB Limitations**

Item	Upper Limit	Comment
database size	unlimited	
number of databases	4,294,950,911	
relations per database	1,431,650,303	
relation size	32 TB	with the default BLCKSZ of 8192 bytes
rows per table	limited by the number of tuples that can fit onto 4,294,967,295 pages	
columns per table	1600	further limited by tuple size fitting on a single page; see note below
columns in a result set	1664	
field size	1 GB	
identifier length	63 bytes	can be increased by recompiling LightDB
indexes per table	unlimited	constrained by maximum relations per database
columns per index	32	can be increased by recompiling LightDB
partition keys	32	can be increased by recompiling LightDB

The maximum number of columns for a table is further reduced as the tuple being stored must fit in a single 8192-byte heap page. For example, excluding the tuple header, a tuple made up of 1600 `int` columns would consume 6400 bytes and could be stored in a heap page, but a tuple of 1600 `bigint` columns would consume 12800 bytes and would therefore not fit inside a heap page. Variable-length fields of types such as `text`, `varchar`, and `char` can have their values stored out of line in the table's TOAST table when the values are large enough to require it. Only an 18-byte pointer must remain inside the tuple in the table's heap. For shorter length variable-length fields, either a 4-byte or 1-byte field header is used and the value is stored inside the heap tuple.

Columns that have been dropped from the table also contribute to the maximum column limit. Moreover, although the dropped column values for newly created tuples are internally marked as null in the tuple's null bitmap, the null bitmap also occupies space.

---

# Appendix J. Acronyms

This is a list of acronyms commonly used in the LightDB documentation and in discussions about LightDB.

## ANSI

American National Standards Institute<sup>1</sup>

## API

Application Programming Interface<sup>2</sup>

## ASCII

American Standard Code for Information Interchange<sup>3</sup>

## BKI

Backend Interface

## CA

Certificate Authority<sup>4</sup>

## CIDR

Classless Inter-Domain Routing<sup>5</sup>

## CPAN

Comprehensive Perl Archive Network<sup>6</sup>

## CRL

Certificate Revocation List<sup>7</sup>

## CSV

Comma Separated Values<sup>8</sup>

## CTE

Common Table Expression

## CVE

Common Vulnerabilities and Exposures<sup>9</sup>

## DBA

Database Administrator<sup>10</sup>

---

<sup>1</sup> [https://en.wikipedia.org/wiki/American\\_National\\_Standards\\_Institute](https://en.wikipedia.org/wiki/American_National_Standards_Institute)

<sup>2</sup> <https://en.wikipedia.org/wiki/API>

<sup>3</sup> <https://en.wikipedia.org/wiki/Ascii>

<sup>4</sup> [https://en.wikipedia.org/wiki/Certificate\\_authority](https://en.wikipedia.org/wiki/Certificate_authority)

<sup>5</sup> [https://en.wikipedia.org/wiki/Classless\\_Inter-Domain\\_Routing](https://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing)

<sup>6</sup> <https://www.cpan.org/>

<sup>7</sup> [https://en.wikipedia.org/wiki/Certificate\\_revocation\\_list](https://en.wikipedia.org/wiki/Certificate_revocation_list)

<sup>8</sup> [https://en.wikipedia.org/wiki/Comma-separated\\_values](https://en.wikipedia.org/wiki/Comma-separated_values)

<sup>9</sup> <https://cve.mitre.org/>

<sup>10</sup> [https://en.wikipedia.org/wiki/Database\\_administrator](https://en.wikipedia.org/wiki/Database_administrator)

DBI

Database Interface (Perl)<sup>11</sup>

DBMS

Database Management System<sup>12</sup>

DDL

Data Definition Language<sup>13</sup>, SQL commands such as CREATE TABLE, ALTER USER

DML

Data Manipulation Language<sup>14</sup>, SQL commands such as INSERT, UPDATE, DELETE

DST

Daylight Saving Time<sup>15</sup>

ECPG

Embedded C for LightDB

ESQL

Embedded SQL<sup>16</sup>

FAQ

Frequently Asked Questions<sup>17</sup>

FSM

Free Space Map

GEQO

Genetic Query Optimizer

GIN

Generalized Inverted Index

Git

Git<sup>18</sup>

GMT

Greenwich Mean Time<sup>19</sup>

GSSAPI

Generic Security Services Application Programming Interface<sup>20</sup>

---

<sup>11</sup> <https://dbi.perl.org/>

<sup>12</sup> <https://en.wikipedia.org/wiki/Dbms>

<sup>13</sup> [https://en.wikipedia.org/wiki/Data\\_Definition\\_Language](https://en.wikipedia.org/wiki/Data_Definition_Language)

<sup>14</sup> [https://en.wikipedia.org/wiki/Data\\_Manipulation\\_Language](https://en.wikipedia.org/wiki/Data_Manipulation_Language)

<sup>15</sup> [https://en.wikipedia.org/wiki/Daylight\\_saving\\_time](https://en.wikipedia.org/wiki/Daylight_saving_time)

<sup>16</sup> [https://en.wikipedia.org/wiki/Embedded\\_SQL](https://en.wikipedia.org/wiki/Embedded_SQL)

<sup>17</sup> <https://en.wikipedia.org/wiki/FAQ>

<sup>18</sup> [https://en.wikipedia.org/wiki/Git\\_\(software\)](https://en.wikipedia.org/wiki/Git_(software))

<sup>19</sup> <https://en.wikipedia.org/wiki/GMT>

<sup>20</sup> [https://en.wikipedia.org/wiki/Generic\\_Security\\_Services\\_Application\\_Program\\_Interface](https://en.wikipedia.org/wiki/Generic_Security_Services_Application_Program_Interface)



GUC

Grand Unified Configuration, the LightDB subsystem that handles server configuration

HBA

Host-Based Authentication

HOT

Heap-Only Tuples<sup>21</sup>

IEC

International Electrotechnical Commission<sup>22</sup>

IEEE

Institute of Electrical and Electronics Engineers<sup>23</sup>

IPC

Inter-Process Communication<sup>24</sup>

ISO

International Organization for Standardization<sup>25</sup>

ISSN

International Standard Serial Number<sup>26</sup>

JDBC

Java Database Connectivity<sup>27</sup>

JIT

Just-in-Time compilation<sup>28</sup>

JSON

JavaScript Object Notation<sup>29</sup>

LDAP

Lightweight Directory Access Protocol<sup>30</sup>

LSN

Log Sequence Number, see `pg_lsn` and WAL Internals.

MSVC

Microsoft Visual C<sup>31</sup>

---

<sup>21</sup> <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/backend/access/heap/README.HOT;hb=HEAD>

<sup>22</sup> [https://en.wikipedia.org/wiki/International\\_Electrotechnical\\_Commission](https://en.wikipedia.org/wiki/International_Electrotechnical_Commission)

<sup>23</sup> <https://standards.ieee.org/>

<sup>24</sup> [https://en.wikipedia.org/wiki/Inter-process\\_communication](https://en.wikipedia.org/wiki/Inter-process_communication)

<sup>25</sup> <https://www.iso.org/home.html>

<sup>26</sup> <https://en.wikipedia.org/wiki/Issn>

<sup>27</sup> [https://en.wikipedia.org/wiki/Java\\_Database\\_Connectivity](https://en.wikipedia.org/wiki/Java_Database_Connectivity)

<sup>28</sup> [https://en.wikipedia.org/wiki/Just-in-time\\_compilation](https://en.wikipedia.org/wiki/Just-in-time_compilation)

<sup>29</sup> <https://www.json.org>

<sup>30</sup> [https://en.wikipedia.org/wiki/Lightweight\\_Directory\\_Access\\_Protocol](https://en.wikipedia.org/wiki/Lightweight_Directory_Access_Protocol)

<sup>31</sup> [https://en.wikipedia.org/wiki/Visual\\_C++](https://en.wikipedia.org/wiki/Visual_C++)

MVCC

Multi-Version Concurrency Control

NLS

National Language Support<sup>32</sup>

ODBC

Open Database Connectivity<sup>33</sup>

OID

Object Identifier

OLAP

Online Analytical Processing<sup>34</sup>

OLTP

Online Transaction Processing<sup>35</sup>

ORDBMS

Object-Relational Database Management System<sup>36</sup>

PAM

Pluggable Authentication Modules<sup>37</sup>

PGSQL

LightDB

PGXS

LightDB Extension System

PID

Process Identifier<sup>38</sup>

PITR

Point-In-Time Recovery (Continuous Archiving)

PL

Procedural Languages (server-side)

POSIX

Portable Operating System Interface<sup>39</sup>

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<sup>32</sup> [https://en.wikipedia.org/wiki/Internationalization\\_and\\_localization](https://en.wikipedia.org/wiki/Internationalization_and_localization)

<sup>33</sup> [https://en.wikipedia.org/wiki/Open\\_Database\\_Connectivity](https://en.wikipedia.org/wiki/Open_Database_Connectivity)

<sup>34</sup> <https://en.wikipedia.org/wiki/Olap>

<sup>35</sup> <https://en.wikipedia.org/wiki/OLTP>

<sup>36</sup> <https://en.wikipedia.org/wiki/ORDBMS>

<sup>37</sup> [https://en.wikipedia.org/wiki/Pluggable\\_Authentication\\_Modules](https://en.wikipedia.org/wiki/Pluggable_Authentication_Modules)

<sup>38</sup> [https://en.wikipedia.org/wiki/Process\\_identifier](https://en.wikipedia.org/wiki/Process_identifier)

<sup>39</sup> <https://en.wikipedia.org/wiki/POSIX>

RDBMS

Relational Database Management System<sup>40</sup>

RFC

Request For Comments<sup>41</sup>

SGML

Standard Generalized Markup Language<sup>42</sup>

SPI

Server Programming Interface

SQL

Structured Query Language<sup>43</sup>

SRF

Set-Returning Function

SSH

Secure Shell<sup>44</sup>

SSL

Secure Sockets Layer<sup>45</sup>

SSPI

Security Support Provider Interface<sup>46</sup>

SYSV

Unix System V<sup>47</sup>

TCP/IP

Transmission Control Protocol (TCP) / Internet Protocol (IP)<sup>48</sup>

TID

Tuple Identifier

TLS

Transport Layer Security<sup>49</sup>

TOAST

The Oversized-Attribute Storage Technique

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<sup>40</sup> [https://en.wikipedia.org/wiki/Relational\\_database\\_management\\_system](https://en.wikipedia.org/wiki/Relational_database_management_system)

<sup>41</sup> [https://en.wikipedia.org/wiki/Request\\_for\\_Comments](https://en.wikipedia.org/wiki/Request_for_Comments)

<sup>42</sup> <https://en.wikipedia.org/wiki/SGML>

<sup>43</sup> <https://en.wikipedia.org/wiki/SQL>

<sup>44</sup> [https://en.wikipedia.org/wiki/Secure\\_Shell](https://en.wikipedia.org/wiki/Secure_Shell)

<sup>45</sup> [https://en.wikipedia.org/wiki/Secure\\_Sockets\\_Layer](https://en.wikipedia.org/wiki/Secure_Sockets_Layer)

<sup>46</sup> <https://msdn.microsoft.com/en-us/library/aa380493%28VS.85%29.aspx>

<sup>47</sup> [https://en.wikipedia.org/wiki/System\\_V](https://en.wikipedia.org/wiki/System_V)

<sup>48</sup> [https://en.wikipedia.org/wiki/Transmission\\_Control\\_Protocol](https://en.wikipedia.org/wiki/Transmission_Control_Protocol)

<sup>49</sup> [https://en.wikipedia.org/wiki/Transport\\_Layer\\_Security](https://en.wikipedia.org/wiki/Transport_Layer_Security)

TPC

Transaction Processing Performance Council<sup>50</sup>

URL

Uniform Resource Locator<sup>51</sup>

UTC

Coordinated Universal Time<sup>52</sup>

UTF

Unicode Transformation Format<sup>53</sup>

UTF8

Eight-Bit Unicode Transformation Format<sup>54</sup>

UUID

Universally Unique Identifier

WAL

Write-Ahead Log

XID

Transaction Identifier

XML

Extensible Markup Language<sup>55</sup>

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<sup>50</sup> <http://www.tpc.org/>

<sup>51</sup> <https://en.wikipedia.org/wiki/URL>

<sup>52</sup> [https://en.wikipedia.org/wiki/Coordinated\\_Universal\\_Time](https://en.wikipedia.org/wiki/Coordinated_Universal_Time)

<sup>53</sup> <https://www.unicode.org/>

<sup>54</sup> <https://en.wikipedia.org/wiki/Utf8>

<sup>55</sup> <https://en.wikipedia.org/wiki/XML>

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# Appendix K. Glossary

This is a list of terms and their meaning in the context of LightDB and relational database systems in general.

ACID	<i>Atomicity, Consistency, Isolation, and Durability.</i> This set of properties of database transactions is intended to guarantee validity in concurrent operation and even in event of errors, power failures, etc.
Aggregate function (routine)	<p>A <i>function</i> that combines (<i>aggregates</i>) multiple input values, for example by counting, averaging or adding, yielding a single output value.</p> <p>For more information, see Section 9.21.</p> <p>See Also Window function (routine).</p>
Analytic function	See Window function (routine).
Analyze (operation)	<p>The process of collecting statistics from data in <i>tables</i> and other <i>relations</i> to help the <i>query planner</i> to make decisions about how to execute <i>queries</i>.</p> <p>(Don't confuse this term with the <code>ANALYZE</code> option to the <code>EXPLAIN</code> command.)</p> <p>For more information, see <code>ANALYZE</code>.</p>
Atomic	<p>In reference to a <i>datum</i>: the fact that its value cannot be broken down into smaller components.</p> <p>In reference to a <i>database transaction</i>: see <i>atomicity</i>.</p>
Atomicity	The property of a <i>transaction</i> that either all its operations complete as a single unit or none do. In addition, if a system failure occurs during the execution of a transaction, no partial results are visible after recovery. This is one of the ACID properties.
Attribute	An element with a certain name and data type found within a <i>tuple</i> .
Autovacuum (process)	<p>A set of background processes that routinely perform <i>vacuum</i> and <i>analyze</i> operations.</p> <p>For more information, see Section 22.1.6.</p>
Backend (process)	<p>Process of an <i>instance</i> which acts on behalf of a <i>client session</i> and handles its requests.</p> <p>(Don't confuse this term with the similar terms <i>Background Worker</i> or <i>Background Writer</i>).</p>
Background worker (process)	<p>Process within an <i>instance</i>, which runs system- or user-supplied code. Serves as infrastructure for several features in LightDB, such as <i>logical replication</i> and <i>parallel queries</i>. In addition, <i>Extensions</i> can add custom background worker processes.</p> <p>For more information, see Chapter 44.</p>
Background writer (process)	A process that writes dirty <i>data pages</i> from <i>shared memory</i> to the file system. It wakes up periodically, but works only for a

	<p>short period in order to distribute its expensive I/O activity over time to avoid generating larger I/O peaks which could block other processes.</p> <p>For more information, see Section 17.4.5.</p>
Bloat	<p>Space in data pages which does not contain current row versions, such as unused (free) space or outdated row versions.</p>
Cast	<p>A conversion of a <i>datum</i> from its current data type to another data type.</p> <p>For more information, see CREATE CAST.</p>
Catalog	<p>The SQL standard uses this term to indicate what is called a <i>database</i> in LightDB's terminology.</p> <p>(Don't confuse this term with <i>system catalog</i>).</p> <p>For more information, see Section 20.1.</p>
Check constraint	<p>A type of <i>constraint</i> defined on a <i>relation</i> which restricts the values allowed in one or more <i>attributes</i>. The check constraint can make reference to any attribute of the same row in the relation, but cannot reference other rows of the same relation or other relations.</p> <p>For more information, see Section 5.4.</p>
Checkpoint	<p>A point in the <i>WAL</i> sequence at which it is guaranteed that the heap and index data files have been updated with all information from <i>shared memory</i> modified before that checkpoint; a <i>checkpoint record</i> is written and flushed to <i>WAL</i> to mark that point.</p> <p>A checkpoint is also the act of carrying out all the actions that are necessary to reach a checkpoint as defined above. This process is initiated when predefined conditions are met, such as a specified amount of time has passed, or a certain volume of records has been written; or it can be invoked by the user with the command CHECKPOINT.</p> <p>For more information, see Section 27.4.</p>
Checkpointer (process)	<p>A specialized process responsible for executing checkpoints.</p>
Class (archaic)	<p>See Relation.</p>
Client (process)	<p>Any process, possibly remote, that establishes a <i>session</i> by <i>connecting</i> to an <i>instance</i> to interact with a <i>database</i>.</p>
Column	<p>An <i>attribute</i> found in a <i>table</i> or <i>view</i>.</p>
Commit	<p>The act of finalizing a <i>transaction</i> within the <i>database</i>, which makes it visible to other transactions and assures its <i>durability</i>.</p> <p>For more information, see COMMIT.</p>
Concurrency	<p>The concept that multiple independent operations happen within the <i>database</i> at the same time. In LightDB, concurrency is controlled by the <i>multiversion concurrency control</i> mechanism.</p>

Connection	<p>An established line of communication between a client process and a <i>backend</i> process, usually over a network, supporting a <i>session</i>. This term is sometimes used as a synonym for session.</p> <p>For more information, see Section 17.3.</p>
Consistency	<p>The property that the data in the <i>database</i> is always in compliance with <i>integrity constraints</i>. Transactions may be allowed to violate some of the constraints transiently before it commits, but if such violations are not resolved by the time it commits, such a transaction is automatically <i>rolled back</i>. This is one of the ACID properties.</p>
Constraint	<p>A restriction on the values of data allowed within a <i>table</i>, or in attributes of a <i>domain</i>.</p> <p>For more information, see Section 5.4.</p>
Data area	<p>See Data directory.</p>
Database	<p>A named collection of <i>local SQL objects</i>.</p> <p>For more information, see Section 20.1.</p>
Database cluster	<p>A collection of databases and global SQL objects, and their common static and dynamic metadata. Sometimes referred to as a <i>cluster</i>.</p> <p>In LightDB, the term <i>cluster</i> is also sometimes used to refer to an instance. (Don't confuse this term with the SQL command CLUSTER.)</p>
Database server	<p>See Instance.</p>
Data directory	<p>The base directory on the file system of a <i>server</i> that contains all data files and subdirectories associated with a <i>database cluster</i> (with the exception of <i>tablespaces</i>, and optionally <i>WAL</i>). The environment variable <code>LTDATA</code> is commonly used to refer to the data directory.</p> <p>A <i>cluster's</i> storage space comprises the data directory plus any additional tablespaces.</p> <p>For more information, see Section 64.1.</p>
Data page	<p>The basic structure used to store relation data. All pages are of the same size. Data pages are typically stored on disk, each in a specific file, and can be read to <i>shared buffers</i> where they can be modified, becoming <i>dirty</i>. They become clean when written to disk. New pages, which initially exist in memory only, are also dirty until written.</p>
Datum	<p>The internal representation of one value of an SQL data type.</p>
Delete	<p>An SQL command which removes <i>rows</i> from a given <i>table</i> or <i>relation</i>.</p> <p>For more information, see DELETE.</p>
Durability	<p>The assurance that once a <i>transaction</i> has been <i>committed</i>, the changes remain even after a system failure or crash. This is one of the ACID properties.</p>

Epoch	See Transaction ID.
Extension	<p>A software add-on package that can be installed on an <i>instance</i> to get extra features.</p> <p>For more information, see Section 36.17.</p>
File segment	<p>A physical file which stores data for a given <i>relation</i>. File segments are limited in size by a configuration value (typically 1 gigabyte), so if a relation exceeds that size, it is split into multiple segments.</p> <p>For more information, see Section 64.1.</p> <p>(Don't confuse this term with the similar term <i>WAL segment</i>).</p>
Foreign data wrapper	<p>A means of representing data that is not contained in the local <i>database</i> so that it appears as if were in local <i>table(s)</i>. With a foreign data wrapper it is possible to define a <i>foreign server</i> and <i>foreign tables</i>.</p> <p>For more information, see CREATE FOREIGN DATA WRAPPER.</p>
Foreign key	A type of <i>constraint</i> defined on one or more <i>columns</i> in a <i>table</i> which requires the value(s) in those <i>columns</i> to identify zero or one <i>row</i> in another (or, infrequently, the same) <i>table</i> .
Foreign server	<p>A named collection of <i>foreign tables</i> which all use the same <i>foreign data wrapper</i> and have other configuration values in common.</p> <p>For more information, see CREATE SERVER.</p>
Foreign table (relation)	<p>A <i>relation</i> which appears to have <i>rows</i> and <i>columns</i> similar to a regular <i>table</i>, but will forward requests for data through its <i>foreign data wrapper</i>, which will return <i>result sets</i> structured according to the definition of the <i>foreign table</i>.</p> <p>For more information, see CREATE FOREIGN TABLE.</p>
Fork	Each of the separate segmented file sets in which a relation is stored. The <i>main fork</i> is where the actual data resides. There also exist two secondary forks for metadata: the <i>free space map</i> and the <i>visibility map</i> . <i>Unlogged relations</i> also have an <i>init fork</i> .
Free space map (fork)	<p>A storage structure that keeps metadata about each data page of a table's main fork. The free space map entry for each page stores the amount of free space that's available for future tuples, and is structured to be efficiently searched for available space for a new tuple of a given size.</p> <p>For more information, see Section 64.3.</p>
Function (routine)	<p>A type of routine that receives zero or more arguments, returns zero or more output values, and is constrained to run within one transaction. Functions are invoked as part of a query, for example via SELECT. Certain functions can return <i>sets</i>; those are called <i>set-returning functions</i>.</p> <p>Functions can also be used for <i>triggers</i> to invoke.</p>



	For more information, see CREATE FUNCTION.
Grant	An SQL command that is used to allow a <i>user</i> or <i>role</i> to access specific objects within the <i>database</i> .  For more information, see GRANT.
Heap	Contains the values of <i>row</i> attributes (i.e., the data) for a <i>relation</i> . The heap is realized within one or more <i>file segments</i> in the relation's <i>main fork</i> .
Host	A computer that communicates with other computers over a network. This is sometimes used as a synonym for <i>server</i> . It is also used to refer to a computer where <i>client processes</i> run.
Index (relation)	A <i>relation</i> that contains data derived from a <i>table</i> or <i>materialized view</i> . Its internal structure supports fast retrieval of and access to the original data.  For more information, see CREATE INDEX.
Insert	An SQL command used to add new data into a <i>table</i> .  For more information, see INSERT.
Instance	A group of backend and auxiliary processes that communicate using a common shared memory area. One <i>postmaster process</i> manages the instance; one instance manages exactly one <i>database cluster</i> with all its databases. Many instances can run on the same <i>server</i> as long as their TCP ports do not conflict.  The instance handles all key features of a DBMS: read and write access to files and shared memory, assurance of the ACID properties, <i>connections</i> to <i>client processes</i> , privilege verification, crash recovery, replication, etc.
Isolation	The property that the effects of a transaction are not visible to <i>concurrent transactions</i> before it commits. This is one of the ACID properties.  For more information, see Section 13.2.
Join	An operation and SQL keyword used in <i>queries</i> for combining data from multiple <i>relations</i> .
Key	A means of identifying a <i>row</i> within a <i>table</i> or other <i>relation</i> by values contained within one or more <i>attributes</i> in that relation.
Lock	A mechanism that allows a process to limit or prevent simultaneous access to a resource.
Log file	Log files contain human-readable text lines about events. Examples include login failures, long-running queries, etc.  For more information, see Section 22.3.
Logged	A <i>table</i> is considered <i>logged</i> if changes to it are sent to the <i>WAL</i> . By default, all regular tables are logged. A table can be specified as <i>unlogged</i> either at creation time or via the ALTER TABLE command.

Logger (process)	<p>If activated, the process writes information about database events into the current <i>log file</i>. When reaching certain time- or volume-dependent criteria, a new log file is created. Also called <i>syslogger</i>.</p> <p>For more information, see Section 17.8.</p>
Log record	Archaic term for a <i>WAL record</i> .
Master (server)	See Primary (server).
Materialized	<p>The property that some information has been pre-computed and stored for later use, rather than computing it on-the-fly.</p> <p>This term is used in <i>materialized view</i>, to mean that the data derived from the view's query is stored on disk separately from the sources of that data.</p> <p>This term is also used to refer to some multi-step queries to mean that the data resulting from executing a given step is stored in memory (with the possibility of spilling to disk), so that it can be read multiple times by another step.</p>
Materialized view (relation)	<p>A <i>relation</i> that is defined by a <code>SELECT</code> statement (just like a <i>view</i>), but stores data in the same way that a <i>table</i> does. It cannot be modified via <code>INSERT</code>, <code>UPDATE</code>, or <code>DELETE</code> operations.</p> <p>For more information, see <code>CREATE MATERIALIZED VIEW</code>.</p>
Multi-version concurrency control (MVCC)	A mechanism designed to allow several <i>transactions</i> to be reading and writing the same rows without one process causing other processes to stall. In LightDB, MVCC is implemented by creating copies ( <i>versions</i> ) of <i>tuples</i> as they are modified; after transactions that can see the old versions terminate, those old versions need to be removed.
Null	A concept of non-existence that is a central tenet of relational database theory. It represents the absence of a definite value.
Optimizer	See Query planner.
Parallel query	The ability to handle parts of executing a <i>query</i> to take advantage of parallel processes on servers with multiple CPUs.
Partition	<p>One of several disjoint (not overlapping) subsets of a larger set.</p> <p>In reference to a <i>partitioned table</i>: One of the tables that each contain part of the data of the partitioned table, which is said to be the <i>parent</i>. The partition is itself a table, so it can also be queried directly; at the same time, a partition can sometimes be a partitioned table, allowing hierarchies to be created.</p> <p>In reference to a <i>window function</i> in a <i>query</i>, a partition is a user-defined criterion that identifies which neighboring <i>rows</i> of the <i>query's result set</i> can be considered by the function.</p>
Partitioned table (relation)	A <i>relation</i> that is in semantic terms the same as a <i>table</i> , but whose storage is distributed across several <i>partitions</i> .
Postmaster (process)	The very first process of an <i>instance</i> . It starts and manages the other auxiliary processes and creates <i>backend processes</i> on demand.

	For more information, see Section 16.3.
Primary key	A special case of a <i>unique constraint</i> defined on a <i>table</i> or other <i>relation</i> that also guarantees that all of the <i>attributes</i> within the <i>primary key</i> do not have <i>null</i> values. As the name implies, there can be only one primary key per table, though it is possible to have multiple unique constraints that also have no null-capable attributes.
Primary (server)	When two or more <i>databases</i> are linked via <i>replication</i> , the <i>server</i> that is considered the authoritative source of information is called the <i>primary</i> , also known as a <i>master</i> .
Procedure (routine)	A type of routine. Their distinctive qualities are that they do not return values, and that they are allowed to make transactional statements such as COMMIT and ROLLBACK. They are invoked via the CALL command.  For more information, see CREATE PROCEDURE.
Query	A request sent by a client to a <i>backend</i> , usually to return results or to modify data on the database.
Query planner	The part of LightDB that is devoted to determining ( <i>planning</i> ) the most efficient way to execute <i>queries</i> . Also known as <i>query optimizer</i> , <i>optimizer</i> , or simply <i>planner</i> .
Record	See Tuple.
Recycling	See WAL file.
Referential integrity	A means of restricting data in one <i>relation</i> by a <i>foreign key</i> so that it must have matching data in another <i>relation</i> .
Relation	The generic term for all objects in a <i>database</i> that have a name and a list of <i>attributes</i> defined in a specific order. <i>Tables</i> , <i>sequences</i> , <i>views</i> , <i>foreign tables</i> , <i>materialized views</i> , composite types, and <i>indexes</i> are all relations.  More generically, a relation is a set of tuples; for example, the result of a query is also a relation.  In LightDB, <i>Class</i> is an archaic synonym for <i>relation</i> .
Replica (server)	A <i>database</i> that is paired with a <i>primary</i> database and is maintaining a copy of some or all of the primary database's data. The foremost reasons for doing this are to allow for greater access to that data, and to maintain availability of the data in the event that the <i>primary</i> becomes unavailable.
Replication	The act of reproducing data on one <i>server</i> onto another server called a <i>replica</i> . This can take the form of <i>physical replication</i> , where all file changes from one server are copied verbatim, or <i>logical replication</i> where a defined subset of data changes are conveyed using a higher-level representation.
Result set	A <i>relation</i> transmitted from a <i>backend process</i> to a <i>client</i> upon the completion of an SQL command, usually a SELECT but it can be an INSERT, UPDATE, or DELETE command if the RETURNING clause is specified.

	<p>The fact that a result set is a relation means that a query can be used in the definition of another query, becoming a <i>subquery</i>.</p>
Revoke	<p>A command to prevent access to a named set of <i>database</i> objects for a named list of <i>roles</i>.</p> <p>For more information, see REVOKE.</p>
Role	<p>A collection of access privileges to the <i>instance</i>. Roles are themselves a privilege that can be granted to other roles. This is often done for convenience or to ensure completeness when multiple <i>users</i> need the same privileges.</p> <p>For more information, see CREATE ROLE.</p>
Rollback	<p>A command to undo all of the operations performed since the beginning of a <i>transaction</i>.</p> <p>For more information, see ROLLBACK.</p>
Routine	<p>A defined set of instructions stored in the database system that can be invoked for execution. A routine can be written in a variety of programming languages. Routines can be <i>functions</i> (including set-returning functions and <i>trigger functions</i>), <i>aggregate functions</i>, and <i>procedures</i>.</p> <p>Many routines are already defined within LightDB itself, but user-defined ones can also be added.</p>
Row	<p>See Tuple.</p>
Savepoint	<p>A special mark in the sequence of steps in a <i>transaction</i>. Data modifications after this point in time may be reverted to the time of the savepoint.</p> <p>For more information, see SAVEPOINT.</p>
Schema	<p>A schema is a namespace for <i>SQL objects</i>, which all reside in the same <i>database</i>. Each SQL object must reside in exactly one schema.</p> <p>All system-defined SQL objects reside in schema <code>pg_catalog</code>.</p> <p>More generically, the term <i>schema</i> is used to mean all data descriptions (<i>table</i> definitions, <i>constraints</i>, comments, etc) for a given <i>database</i> or subset thereof.</p> <p>For more information, see Section 5.9.</p>
Segment	<p>See File segment.</p>
Select	<p>The SQL command used to request data from a <i>database</i>. Normally, SELECT commands are not expected to modify the <i>database</i> in any way, but it is possible that <i>functions</i> invoked within the query could have side effects that do modify data.</p> <p>For more information, see SELECT.</p>
Sequence (relation)	<p>A type of relation that is used to generate values. Typically the generated values are sequential non-repeating numbers. They are commonly used to generate surrogate <i>primary key</i> values.</p>

Server	<p>A computer on which LightDB <i>instances</i> run. The term <i>server</i> denotes real hardware, a container, or a <i>virtual machine</i>.</p> <p>This term is sometimes used to refer to an instance or to a host.</p>
Session	<p>A state that allows a client and a backend to interact, communicating over a <i>connection</i>.</p>
Shared memory	<p>RAM which is used by the processes common to an <i>instance</i>. It mirrors parts of <i>database</i> files, provides a transient area for <i>WAL records</i>, and stores additional common information. Note that shared memory belongs to the complete instance, not to a single database.</p> <p>The largest part of shared memory is known as <i>shared buffers</i> and is used to mirror part of data files, organized into pages. When a page is modified, it is called a dirty page until it is written back to the file system.</p> <p>For more information, see Section 17.4.1.</p>
SQL object	<p>Any object that can be created with a CREATE command. Most objects are specific to one database, and are commonly known as <i>local objects</i>.</p> <p>Most local objects belong to a specific <i>schema</i> in their containing database, such as <i>relations</i> (all types), <i>routines</i> (all types), data types, etc. The names of such objects of the same type in the same schema are enforced to be unique.</p> <p>There also exist local objects that do not belong to schemas; some examples are <i>extensions</i>, <i>data type casts</i>, and <i>foreign data wrappers</i>. The names of such objects of the same type are enforced to be unique within the database.</p> <p>Other object types, such as <i>roles</i>, <i>tablespaces</i>, replication origins, subscriptions for logical replication, and databases themselves are not local SQL objects since they exist entirely outside of any specific database; they are called <i>global objects</i>. The names of such objects are enforced to be unique within the whole database cluster.</p> <p>For more information, see Section 20.1.</p>
SQL standard	<p>A series of documents that define the SQL language.</p>
Standby (server)	<p>See Replica (server).</p>
Stats collector (process)	<p>This process collects statistical information about the <i>instance's</i> activities.</p> <p>For more information, see Section 25.2.</p>
System catalog	<p>A collection of <i>tables</i> which describe the structure of all <i>SQL objects</i> of the instance. The system catalog resides in the schema <code>pg_catalog</code>. These tables contain data in internal representation and are not typically considered useful for user examination; a number of user-friendlier <i>views</i>, also in schema <code>pg_catalog</code>, offer more convenient access to some of that information, while additional tables and views exist in schema <code>information_schema</code> (see Chapter 35) that expose some of</p>

	<p>the same and additional information as mandated by the <i>SQL standard</i>.</p> <p>For more information, see Section 5.9.</p>
Table	<p>A collection of <i>tuples</i> having a common data structure (the same number of <i>attributes</i>, in the same order, having the same name and type per position). A table is the most common form of <i>relation</i> in LightDB.</p> <p>For more information, see CREATE TABLE.</p>
Tablespace	<p>A named location on the server file system. All <i>SQL objects</i> which require storage beyond their definition in the <i>system catalog</i> must belong to a single tablespace. Initially, a database cluster contains a single usable tablespace which is used as the default for all SQL objects, called <code>pg_default</code>.</p> <p>For more information, see Section 20.6.</p>
Temporary table	<p><i>Tables</i> that exist either for the lifetime of a <i>session</i> or a <i>transaction</i>, as specified at the time of creation. The data in them is not visible to other sessions, and is not <i>logged</i>. Temporary tables are often used to store intermediate data for a multi-step operation.</p> <p>For more information, see CREATE TABLE.</p>
TOAST	<p>A mechanism by which large attributes of table rows are split and stored in a secondary table, called the <i>TOAST table</i>. Each relation with large attributes has its own TOAST table.</p> <p>For more information, see Section 64.2.</p>
Transaction	<p>A combination of commands that must act as a single <i>atomic</i> command: they all succeed or all fail as a single unit, and their effects are not visible to other <i>sessions</i> until the transaction is complete, and possibly even later, depending on the isolation level.</p> <p>For more information, see Section 13.2.</p>
Transaction ID	<p>The numerical, unique, sequentially-assigned identifier that each transaction receives when it first causes a database modification. Frequently abbreviated as <i>xid</i>. When stored on disk, xids are only 32-bits wide, so only approximately four billion write transaction IDs can be generated; to permit the system to run for longer than that, <i>epochs</i> are used, also 32 bits wide. When the counter reaches the maximum xid value, it starts over at 3 (values under that are reserved) and the epoch value is incremented by one. In some contexts, the epoch and xid values are considered together as a single 64-bit value.</p> <p>For more information, see Section 8.19.</p>
Transactions per second (TPS)	<p>Average number of transactions that are executed per second, totaled across all sessions active for a measured run. This is used as a measure of the performance characteristics of an instance.</p>
Trigger	<p>A <i>function</i> which can be defined to execute whenever a certain operation (<code>INSERT</code>, <code>UPDATE</code>, <code>DELETE</code>, <code>TRUNCATE</code>) is applied</p>

to a *relation*. A trigger executes within the same *transaction* as the statement which invoked it, and if the function fails, then the invoking statement also fails.

For more information, see CREATE TRIGGER.

Tuple	<p>A collection of <i>attributes</i> in a fixed order. That order may be defined by the <i>table</i> (or other <i>relation</i>) where the tuple is contained, in which case the tuple is often called a <i>row</i>. It may also be defined by the structure of a result set, in which case it is sometimes called a <i>record</i>.</p>
Unique constraint	<p>A type of <i>constraint</i> defined on a <i>relation</i> which restricts the values allowed in one or a combination of columns so that each value or combination of values can only appear once in the relation — that is, no other row in the relation contains values that are equal to those.</p> <p>Because <i>null values</i> are not considered equal to each other, multiple rows with null values are allowed to exist without violating the unique constraint.</p>
Unlogged	<p>The property of certain <i>relations</i> that the changes to them are not reflected in the <i>WAL</i>. This disables replication and crash recovery for these relations.</p> <p>The primary use of unlogged tables is for storing transient work data that must be shared across processes.</p> <p><i>Temporary tables</i> are always unlogged.</p>
Update	<p>An SQL command used to modify <i>rows</i> that may already exist in a specified <i>table</i>. It cannot create or remove rows.</p> <p>For more information, see UPDATE.</p>
User	<p>A <i>role</i> that has the LOGIN privilege.</p>
User mapping	<p>The translation of login credentials in the local <i>database</i> to credentials in a remote data system defined by a <i>foreign data wrapper</i>.</p> <p>For more information, see CREATE USER MAPPING.</p>
Vacuum	<p>The process of removing outdated <i>tuple versions</i> from tables or materialized views, and other closely related processing required by LightDB's implementation of <i>MVCC</i>. This can be initiated through the use of the VACUUM command, but can also be handled automatically via <i>autovacuum</i> processes.</p> <p>For more information, see Section 22.1 .</p>
View	<p>A <i>relation</i> that is defined by a SELECT statement, but has no storage of its own. Any time a query references a view, the definition of the view is substituted into the query as if the user had typed it as a subquery instead of the name of the view.</p> <p>For more information, see CREATE VIEW.</p>
Visibility map (fork)	<p>A storage structure that keeps metadata about each data page of a table's main fork. The visibility map entry for each page stores</p>

	two bits: the first one ( <code>all-visible</code> ) indicates that all tuples in the page are visible to all transactions. The second one ( <code>all-frozen</code> ) indicates that all tuples in the page are marked frozen.
WAL	See Write-ahead log.
WAL archiver (process)	<p>A process that saves copies of <i>WAL files</i> for the purpose of creating backups or keeping <i>replicas</i> current.</p> <p>For more information, see Section 23.3.</p>
WAL file	<p>Also known as <i>WAL segment</i> or <i>WAL segment file</i>. Each of the sequentially-numbered files that provide storage space for <i>WAL</i>. The files are all of the same predefined size and are written in sequential order, interspersing changes as they occur in multiple simultaneous sessions. If the system crashes, the files are read in order, and each of the changes is replayed to restore the system to the state it was in before the crash.</p> <p>Each WAL file can be released after a <i>checkpoint</i> writes all the changes in it to the corresponding data files. Releasing the file can be done either by deleting it, or by changing its name so that it will be used in the future, which is called <i>recycling</i>.</p> <p>For more information, see Section 27.5.</p>
WAL record	<p>A low-level description of an individual data change. It contains sufficient information for the data change to be re-executed (<i>replayed</i>) in case a system failure causes the change to be lost. WAL records use a non-printable binary format.</p> <p>For more information, see Section 27.5.</p>
WAL segment	See WAL file.
WAL writer (process)	<p>A process that writes <i>WAL records</i> from <i>shared memory</i> to <i>WAL files</i>.</p> <p>For more information, see Section 17.5.</p>
Window function (routine)	<p>A type of <i>function</i> used in a <i>query</i> that applies to a <i>partition</i> of the query's <i>result set</i>; the function's result is based on values found in <i>rows</i> of the same partition or frame.</p> <p>All <i>aggregate functions</i> can be used as window functions, but window functions can also be used to, for example, give ranks to each of the rows in the partition. Also known as <i>analytic functions</i>.</p> <p>For more information, see Section 3.5.</p>
Write-ahead log	The journal that keeps track of the changes in the <i>database cluster</i> as user- and system-invoked operations take place. It comprises many individual <i>WAL records</i> written sequentially to <i>WAL files</i> .



---

# Appendix L. Color Support

Most programs in the LightDB package can produce colorized console output. This appendix describes how that is configured.

## L.1. When Color is Used

To use colorized output, set the environment variable `LT_COLOR` as follows:

1. If the value is `always`, then color is used.
2. If the value is `auto` and the standard error stream is associated with a terminal device, then color is used.
3. Otherwise, color is not used.

## L.2. Configuring the Colors

The actual colors to be used are configured using the environment variable `LT_COLORS` (note plural). The value is a colon-separated list of `key=value` pairs. The keys specify what the color is to be used for. The values are SGR (Select Graphic Rendition) specifications, which are interpreted by the terminal.

The following keys are currently in use:

`error`

used to highlight the text “error” in error messages

`warning`

used to highlight the text “warning” in warning messages

`locus`

used to highlight location information (e.g., program name and file name) in messages

The default value is `error=01;31:warning=01;35:locus=01` (01;31 = bold red, 01;35 = bold magenta, 01 = bold default color).

### Tip

This color specification format is also used by other software packages such as GCC, GNU coreutils, and GNU grep.

---

# Appendix M. LightDB JDBC

The LightDB JDBC Driver allows Java programs to connect to a LightDB using standard, database independent Java code.

In addition to the standard connection parameters the driver supports a number of additional properties which can be used to specify additional driver behaviour specific to LightDB.

- *lightdbSyntaxCompatibleType* (*String*) specifies LightDB compatible type, valid values are oracle/mysql/off,default value is off. It can compatible with Oracle Database,MySQL DataBase. For example:

```
jdbc:postgresql://localhost:5432/postgres?  
lightdbSyntaxCompatibleType=oracle
```

*jdbc can compatible with Oracle*

*Database*

- *currentSchema* (*String*) specifies the schema (or several schema separated by commas) to be set in the search-path. This schema will be used to resolve unqualified object names used in statements over this connection. For example:

```
jdbc:postgresql://localhost:5432/postgres?  
currentSchema=\"$user\", oracle
```

*jdbc will automatically supplement  
public to search\_path. Actual search\_path is \"\$user\", oracle,  
public, lt\_catalog*

- *options* (*String*) specifies the guc parameter in options. The format is as follows: options=-c guc parameter name=parameter value, where the value after options needs encode. For example:

```
jdbc:postgresql://localhost:5432/postgres?  
options=-c%20search_path=\"$user\",public,oracle,lt_catalog%20-c  
%20statement_timeout=90000
```

*search\_path is part of the guc  
parameter, so you can also set search\_path*

# Appendix N. Hooks List For Extension

There are many hooks that can be used by extension to extend internal functionality. Hooks can modify behavior at different places, including when running SQL statements.

A list of available hooks is listed below

**Table N.1. Hooks list**

Position	Hook	Description
analyze.h	post_parse_analyze_hook	Hook for plugins to get control at end of parse analysis
	lt_post_parse_analyze_stmt_hook	Hook for plugins to get control at end of stmt parse analysis.
planner.h	planner_hook	Hook for plugins to get control in planner()
	create_upper_paths_hook	Hook for plugins to get control when grouping_planner() plans upper rels
	pre_create_ordinary_grouping_paths_hook	Hook for plugins to get control before create_ordinary_grouping_paths.
	lt_distribute_qual_to_rels_hook	Hook for plugins to get control of distribute qual to rels.
paths.h	set_rel_pathlist_hook	Hook for plugins to get control in set_rel_pathlist()
	set_join_pathlist_hook	Hook for plugins to get control in add_paths_to_joinrel()
	join_search_hook	Hook for plugins to replace standard_join_search()
	pushdownquals_to_subquery_hook	Hook for plugins to decide whether to pushdown quals to subquery.
planmain.h	support_semijoin_to_inner_join_hook	Hook for plugins to get control of converting semijoin to inner join.
	lt_order_qual_clauses_hook	Hook for plugins to get control of order qual clauses.
Executor.h	ExecutorStart_hook	Hook for plugins to get control in ExecutorStart()
	ExecutorRun_hook	Hook for plugins to get control in ExecutorRun()
	ExecutorFinish_hook	Hook for plugins to get control in ExecutorFinish()
	ExecutorEnd_hook	Hook for plugins to get control in ExecutorEnd()
	ExecutorCheckPerms_hook	Hook for plugins to get control in ExecCheckRTPerms()

Hooks List For Extension

Position	Hook	Description
Utility.h	ProcessUtility_hook	Hook for plugins to get control in ProcessUtility()
plancat.h	get_relation_info_hook	Hook for plugins to get control in get_relation_info()
auth.h	ClientAuthentication_hook	Hook for plugins to get control in ClientAuthentication()
explain.h	ExplainOneQuery_hook	Hook for plugins to get control in ExplainOneQuery()
	explain_get_index_name_hook	Hook for plugins to get control in explain_get_index_name()
user.h	check_password_hook	Hook to check passwords in CreateRole() and AlterRole()
elog.h	emit_log_hook	Hook for intercepting messages before they are sent to the server log
fmgr.h	needs_fmgr_hook	Hooks for function calls
	fmgr_hook	Hooks for function calls
lsyscache.h	get_attavgwidth_hook	Hook for plugins to get control in get_attavgwidth()
selfuncs.h	get_relation_stats_hook	Hooks for plugins to get control when we ask for stats
	get_index_stats_hook	Hooks for plugins to get control when we ask for stats
objectaccess.h	object_access_hook	Plugin provides a hook function matching this signature
libpq-be.h	openssl_tls_init_hook	init hook for SSL, the default sets the password callback if appropriate
rowsecurity.h	row_security_policy_hook_permissions	hooks to allow extensions to add their own security policies, it is used to add policies which are combined with the other permissive policies, using OR.
ipc.h	shmem_startup_hook	hooks to allow extensions to set up their shmem allocations.
prep.h	It_judge_can_pull_up_hook	Hook for plugins to decide is or not to pull up sub query.
	It_judge_sublink_can_pull_up_hook	Hook for plugins to decide is or not to pull up sublink.

---

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