

PL/pgSQL Overview and Programming Structures

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PL/pgSQL history

Block structure and declaration of variables

Anonymous blocks

Routines in PL/pgSQL

Conditional operators and loops

Expression computing

PL/pgSQL history



Introduced in PostgreSQL 6.4 in 1998

comes out of the box since PostgreSQL 9.0

Objectives

- create a simple language for custom functions and triggers

- add control structures to the SQL language

- keep the ability to use any custom types, functions, and operators

Inspired by: Oracle PL/SQL, Ada

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PL/pgSQL is one of the first procedural languages for PostgreSQL. It first appeared in 1998 in PostgreSQL 6.4, and since 9.0, it has been installed by default when a database is created.

PL/pgSQL extends the SQL functionality, providing variables and cursors, conditional operators, loops, error handling, and other features commonly seen in procedural languages.

PL/pgSQL is based on the Oracle PL/SQL language, which, in turn, is derived from a subset of the Ada language, with its roots going back to Algol and Pascal. Most of the modern programming languages belong to another branch of the C-like languages, that's why PL/pgSQL can at first seem unconventional and excessively verbose (its distinctive feature is using BEGIN and END keywords instead of curly brackets). However, this syntax goes perfectly with the SQL syntax.

<https://postgrespro.com/docs/postgresql/17/plpgsql-overview>

Block structure



Block label

Declaration of variables

the lifetime of a variable is limited to a block

the visibility scope can be overridden by a nested block, but a variable can still be referenced by a block label

any SQL types and references to object types (%TYPE) are allowed

Operators

control structures

SQL operators, except for the service ones

nested blocks

Exception handling

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PL/pgSQL operators are organized into blocks. A block structure comprises several components:

- An optional label that can be used to eliminate naming ambiguities.
- An optional section for *declaration* of local variables and cursors. Any types defined in SQL are allowed. You can also use the %TYPE construct to refer to the type of a table column or other object.
- The main execution section that contains *operators*.
- An optional section for handling *exceptions*.

You can use both PL/pgSQL commands and most of SQL commands as operators, so the two languages are integrated almost seamlessly. Exceptions are SQL service commands, such as VACUUM, which are not allowed, and transaction control commands, such as COMMIT and ROLLBACK, which are allowed only in procedures.

Another (nested) PL/pgSQL block can also be used as an operator.

<https://postgrespro.com/docs/postgresql/17/plpgsql-structure>

<https://postgrespro.com/docs/postgresql/17/plpgsql-declarations#PLPGSQL-DECLARATION-TYPE>

Anonymous blocks



Ad-hoc execution of procedures

- without creating a stored routine
- with no parameters
- with no return values

The DO operator in the SQL language

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You can use PL/pgSQL without creating routines. The PL/pgSQL code can be written as an anonymous block and executed using the SQL's DO command.

This command can be used with various server languages, but if you do not specify the language explicitly, it will be assumed that PL/pgSQL is used.

The code of anonymous blocks is not saved on the server. Anonymous blocks do not take arguments or return any values (but there are ways to circumvent that: for example, by using tables).

<https://postgrespro.com/docs/postgresql/16/sql-do>

Anonymous blocks

A general structure of a PL/pgSQL block:

```
<<label>>
DECLARE
    -- declaration of variables
BEGIN
    -- operators
EXCEPTION
    -- error handling
END label;
```

- All sections except for the operators' section are optional.

The smallest block of PL/pgSQL code:

```
=> DO $$
BEGIN
    -- there can be no operators
END
$$;

DO
```

One of the implementations of “Hello, World!”:

```
=> DO $$
DECLARE
    -- This is a one-line comment.
    /* This is a multi-line comment.
       Each declaration is ended by a semicolon ';'.
       A semicolon is also placed after each operator.
    */
    foo text;
    bar text := 'World'; -- you can also use = or DEFAULT
BEGIN
    foo := 'Hello'; -- this is an assignment operation
    RAISE NOTICE '%, %!', foo, bar; -- message output
END
$$;

NOTICE: Hello, World!
DO
```

- There must be no semicolon after BEGIN!

Variables can have modifiers:

- CONSTANT — once a variable is initialized, its value must not change;
- NOT NULL — undefined values are not allowed.

```
=> DO $$
DECLARE
    foo integer NOT NULL := 0;
    bar CONSTANT text := 42;
BEGIN
    bar := bar + 1; -- error
END
$$;
```

```
ERROR: variable "bar" is declared CONSTANT
LINE 6:     bar := bar + 1; -- error
      ^
```

Here is an example of nested blocks. A variable in the inner block overrides the one declared in the outer block, but you can refer to any of them using labels:

```
=> DO $$  
<<outer_block>>  
DECLARE  
    foo text := 'Hello';  
BEGIN  
    <<inner_block>>  
    DECLARE  
        foo text := 'World';  
    BEGIN  
        RAISE NOTICE '%, %!', outer_block.foo, inner_block.foo;  
        RAISE NOTICE 'An inner variable, without a label: %', foo;  
    END inner_block;  
END outer_block  
$$;
```

NOTICE: Hello, World!

NOTICE: An inner variable, without a label: World

DO



A routine header is language-agnostic

name, input and output parameters

for functions: the return value and volatility category

Definition: `LANGUAGE plpgsql`

Returning values

the `RETURN` operator

assigning values to output parameters (`INOUT`, `OUT`)

We have already learned about stored functions and procedures, using the SQL language as an example. Most of the information related to creation and management of routines applies to PL/pgSQL routines as well:

- creating, modifying, and deleting routines,
- location in the system catalog (`pg_proc`),
- parameters,
- return value and volatility categories (for functions),
- overloading and polymorphism,
- etc.

While SQL routines return a value produced by the last SQL operator, PL/pgSQL routines either have to assign return values to `INOUT` or `OUT` parameters, or use a special `RETURN` operator (which is available for functions).

PL/pgSQL routines

Here is an example of a function that returns a value using the RETURN operator:

```
=> CREATE FUNCTION sqr_in(IN a numeric) RETURNS numeric
AS $$
BEGIN
    RETURN a * a;
END
$$ LANGUAGE plpgsql IMMUTABLE;

CREATE FUNCTION
```

Now let's take a look at the same function with the OUT parameter. The return value is assigned to this parameter:

```
=> CREATE FUNCTION sqr_out(IN a numeric, OUT retval numeric)
AS $$
BEGIN
    retval := a * a;
END
$$ LANGUAGE plpgsql IMMUTABLE;

CREATE FUNCTION
```

Here is the same function with the INOUT parameter. This parameter is used for both providing input values and returning the function value:

```
=> CREATE FUNCTION sqr_inout(INOUT a numeric)
AS $$
BEGIN
    a := a * a;
END
$$ LANGUAGE plpgsql IMMUTABLE;

CREATE FUNCTION
```

```
=> SELECT sqr_in(3), sqr_out(3), sqr_inout(3);
```

sqr_in	sqr_out	sqr_inout
9	9	9

(1 row)

Conditional operators



IF

a regular conditional operator

CASE

similar to CASE in the SQL language, but does not return a value

Note: three-valued logic!

the condition must be true; false and NULL are ignored

PL/pgSQL provides two conditional operators: IF and CASE.

The first one is the bread and butter operator available in all languages.

The CASE operator is similar to the SQL one, but does not return a value. It is not unlike the `switch` operator in C or Java.

Remember that boolean expressions in SQL (and, consequently, in PL/pgSQL) can take three values: *true*, *false*, and *NULL*. A condition is triggered only when it is *true*, and is not triggered when it is *false* or undefined. This is equally applicable to both WHERE conditions in SQL and conditional operators in PL/pgSQL.

<https://postgrespro.com/docs/postgresql/17/plpgsql-control-structures#PLPGSQL-CONDITIONALS>

Conditional operators

A generic form of the IF operator:

```
IF condition THEN
  -- operators
ELSIF condition THEN
  -- operators
ELSE
  -- operators
END IF;
```

- The ELSIF section can be used several times, or there can be no such section at all.
- There can be no ELSE section.
- The operators corresponding to the first true condition will be executed.
- If none of the conditions is true, the operators of the ELSE section are executed (if available).

Consider an example of a function that uses a conditional operator for decoding an ISBN-10 number. The function returns three values:

```
=> CREATE FUNCTION decode_isbn(
  IN isbn text,
  OUT country text,
  OUT publisher_and_book text,
  OUT check_digit integer
) AS $$
DECLARE
  country_len integer;
BEGIN
  IF left(isbn,1)::integer IN (0,1,2,3,4,5,7) THEN
    country_len := 1;
  ELSIF left(isbn,2)::integer BETWEEN 80 AND 94 THEN
    country_len := 2;
  ELSIF left(isbn,3)::integer BETWEEN 600 AND 649 THEN
    country_len := 3;
  ELSIF left(isbn,3)::integer BETWEEN 950 AND 993 THEN
    country_len := 3;
  ELSIF left(isbn,4)::integer BETWEEN 9940 AND 9989 THEN
    country_len := 4;
  ELSE
    country_len := 5;
  END IF;
  country := left(isbn, country_len);
  publisher_and_book := substr(isbn, country_len+1, 12);
  check_digit := right(isbn, 1);
END
$$ LANGUAGE plpgsql IMMUTABLE;
```

CREATE FUNCTION

```
=> SELECT * FROM decode_isbn('1484268849');
```

country	publisher_and_book	check_digit
1	484268849	9

(1 row)

```
=> SELECT * FROM decode_isbn('8845210669');
```

country	publisher_and_book	check_digit
88	45210669	9

(1 row)

A generic form of the CASE operator (by condition):

```
CASE
  WHEN condition THEN
    -- operators
  ELSE
    -- operators
END CASE;
```

- There can be several WHEN sections.
- There can be no ELSE section.
- The operators corresponding to the first true condition will be executed.
- If none of the conditions is true, ELSE operators are executed (it is an error to have no ELSE in this case).

Usage example:

```
=> DO $$
DECLARE
    country text := (decode_isbn('1484268849')).country;
BEGIN
    CASE
        WHEN country IN ('0','1') THEN
            RAISE NOTICE '% - English-speaking area', country;
        WHEN country = '7' THEN
            RAISE NOTICE '% - Russia', country;
        WHEN country = '88' THEN
            RAISE NOTICE '% - Italy', country;
        ELSE
            RAISE NOTICE '% - Other', country;
    END CASE;
END
$$;

NOTICE:  1 - English-speaking area
DO
```

A generic form of the CASE operator (by expression):

```
CASE expression
    WHEN value, ... THEN
        -- operators
    ELSE
        -- operators
END CASE;
```

- There can be several WHEN sections.
- There can be no ELSE section.
- The operators corresponding to the first true condition “expression = value” will be executed.
- If none of the conditions is true, ELSE operators are executed (it is an error to have no ELSE in this case).

If conditions are similar, this form of the CASE operator can turn out to be shorter:

```
=> DO $$
DECLARE
    country text := (decode_isbn('8845210669')).country;
BEGIN
    CASE country
        WHEN '0', '1' THEN
            RAISE NOTICE '% - English-speaking area', country;
        WHEN '7' THEN
            RAISE NOTICE '% - Russia', country;
        WHEN '88' THEN
            RAISE NOTICE '% - Italy', country;
        ELSE
            RAISE NOTICE '% - Other', country;
    END CASE;
END
$$;

NOTICE:  88 - Italy
DO
```

Loops



A FOR loop over a range of integers

A WHILE loop with a precondition

An infinite loop

A loop can have its own label, just like any block

Loop controls

exit a loop (EXIT)

initiate a new iteration (CONTINUE)

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For repeated execution of a set of operators, PL/pgSQL offers several types of loops:

- a FOR loop over a range of integers,
- a WHILE loop with a precondition,
- an infinite loop.

A loop is a type of a block; it can have its own label. You can additionally control loop execution by initiating a new iteration or exiting the loop.

<https://postgrespro.com/docs/postgresql/17/plpgsql-control-structures#PLPGSQL-CONTROL-STRUCTURES-LOOPS>

In addition to working with integer ranges, FOR loops can iterate through query results and arrays. Such FOR loops will be discussed later on.

Loops

In PL/pgSQL, all loops have the same structure:

```
LOOP
    -- operators
END LOOP;
```

It can be extended by a header that defines the exit condition for the loop.

A FOR loop over a range is executed while the loop counter goes over the values from bottom to top. Each iteration increases the counter by 1 (but the increment can be changed in the optional BY clause).

```
FOR name IN bottom .. top BY increment
LOOP
    -- operators
END LOOP;
```

- The variable used as a counter is declared implicitly and exists only within the LOOP — END LOOP block.
-

If REVERSE is specified, the counter value is reduced with each iteration, and the top and bottom of the loop have to be swapped:

```
FOR name IN REVERSE top .. bottom BY increment
LOOP
    -- operators
END LOOP;
```

An example of using a FOR loop is a function that reverses a string:

```
=> CREATE FUNCTION reverse_for (line text) RETURNS text
AS $$
DECLARE
    line_length CONSTANT int := length(line);
    retval text := '';
BEGIN
    FOR i IN 1 .. line_length
    LOOP
        retval := substr(line, i, 1) || retval;
    END LOOP;
    RETURN retval;
END
$$ LANGUAGE plpgsql IMMUTABLE STRICT;
```

CREATE FUNCTION

As you might remember, a STRICT function returns NULL right away if at least one of the input parameters is undefined. The function body is not executed in this case.

A WHILE loop is executed while the condition is true:

```
WHILE condition
LOOP
    -- operators
END LOOP;
```

Here is the same function that reverses a string using a WHILE loop:

```
=> CREATE FUNCTION reverse_while (line text) RETURNS text
AS $$
DECLARE
    line_length CONSTANT int := length(line);
    i int := 1;
    retval text := '';
BEGIN
    WHILE i <= line_length
    LOOP
        retval := substr(line, i, 1) || retval;
        i := i + 1;
    END LOOP;
    RETURN retval;
END
$$ LANGUAGE plpgsql IMMUTABLE STRICT;
```

CREATE FUNCTION

A LOOP without a header runs infinitely. To terminate it, use the EXIT operator.

EXIT label **WHEN** condition;

- The label is optional; if it is not specified, the innermost loop will be terminated.
 - The WHEN condition is also optional; if it is not specified, the loop is exited unconditionally.
-

LOOP usage example:

```
=> CREATE FUNCTION reverse_loop (line text) RETURNS text
AS $$
DECLARE
    line_length CONSTANT int := length(reverse_loop.line);
    i int := 1;
    retval text := '';
BEGIN
    <<main_loop>>
    LOOP
        EXIT main_loop WHEN i > line_length;
        retval := substr(reverse_loop.line, i,1) || retval;
        i := i + 1;
    END LOOP;
    RETURN retval;
END
$$ LANGUAGE plpgsql IMMUTABLE STRICT;
```

CREATE FUNCTION

- The function body is placed into an implicit block, with the function name used as the block label. So you can access parameters using the “function_name.parameter” notation.
-

Let's make sure that all functions work correctly:

```
=> SELECT reverse_for('AMBULANCE') as "for",
         reverse_while('AMBULANCE') as "while",
         reverse_loop('AMBULANCE') as "loop";
```

for	while	loop
ECNALUBMA	ECNALUBMA	ECNALUBMA

(1 row)

Note: PostgreSQL has a built-in reverse function.

It is sometimes useful to apply the CONTINUE operator, which starts a new iteration of the loop:

```
=> DO $$
DECLARE
    s integer := 0;
BEGIN
    FOR i IN 1 .. 100
    LOOP
        s := s + i;
        CONTINUE WHEN mod(i, 10) != 0;
        RAISE NOTICE 'i = %, s = %', i, s;
    END LOOP;
END
$$;
```

```
NOTICE: i = 10, s = 55
NOTICE: i = 20, s = 210
NOTICE: i = 30, s = 465
NOTICE: i = 40, s = 820
NOTICE: i = 50, s = 1275
NOTICE: i = 60, s = 1830
NOTICE: i = 70, s = 2485
NOTICE: i = 80, s = 3240
NOTICE: i = 90, s = 4095
NOTICE: i = 100, s = 5050
DO
```

Expression computing



Any expression is computed in the context of SQL

- an expression is automatically converted into a query
- the query is prepared
- PL/pgSQL variables are substituted as parameters

Features

- you can use all SQL capabilities, including subqueries
- the execution speed is lower although the parsed query (and sometimes the query plan) is cached
- naming ambiguities are an issue

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All expressions in PL/pgSQL code are computed as SQL database queries. The interpreter builds the query by preparing a `SELECT <expr>` statement and puts parameters in place of PL/pgSQL variables. A prepared statement is parsed once, and its parse tree is cached. When the statement is executed, specific values are bound to the parameters, and planning is redone (if PostgreSQL has the query plan cached, this step may be skipped).

While executing SQL queries impacts PL/pgSQL performance, it ensures close integration with SQL. In fact, expressions can leverage any SQL functionality without limitations, including calling built-in or custom functions, running subqueries, etc.

Starting with PostgreSQL 14, the execution of simple expressions (at least those that do not query any tables) has been optimized: such expressions are processed by the server's parser directly, without using the planner at all.

<https://postgrespro.com/docs/postgresql/17/plpgsql-expressions>

Computing expressions

Any PL/pgSQL expression is computed using the SQL engine. Thus, PL/pgSQL provides exactly the same features as SQL. For example, since SQL allows using CASE, the same construct will also work in PL/pgSQL code (as an expression; it should not be confused with the CASE ... END CASE operator, which is available only in PL/pgSQL):

```
=> DO $$
BEGIN
    RAISE NOTICE '%', CASE 2+2 WHEN 4 THEN 'Everything is OK' END;
END
$$;

NOTICE: Everything is OK
DO
```

You can also use subqueries in expressions:

```
=> DO $$
BEGIN
    RAISE NOTICE '%', (
        SELECT code
        FROM (VALUES (1, 'One'), (2, 'Two')) t(id, code)
        WHERE id = 1
    );
END
$$;

NOTICE: One
DO
```

Another PL/pgSQL expression computation example: how many string reverse functions did we have in total?

```
=> DO $$
DECLARE
    s integer;
BEGIN
    s := count(*) FROM pg_proc WHERE proname LIKE 'reverse%';
    RAISE NOTICE 'Total "reverse" functions : %', s;
END
$$;

NOTICE: Total "reverse" functions : 4
DO
```

Takeaways



PL/pgSQL is an easy-to-use language that comes with the system by default, integrated with SQL

Managing routines in PL/pgSQL is similar to other languages

DO is an SQL command for executing anonymous blocks

PL/pgSQL variables can use any SQL types

PL/pgSQL supports regular control structures, such as conditional operators and loops

1. Modify the *book_name* function, so that the length of the return value does not exceed 47 characters.
If the book title gets truncated, it must be concluded with an ellipsis.
Check your implementation in SQL and in the application. Add more books with long titles if required.
2. Modify the *book_name* function again, so that an excessively long title gets cut off at the end of a full word.
Check the implementation.

1. For example:

Travels into Several Remote Nations of the World. In Four Parts.
By Lemuel Gulliver, First a Surgeon, and then a Captain of Several
Ships →

→ Travels into Several Remote Nations of the W...

Here are some cases that are worth checking for:

- The title length is less than 47 characters (should not change).
- The title length is exactly 47 characters (should not change).
- The title length is 48 characters (four characters have to be truncated because three dots will be added).

It is recommended to implement and debug a separate function for truncation, and then use it in *book_name*. It is useful for other reasons as well:

- It may come in handy somewhere else.
- Each function will perform exactly one task.

2. For example:

Travels into Several Remote Nations of the World. In Four Parts.
By Lemuel Gulliver, First a Surgeon, and then a Captain of Several
Ships →

→ Travels into Several Remote Nations of the...

Will your implementation work properly if the title consists of a single long word without spaces?

Task 1. Truncating book titles

Let's create a more general function that accepts the following parameters: the string to truncate, the maximum length, and the suffix to be used in case of truncation. It won't complicate the code and will allow us to do without magic numbers.

```
=> CREATE FUNCTION shorten(  
    s text,  
    max_len integer DEFAULT 47,  
    suffix text DEFAULT '...'  
)  
RETURNS text AS $$  
DECLARE  
    suffix_len integer := length(suffix);  
BEGIN  
    RETURN CASE WHEN length(s) > max_len  
        THEN left(s, max_len - suffix_len) || suffix  
        ELSE s  
    END;  
END  
$$ IMMUTABLE LANGUAGE plpgsql;
```

CREATE FUNCTION

Let's check the result:

```
=> SELECT shorten(  
    'Travels into Several Remote Nations of the World. In Four Parts. '  
'By Lemuel Gulliver, First a Surgeon, and then a Captain of Several Ships'  
);
```

```
              shorten  
-----  
Travels into Several Remote Nations of the W...  
(1 row)
```

```
=> SELECT shorten(  
    'Travels into Several Remote Nations of the World. In Four Parts. '  
'By Lemuel Gulliver, First a Surgeon, and then a Captain of Several Ships',  
    34  
);
```

```
              shorten  
-----  
Travels into Several Remote Nat...  
(1 row)
```

Let's use the created function:

```
=> CREATE OR REPLACE FUNCTION book_name(book_id integer, title text)  
RETURNS text  
STABLE LANGUAGE sql  
BEGIN ATOMIC  
SELECT shorten(book_name.title) ||  
    CASE WHEN (right(shorten(book_name.title), 3) != '...')  
        THEN '. '::text  
        ELSE ''  
    END ||  
    string_agg(  
        author_name(a.last_name, a.first_name, a.middle_name), ', '  
        ORDER BY ash.seq_num  
    )  
FROM authors a  
JOIN authorship ash ON a.author_id = ash.author_id  
WHERE ash.book_id = book_id;  
END;
```

CREATE FUNCTION

Task 2. Truncating book titles by full words

```

=> CREATE OR REPLACE FUNCTION shorten(
  s text,
  max_len integer DEFAULT 47,
  suffix text DEFAULT '...'
)
RETURNS text
AS $$
DECLARE
  suffix_len integer := length(suffix);
  short text := suffix;
BEGIN
  IF length(s) < max_len THEN
    RETURN s;
  END IF;
  FOR pos in 1 .. least(max_len-suffix_len+1, length(s))
  LOOP
    IF substr(s,pos-1,1) != ' ' AND substr(s,pos,1) = ' ' THEN
      short := left(s, pos-1) || suffix;
    END IF;
  END LOOP;
  RETURN short;
END
$$ IMMUTABLE LANGUAGE plpgsql;

```

CREATE FUNCTION

Let's check the result:

```

=> SELECT shorten(
  'Travels into Several Remote Nations of the World. In Four Parts. '
  'By Lemuel Gulliver, First a Surgeon, and then a Captain of Several Ships'
);

```

```

              shorten
-----
Travels into Several Remote Nations of the...
(1 row)

```

```

=> SELECT shorten(
  'Travels into Several Remote Nations of the World. In Four Parts. '
  'By Lemuel Gulliver, First a Surgeon, and then a Captain of Several Ships',
  34
);

```

```

              shorten
-----
Travels into Several Remote...
(1 row)

```