





DB2  
for Linux, UNIX, and Windows



Version 9 Release 7



**Developing User-defined Routines (SQL and External)**  
**Updated July, 2012**

**Note**

Before using this information and the product it supports, read the general information under Appendix B, "Notices," on page 333.

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## About this book

This book provides information concerning the development of user-defined routines when a system-defined routine that provides the required functionality is not available.

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## Who should use this book

This book is intended for database architects, database administrators, and application developers of all levels.

- Database architects interested in learning about how routine objects can be created and used to modularize SQL and related logic that can be reused in multiple contexts within the database architecture.
- Database administrators interested in learning how to create, manage, deploy, secure, troubleshoot, and improve system performance by using user-defined routines within a database management system.
- Application developers interested in learning how and when to encapsulate SQL statements and application logic into routines so as to improve application modularity and performance as well as the step by step method of designing, creating, and building user-defined routines. Application developers should have experience writing SQL statements and programming experience using one of the supported programming languages for routine development (C, C++, Java, COBOL, C#, Visual Basic, or another .NET CLR supported programming language).



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## Chapter 1. Developing Routines

Development of routines is often done when there is no system-defined routine available that provides the functionality that is required.

### Before you begin

- Read and understand basic routine concepts:
  - To learn about types of routines, useful applications of routines, tools for developing routines, routine best practices and more, see the topic:
    - Chapter 2, “Overview of routines,” on page 3
- Learn about the available routine development tools that make it faster and easier to develop routines:
  - To learn about the available tools for routine development, see the topic:
    - “Tools for developing routines” on page 35

### About this task

There are different functional types of routines and routine implementations, however the basic steps for developing routines are generally common for all routines. You must determine what type of routine to create, what implementation to use, define the interface for the routine, develop the routine logic, execute SQL to create the routine, test your routine, and then deploy it for general use.

Depending on what type of routine you choose to develop there are some specific procedures you must follow. This topic will direct you to the appropriate topics for getting started with routine development.

### Procedure

1. Determine if an existing system-defined routine already meets your routine needs.
  - If a system-defined routine meets your needs, you might want to refer to Chapter 10, “Invoking routines,” on page 295.
2. Determine what functional type of routine to develop.
3. Determine what routine implementation to use.
  - If a SQL routine is required, refer to the information about SQL routines (SQL PL).
  - If an external routine is required, refer to the information about External routines.

### What to do next

The development of SQL and external routines is similar, but there are differences. For both types of routines, you must first design your logic, and then to create the routine in the database you must execute a routine functional type specific CREATE statement. These routine creation statements include CREATE PROCEDURE, CREATE FUNCTION, and CREATE METHOD. The clauses specific to each of the CREATE statements define characteristics of the routine, including the routine name, the number and type of routine parameters, and details about the routine logic. DB2<sup>®</sup> uses the information provided by the clauses to identify and run the routine when it is invoked. Upon successful execution of the CREATE

statement for a routine, the routine is created in the database. The characteristics of the routine are stored in DB2's system catalog tables that users can query. Executing the CREATE statement to create a routine is also referred to as defining a routine or registering a routine.

Because external routines have their logic implemented in user-created libraries or classes located in the database file system, additional steps are required to program the logic, build it, and properly locate the resulting library or class file.

Once you have developed routines, you might want to:

- Debug routines
- Deploy routines to production environments
- Grant privileges to execute routines to users
- Invoke routines
- Tune the performance of routines

---

## Routines

Routines are database objects that can encapsulate programming and database logic that can be invoked like a programming sub-routine from a variety of SQL interfaces. Routines can be system-defined, which means that they are provided with the product, or user-defined, which means that users can create them. Routines can be implemented using SQL statements, a programming language, or a mix of both. Different types of routines provide different interfaces that can be used to extend the functionality of SQL statements, client applications, and some database objects.

For a complete view of the types of routines and implementations that are supported by DB2, refer to the topic: "Types of routines" on page 4.

The many features of routines are part of why there are so many useful applications of routines.

---

## Chapter 2. Overview of routines

Routines are a type of database object that you can use to encapsulate logic that can be invoked like a programming subroutine. There are many useful applications of routines within a database or database application architecture. You can use routines to improve overall database design, database performance, and data security, as well as to implement basic auditing mechanisms, and more.

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### Benefits of using routines

The following benefits can be gained by using routines:

#### **Encapsulate application logic that can be invoked from an SQL interface**

In an environment containing many different client applications that have common requirements, the effective use of routines can simplify code reuse, code standardization, and code maintenance. If a particular aspect of common application behavior needs to be changed in an environment where routines are used, only the affected routine that encapsulates the behavior requires modification. Without routines, application logic changes are required in each application.

#### **Enable controlled access to other database objects**

Routines can be used to control access to database objects. A user might not have permission to generally issue a particular SQL statement, such as CREATE TABLE; however the user can be given permission to invoke routines that contain one or more specific implementations of the statement, thus simplifying privilege management through encapsulation of privileges.

#### **Improve application performance by reducing network traffic**

When applications run on a client computer, each SQL statement is sent separately from the client computer to the database server computer to be executed and each result set is returned separately. This can result in high levels of network traffic. If a piece of work can be identified that requires extensive database interaction and little user interaction, it makes sense to install this piece of work on the server to minimize the quantity of network traffic and to allow the work to be done on the more powerful database servers.

#### **Allow for faster, more efficient SQL execution**

Because routines are database objects, they are more efficient at transmitting SQL requests and data than client applications. Therefore, SQL statements executed within routines can perform better than if executed in client applications. Routines that are created with the NOT FENCED clause run in the same process as the database manager, and can therefore use shared memory for communication, which can result in improved application performance.

#### **Allow the interoperability of logic implemented in different programming languages**

Because code modules might be implemented by different programmers in different programming languages, and because it is generally desirable to reuse code when possible, DB2 routines support a high degree of interoperability.

- Client applications in one programming language can invoke routines that are implemented in a different programming language. For example C client applications can invoke .NET common language runtime routines.
- Routines can invoke other routines regardless of the routine type or routine implementation. For example a Java procedure can invoke an embedded SQL scalar function.
- Routines created in a database server on one operating system can be invoked from a DB2 client running on a different operating system.

The benefits described above are just some of the many benefits of using routines. Using routines can be beneficial to a variety of users including database administrators, database architects, and database application developers. For this reason there are many useful applications of routines that you might want to explore.

There are various kinds of routines that address particular functional needs and various routine implementations. The choice of routine type and implementation can impact the degree to which the above benefits are exhibited. In general, routines are a powerful way of encapsulating logic so that you can extend your SQL, and improve the structure, maintenance, and potentially the performance of your applications.

---

## Types of routines

There are many different types of routines. Routines can be grouped in different ways, but are primarily grouped by their system or user definitions, by their functionality, and by their implementation.

The supported routine definitions are:

- “System-defined routines” on page 6
- “User-defined routines” on page 7

The supported functional types of routines are:

- “Routines: Procedures” on page 10 (also called stored procedures)
- “Routines: Functions” on page 11
- “Routines: Methods” on page 15

The supported routine implementations are:

- “Built-in routine implementation” on page 20
- “Sourced routine implementation” on page 20
- “SQL routine implementation” on page 21
- “External routine implementation” on page 21

The following diagram illustrates the classification hierarchy of routines. All routines can be either system-defined or user-defined. The functional types of routines are in dark grey/blue boxes and the supported routine implementations are in light grey/orange boxes. Built-in routine implementations are emphasized, because this type of implementation is unique.

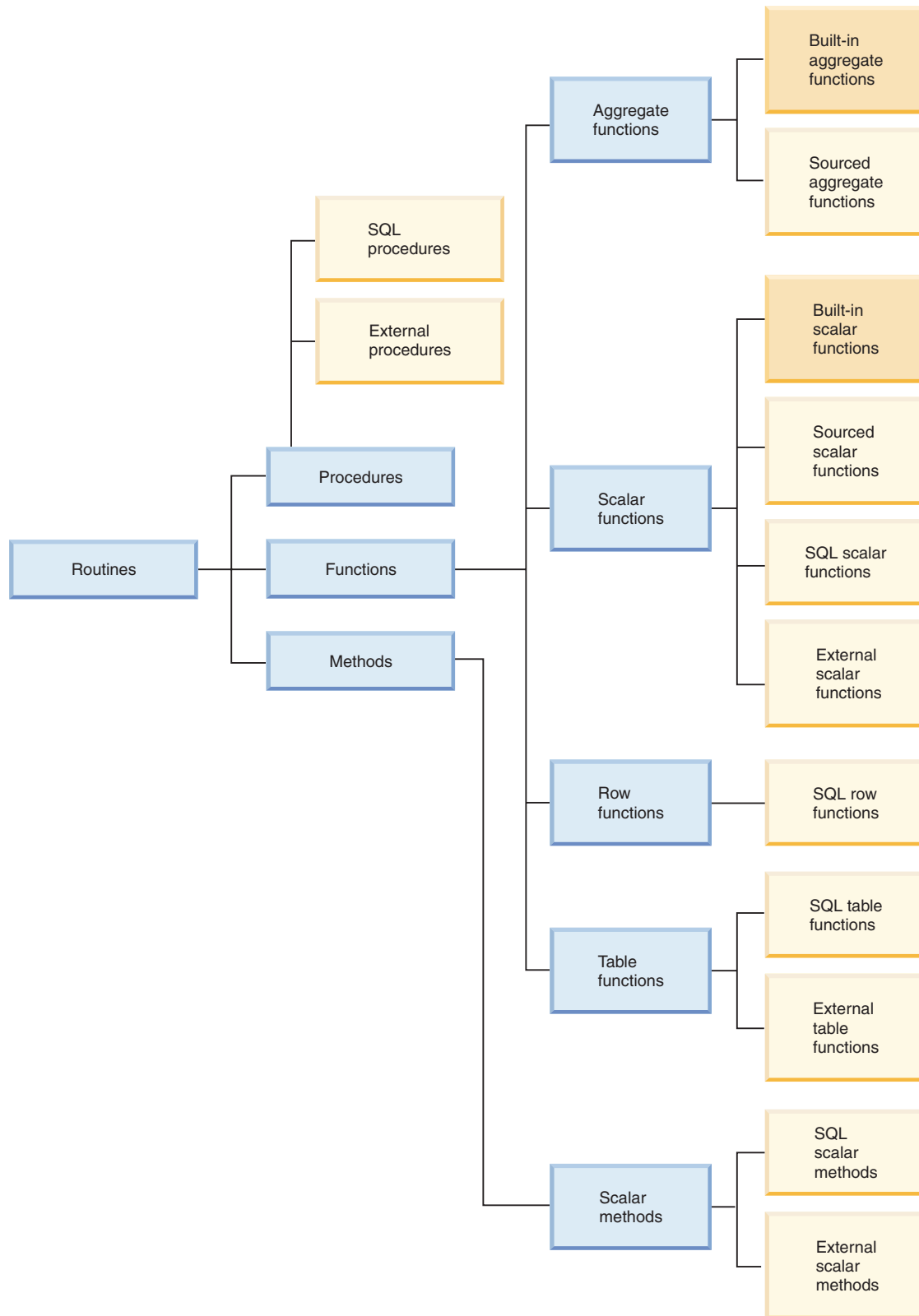


Figure 1. Classifications of routines

The various types of routines provide extensive support for extending SQL language functionality and for developing more modular database applications.

## System-defined and user-defined routines

One of the most straight-forward ways of categorizing routines is to divide them into system-defined routines “System-defined routines” and user-defined routines “User-defined routines” on page 7.

System-defined routines are routines that are provided with the product. These routines provide a wide variety of support for tasks ranging from administrative functions to database system and catalog reporting. They are immediately ready-to-use and require no prerequisite setup or registration steps, although users require the necessary privileges to invoke these routines.

User-defined routines are routines that users create themselves. User-defined routines provide a means for users to extend the SQL language beyond the support which is currently available. User-defined routines can be implemented in a variety of ways which include sourcing (re-using the logic of) built-in routines, using SQL statements only, or using SQL with another programming language.

### System-defined routines

System-defined routines are routines that are provided with the product. These routines provide a wide variety of routine support for tasks ranging from administrative functions to database system and catalog reporting.

They are characterized by the fact that they are immediately ready-to-use, require no prerequisite setup or routine registration steps, although users require privileges to invoke these routines. These can include built-in and system-defined routines, previously called SQL Administrative Routines.

Built-in system-defined routines provide standard operator support and basic scalar function and aggregate function support. Built-in routines are the first choice of routine that you should use because they are strongly typed and will provide the best performance. Do not create external routines that duplicate the behavior of built-in routines. External routines cannot perform as well or be as secure as built-in routines.

Other system-defined routines that you can use are provided with DB2 in the SYSPROC, SYSFUN, and SYSTOOLS schemas. These routines are essentially SQL and external routines that are defined by the system and provided with the product. Although these additional routines are shipped with DB2, they are not built-in routines. Instead they are implemented as pre-installed user-defined routines. These routines typically encapsulate a utility function. Some examples of these include: *SNAP\_GET\_TAB\_V91*, *HEALTH\_DB\_HI*, *SNAP\_WRITE\_FILE*, and *REBIND\_ROUTINE\_PACKAGE*. You can immediately use these functions and procedures, provided that you have the SYSPROC schema and SYSFUN schema in your CURRENT PATH special register. It is a good idea to peruse the set of DB2 provided system-defined routines if you are considering implementing an external routine that performs administrative functionality.

Of particular interest, you might find the *ADMIN\_CMD* procedure useful as it provides a standard interface for executing many popular DB2 commands through an SQL interface.

System-defined routines make it faster and easier for you to implement complex SQL queries and powerful database applications because they are ready-to-use.



## User-defined routines

DB2 provides routines that capture the functionality of most commonly used arithmetic, string, and casting functions. However, DB2 also allows you to create routines to encapsulate logic of your own. These routines are called user-defined routines.

You can create your own procedures, functions and methods in any of the supported implementation styles for the routine type. Refer to “Routines: Procedures” on page 10, “Routines: Functions” on page 11, and “Routines: Methods” on page 15. Generally the prefix 'user-defined' is not used when referring to procedures and methods. User-defined functions are also commonly called UDFs.

## User-defined routine creation

User-defined procedures, functions and methods are created in the database by executing the appropriate CREATE statement for the routine type. These routine creation statements include:

- “CREATE PROCEDURE statement” in the *SQL Reference*
- “CREATE FUNCTION statement” in the *SQL Reference*
- “CREATE METHOD statement” in the *SQL Reference*

The clauses specific to each of the CREATE statements define characteristics of the routine, such as the routine name, the number and type of routine arguments, and details about the routine logic. DB2 uses the information provided by the clauses to identify and run the routine when it is invoked. Upon successful execution of the CREATE statement for a routine, the routine is created in the database. The characteristics of the routine are stored in the DB2 catalog views that users can query. Executing the CREATE statement to create a routine is also referred to as defining a routine or registering a routine.

User-defined routine definitions are stored in the SYSTOOLS system catalog table schema.

## User-defined routine logic implementation

There are three implementation styles that can be used to specify the logic of a routine:

- “Sourced routine implementation” on page 20: user-defined routines can be *sourced* from the logic of existing built-in routines.
- “SQL routine implementation” on page 21: user-defined routines can be implemented using only SQL statements.
- “External routine implementation” on page 21: user-defined routines can be implemented using one of a set of supported programming languages.

When routines are created in a non-SQL programming language, the library or class built from the code is associated with the routine definition by the value specified in the EXTERNAL NAME clause. When the routine is invoked the library or class associated with the routine is run.

User-defined routines can include a variety of SQL statements, but not all SQL statements.

User-defined routines are strongly typed, but type handling and error-handling mechanisms must be developed or enhanced by routine developers.

After a database upgrade, it may be necessary to verify or update routine implementations.

In general, user-defined routines perform well, but not as well as system-defined routines.

User-defined routines can invoke system-defined routines and other user-defined routines implemented in any of the supported formats. This flexibility allows users to essentially have the freedom to build a complete library of routine modules that can be re-used.

In general, user-defined routines provide a means for extending the SQL language and for modularizing logic that will be re-used by multiple queries or database applications where system-defined routines do not exist.

### Comparison of system-defined and user-defined routines

Understanding the differences between system-defined and user-defined routines can help you determine whether you actually need to build your own routines or whether you can re-use existing routines. The ability to determine when to re-use existing routines and when to develop your own routines can save you time and effort as well as ensure that you are maximizing routine performance.

System-defined routines and user-defined routines differ in a variety of ways. These differences are summarized in the following table:

*Table 1. Comparison of system-defined and user-defined routines*

Characteristic	System-defined routines	User-defined routines
Feature support	Extensive numerical operator, string manipulation, and administrative functionality available for immediate use.  To use these routines, simply invoke the routines from supported interfaces.	Although not all SQL statements are supported within user-defined routines, a great many are supported. You can also wrap calls to system-defined routines within user-defined routines if you want to extend the functionality of the system-defined routines. User-defined routines provide a limitless opportunity for routine logic implementation.  To use these routines, you must first develop them and then you can invoke them from supported interfaces.
Maintenance	No maintenance is required.	External routines require that you manage the associated external routine libraries.
Upgrade	No or little upgrade impact.	Release to release upgrades might require you to verify your routines.
Performance	Perform better than equivalent user-defined routines.	Generally do not perform as well as equivalent system-defined routines.
Stability	Error handling.	Error handling must be programmed by the routine developer.

Whenever it is possible to do so, you should choose to use the system-defined routines. These are provided to facilitate SQL statement formulation and

application development and are optimized to perform well. User-defined routines give you the flexibility to build your own routines where no system-defined routine performs the specific business logic that you want to implement.

## **Determining when to use system-defined or user-defined routines**

### **About this task**

“System-defined routines” on page 6 provide you with time-saving ready-to-use encapsulated functionality whereas “User-defined routines” on page 7 provide you with the flexibility to define your own routines when no system-defined routine adequately contains the functionality that you require.

To determine whether to use a system-defined or user-defined routine, do the following:

### **Procedure**

1. Determine what functionality you want the routine to encapsulate.
2. Check the list of available system-defined routines to see if there are any that meet some or all of your requirements.
  - If there is a system-defined routine that meets some, but not all of your requirements:
    - Determine if the functionality that is missing, is functionality that you can add simply to your application? If so, use the system-defined routine and modify your application to cover the missing functionality. If the missing functionality is not easily added to your application or if the missing functionality would have to be repeated in many places consider creating a user-defined routine that contains the missing functionality and that invokes the system-defined routine.
    - If you expect that your routine requirements will evolve and that you might have to frequently modify the routine definition, consider using a user-defined routine rather than the system-defined routine.
    - Determine if there are additional parameters that you might want to pass into or out of the routine. If there are, consider creating a user-defined routine that encapsulates an invocation to the system-defined routine.
  - If no system-defined routine adequately captures the functionality that you want to encapsulate, create a user-defined routine.

### **Results**

To save time and effort, whenever possible consider using system-defined routines. There will be times when the functionality that you require will not be available within a system-defined routine. For these cases you must create a user-defined routine. Other times it might be possible to include a call to system-defined routine from a user-defined routine that covers the extra functionality that you require.

## **Functional types of routines**

There are different functional types of routines. Each functional type provides support for invoking routines from different interfaces for different purposes. Each functional type of routine provides a different set of features and SQL support.

- Procedures, also called stored procedures, serve as sub-routine extensions to client applications, routines, triggers, and dynamic compound statements. Procedures are invoked by executing the CALL statement with a reference to a

procedure. Procedures can have input, output, and input-output parameters, can execute a wide variety of SQL statements, and return multiple result sets to the caller.

- Functions are relationships between sets of input data values and a set of result values. Functions enable you to extend and customize SQL. Functions are invoked from within elements of SQL statements such as a select-list, expression, or a FROM clause. There are four types of functions: aggregate functions, scalar functions, row functions, and table functions.
- Methods allow you to access user-defined type attributes as well as to define additional behaviors for user-defined types. A structured type is a user-defined data type containing one or more named attributes, each of which has a data type. Attributes are properties that describe an instance of a type. A geometric shape, for example, might have attributes such as its list of Cartesian coordinates. A method is generally implemented for a structured type as an operation on the attributes of the structured type. For a geometric shape a method might calculate the volume of the shape.

For specific details on each of the functional routine types refer to the topics for each routine type.

### **Routines: Procedures**

Procedures, also called stored procedures, are database objects created by executing the CREATE PROCEDURE statement. Procedures can encapsulate logic and SQL statement and can serve as sub-routine extensions to client applications, routines, triggers, and dynamic compound statements.

Procedures are invoked by executing the CALL statement with a reference to a procedure. Procedures can take input, output, and input-output parameters, execute a wide variety of SQL statements, and return multiple result sets to the caller.

#### **Features**

- Enable the encapsulation of logic elements and SQL statements that formulate a particular subroutine module
- Can be called from client applications, other routines, triggers, and dynamic compound statements - from anywhere that the CALL statement can be executed.
- Return multiple result-sets
- Support the execution of a large set of SQL statements including SQL statements that read or modify table data in both single and multiple partition databases
- Parameter support for input, output, and input-output parameters
- Nested procedure calls and function invocations are supported
- Recursive calls to procedures are supported
- Savepoints and transaction control are supported within procedures

#### **Limitations**

- Procedures cannot be invoked from within SQL statements other than the CALL statement. As an alternative, functions can be used to express logic that transforms column values.
- Output parameter values and result sets of procedure calls cannot be directly used by another SQL statement. Application logic must be used to assign these to variables that can be used in subsequent SQL statements.

- Procedures cannot preserve state between invocations.
  - Refer to the topic "Restrictions on procedures"

### Common uses

- Standardization of application logic
  - If multiple applications must similarly access or modify the database, a procedure can provide a single interface for the logic. The procedure is then available for re-use. Should the interface need to change to accommodate a change in business logic, only the single procedure must be modified.
- Isolation of database operations from non-database logic within applications
  - Procedures facilitate the implementation of sub-routines that encapsulate the logic and database accesses associated with a particular task that can be reused in multiple instances. For example, an employee management application can encapsulate the database operations specific to the task of hiring an employee. Such a procedure might insert employee information into multiple tables, calculate the employee's weekly pay based on an input parameter, and return the weekly pay value as an output parameter. Another procedure could do statistical analysis of data in a table and return result sets that contain the results of the analysis.
- Simplification of the management of privileges for a group of SQL statements
  - By allowing a grouping of multiple SQL statements to be encapsulated into one named database object, procedures allow database administrators to manage fewer privileges. Instead of having to grant the privileges required to execute each of the SQL statements in the routine, they must only manage the privilege to invoke the routine.

### Supported implementations

- There are system-defined procedures that are ready-to-use, or users can create user-defined procedures. The following user-defined implementations are supported for procedures:
  - SQL implementation
  - External implementation
    - Refer to the topic, "Supported external routine implementation programming languages".

### Routines: Functions

Functions are relationships between sets of input data values and a set of result values. They enable you to extend and customize SQL. Functions are invoked from within elements of SQL statements such as a select-list or a FROM clause.

There are four types of functions:

- "Aggregate functions" in *SQL Reference, Volume 1*
- Scalar functions
- Row functions
- Table functions

### Aggregate functions

Also called a column function, this type of function returns a scalar value that is the result of an evaluation over a set of like input values. The

similar input values can, for example, be specified by a column within a table, or by tuples in a VALUES clause. This set of values is called the argument set. For example, the following query finds the total quantity of bolts that are in stock or on order by using the SUM aggregate function:

```
SELECT SUM (qinstock + qonorder)
FROM inventory
WHERE description LIKE '%Bolt%'
```

### Scalar functions

A scalar function is a function that, for each set of one or more scalar parameters, returns a single scalar value. Examples of scalar functions include the LENGTH function, and the SUBSTR function. Scalar functions can also be created that do complex mathematical calculations on function input parameters. Scalar functions can be referenced anywhere that an expression is valid within an SQL statement, such as in a select-list, or in a FROM clause. The following example shows a query that references the built-in LENGTH scalar function:

```
SELECT lastname, LENGTH(lastname)
FROM employee
```

### Row functions

A row function is a function that for each set of one or more scalar parameters returns a single row. Row functions can only be used as a transform function mapping attributes of a structured type into built-in data type values in a row.

### Table functions

Table functions are functions that for a group of sets of one or more parameters, return a table to the SQL statement that references it. Table functions can only be referenced in the FROM clause of a SELECT statement. The table that is returned by a table function can participate in joins, grouping operations, set operations such as UNION, and any operation that could be applied to a read-only view. The following example demonstrates an SQL table function that updates an inventory table and returns the result set of a query on the updated inventory table:

```
CREATE FUNCTION updateInv(itemNo VARCHAR(20), amount INTEGER)
  RETURNS TABLE (productName VARCHAR(20),
                 quantity INTEGER)
LANGUAGE SQL
MODIFIES SQL DATA
BEGIN ATOMIC

  UPDATE Inventory as I
  SET quantity = quantity + amount
  WHERE I.itemID = itemNo;

  RETURN
  SELECT I.itemName, I.quantity
  FROM Inventory as I
  WHERE I.itemID = itemNo;
END
```

Functions provide support for the following features:

- Functions are supported across the DB2 brand database products including, among others, DB2, DB2 for z/OS<sup>®</sup>, and DB2 Database for System i<sup>®</sup>
- Moderate support for SQL statement execution
- Parameter support for input parameters and scalar or aggregate function return values
- Efficient compilation of function logic into queries that reference functions

- External functions provide support for storing intermediate values between the individual function sub-invocations for each row or value

There are system-defined functions that are ready-to-use, or users can create user-defined functions. Functions can be implemented as SQL functions or as external functions. SQL functions can be either compiled or inlined. Inlined functions perform faster than compiled functions, but can execute only a subset of the SQL PL language. See the CREATE FUNCTION statement for more information.

### **Routines: Scalar functions:**

A scalar function is a function that, for each set of one or more scalar parameters, returns a single scalar value. Examples of scalar functions include the LENGTH function, and the SUBSTR function.

Scalar functions can also be created that do complex mathematical calculations on function input parameters. Scalar functions can be referenced anywhere that an expression is valid within an SQL statement, such as in a select-list, or in a FROM clause.

### **Features**

- Built-in scalar functions perform well.
- Built-in scalar functions are strongly typed.
- Can be referenced with SQL statements wherever expressions are supported.
- Logic is executed on the server as part of the SQL statement that references it.
- Output of a scalar UDF can be used directly by the statement that references the function.
- When used in predicates, scalar UDF usage can improve overall query performance. When a scalar functions are applied to a set of candidate rows at the server, it can act as a filter, thus limiting the number of rows that must be returned to the client.
- For external scalar user-defined functions, state can be maintained between the iterative invocations of the function by using a scratchpad.

### **Limitations**

- By design, they only return a single scalar value.
- Transaction management is not supported within scalar functions. Commits and rollbacks cannot be executed within scalar function bodies.
- Result sets cannot be returned from scalar functions.
- In a single partition database user-defined external scalar UDFs can contain SQL statements. These statements can read data from tables, but cannot modify data in tables.
- In a multi-partition database environment, user-defined scalar UDFs cannot contain SQL statements.
- Refer to: Restrictions on scalar functions.

### **Common uses**

- To manipulate strings within SQL statements.
- To perform basic mathematical operations within SQL statements.

- User-defined scalar functions can be created to extend the existing set of built-in scalar functions. For example, you can create a complex mathematical function, by re-using the existing built-in scalar functions along with other logic.

#### **Supported implementations**

- Sourced implementation
- External implementation
  - Refer to the topic, “Comparison of supported APIs and programming languages for external routine development” on page 22.

#### **Routines: Row functions:**

A row function is a function, which can only be used with user-defined structured types, that for each set of one or more scalar parameters returns a single row.

Row functions can only be used as a transform function mapping attributes of a structured type into built-in data type values in a row. Row functions cannot be used in a standalone manner or within SQL statements outside of the context of abstract data types.

#### **Features**

- Allows you to map structured type attributes to a row of built-in data type values.

#### **Limitations**

- Cannot be used in a standalone manner or in SQL statements outside of the context of user-defined structured types.
- Refer to the topic: "Restrictions on row functions"

#### **Common uses**

To make structured type attributes accessible in queries or operations. For example, consider a user-defined structured data type named, 'manager' that extends another structured type person and that has a combination of person attributes and manager specific attributes. If you wanted to refer to these values in a query, you would create a row function to translate the attribute values into a row of values that can be referenced.

#### **Supported implementations**

- SQL implementation

#### **Routines: Table functions:**

Table functions are functions that for a group of sets of one or more parameters, returns a table to the SQL statement that references it.

Table functions can only be referenced in the FROM clause of a SELECT statement. The table that is returned by a table function can participate in joins, grouping operations, set operation such as UNION, and any operation that could be applied to a read-only view.

#### **Features**

- Returns a set of data values for processing.
- Can be referenced as part of a SQL query.
- Can make operating system calls, read data from files or even access data across a network in a single partitioned database.



- Results of table function invocations can be directly accessed by the SQL statement that references the table function.
- SQL table functions can encapsulate SQL statements that modify SQL table data. External table functions cannot encapsulate SQL statements.
- For a single table function reference, a table function can be iteratively invoked multiple times and maintain state between these invocations by using a scratchpad.

#### **Limitations**

- Transaction management is not supported within user-defined table functions. Commits and rollbacks cannot be executed within table UDFs.
- Result sets cannot be returned from table functions.
- Not designed for single invocations.
- Can only be referenced in the FROM clause of a query.
- User-defined external table functions can read SQL data, but cannot modify SQL data. As an alternative SQL table functions can be used to contain SQL statements that modify SQL data.
- Refer to the topic, "Restrictions on table functions".

#### **Common uses**

- Encapsulate a complex, but commonly used sub-query.
- Provide a tabular interface to non-relational data. For example a user-defined external table function can read a spreadsheet and produce a table of values that can be directly inserted into a table or directly and immediately accessed within a query.

#### **Supported implementations**

- SQL implementation
- External implementation

### **Routines: Methods**

Methods allow you to access structured type attributes as well as to define additional behaviors for structured types. A structured type is a user-defined data type containing one or more named attributes, each of which has a data type. Attributes are properties that describe an instance of a type. A geometric shape, for example, might have attributes such as its list of Cartesian coordinates.

Methods are generally implemented for a structured type to represent operations on the attributes of the structured type. For a geometric shape a method might calculate the volume of the shape. Methods share all of the features of scalar functions.

#### **Features**

- Ability to access structured type attributes
- Ability to set structured type attributes
- Ability to create operations on structured type attributes and return a function value
- Sensitive to the dynamic type of the subject type

#### **Limitations**

- Can only return a scalar value
- Can only be used with structured types
- Cannot be invoked for typed tables

### **Common uses**

- Create operations on structured types
- Encapsulate the structured type

### **Supported implementations**

There are no system-defined methods. Users can create user-defined methods for existing user-defined structured types. Methods can be implemented using one of the following implementations:

- “SQL routine implementation” on page 21
- “External routine implementation” on page 21: C, C++, Java, C# (using OLE API), Visual Basic (using OLE API)

SQL methods are easy to implement, but are generally designed in conjunction with the design of a structured type. External methods provide greater support for flexible logic implementation and allow a user to develop method logic in their preferred programming language.

### **Comparison of functional types of routines**

Understanding the differences between procedures, functions, and methods can help you determine which functional type to implement when building your own routines and can help you determine where and how you can reference existing routines. This can save you time and effort as well as ensure that you are maximizing the functionality and performance of routines.

Procedures, functions, and methods differ in a variety of ways. These differences are outlined in the following table:

Table 2. Comparison of the functional types of routine

Characteristic	Procedures	Functions	Methods
Unique functional characteristics and useful applications	<ul style="list-style-type: none"> <li>• Enable the encapsulation of logic and SQL statements.</li> <li>• Serve as sub-routine extensions to client applications, routines, triggers, and dynamic compound statements.</li> <li>• Procedures are invoked by executing the CALL statement with a reference to a procedure.</li> <li>• Nested procedure calls are supported</li> <li>• Recursive procedure calls are supported</li> <li>• Parameter support for input, output, and input-output parameters</li> <li>• Extensive support for SQL statement execution</li> <li>• Can return one or more result-sets</li> <li>• Savepoints and transaction control</li> </ul>	<ul style="list-style-type: none"> <li>• Enable the encapsulation of logic and SQL statements.</li> <li>• Functions are relationships between sets of input data values and a set of result values.</li> <li>• Functions enable you to extend and customize SQL.</li> <li>• Functions are invoked from within elements of SQL statements such as a select-list or a FROM clause.</li> <li>• Moderate support for SQL statement execution.</li> <li>• Parameter support for input parameters and scalar or aggregate function return values.</li> <li>• External functions provide support for storing intermediate values between the individual function sub-invocations for each row or value using a scratchpad.</li> <li>• Efficient compilation of function logic into queries that reference functions.</li> </ul>	<ul style="list-style-type: none"> <li>• Enable the encapsulation of logic and SQL statements.</li> <li>• Methods allow you to access structured type attributes as well as to define additional behaviors for structured types.</li> <li>• Ability to access structured type attributes.</li> <li>• Ability to set structured type attributes.</li> <li>• Ability to create operations on structured type attributes and return a function value.</li> </ul>
Functional sub-types of routine	<ul style="list-style-type: none"> <li>• Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>• Scalar functions</li> <li>• Aggregate functions</li> <li>• Row functions</li> <li>• Table functions</li> </ul>	<ul style="list-style-type: none"> <li>• Not applicable</li> </ul>
Invocation interface	<ul style="list-style-type: none"> <li>• Invocation is done through execution of the CALL statement with a reference to the procedure.</li> <li>• Procedure invocation supported wherever CALL statement is supported.</li> </ul>	<ul style="list-style-type: none"> <li>• Invocation is done within an SQL statement within a column select-list, an expression, or in a FROM clause of a select statement, among other locations.</li> </ul>	<ul style="list-style-type: none"> <li>• Invocation is done within an SQL statement that references the structured type associated with the method.</li> </ul>
Are there any system defined routines of this type?	<ul style="list-style-type: none"> <li>• Yes, many.</li> <li>• See the SQL reference for a list of system-defined procedures.</li> </ul>	<ul style="list-style-type: none"> <li>• Yes, many.</li> <li>• See the SQL reference for a list of system-defined functions.</li> </ul>	<ul style="list-style-type: none"> <li>• No</li> </ul>

Table 2. Comparison of the functional types of routine (continued)

Characteristic	Procedures	Functions	Methods
Supported user-defined routine implementations	<ul style="list-style-type: none"> <li>• SQL</li> <li>• External                             <ul style="list-style-type: none"> <li>– C/C++ (with embedded SQL or CLI API calls)</li> <li>– COBOL</li> <li>– Java (JDBC)</li> <li>– Java (SQLJ)</li> <li>– .NET CLR</li> <li>– OLE: Visual Basic, Visual C++</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• SQL</li> <li>• External                             <ul style="list-style-type: none"> <li>– C/C++</li> <li>– Java (JDBC)</li> <li>– Java (SQLJ)</li> <li>– .NET CLR</li> <li>– OLE DB: Visual Basic, Visual C++ (table functions only)</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• SQL</li> <li>• External                             <ul style="list-style-type: none"> <li>– C</li> <li>– C++</li> </ul> </li> </ul>
Nested call support	<ul style="list-style-type: none"> <li>• Yes</li> </ul>	<ul style="list-style-type: none"> <li>• No, however functions are repeatedly invoked for every value in the input set and intermediate values can be stored using a scratchpad.</li> </ul>	<ul style="list-style-type: none"> <li>• No</li> </ul>
Performance	<ul style="list-style-type: none"> <li>• Perform well if routine logic is efficient and best practices are adopted.</li> </ul>	<ul style="list-style-type: none"> <li>• Perform well if routine logic is efficient and best practices are adopted.</li> <li>• Can perform better than a logically equivalent procedure, if the logic only queries data and does not modify data.</li> </ul>	<ul style="list-style-type: none"> <li>• Good performance</li> </ul>
Portability	<ul style="list-style-type: none"> <li>• Highly portable</li> <li>• Particularly portable if SQL implementation is used.</li> <li>• 32-bit and 64-bit external routines supported in a variety of programming languages</li> </ul>	<ul style="list-style-type: none"> <li>• Highly portable</li> <li>• Particularly portable if SQL implementation is used.</li> <li>• 32-bit and 64-bit external routines supported in a variety of programming languages</li> </ul>	<ul style="list-style-type: none"> <li>• Highly portable</li> </ul>
Interoperability	<ul style="list-style-type: none"> <li>• Procedures can call other procedures and can contain SQL statements that invoke functions with SQL access levels less than or equal to the SQL access level of the procedure.</li> </ul>	<ul style="list-style-type: none"> <li>• Functions can contain SQL statements that invoke other functions and can call procedures with SQL access levels less than or equal to the SQL access level of the function.</li> </ul>	<ul style="list-style-type: none"> <li>• Methods can invoke functions with an SQL access level less than or equal to the SQL access level of the method.</li> <li>• Methods cannot call procedures or other methods</li> </ul>
Restrictions		<ul style="list-style-type: none"> <li>• Table functions can only return a single table-reference that must be referenced in the FROM clause of a SELECT statement. output.</li> </ul>	

In general the functional characteristics and applications of routines determine what routine type should be used. However, performance and the supported routine implementations also play an important role in determining what routine type should be used.

### **Determining what functional type of routine to use**

Procedures, functions, and methods provide different functional routine and feature support. Determining what routine type to use or implement will determine where and how you can reference and invoke the routine functionality, influence what routine implementations you can use, and can influence what types of functionality your routine can contain.

### **Before you begin**

Determining what routine type is best suited to your needs before beginning to implement it will save you time and possible frustration later.

Read about the functional types of routines to learn about their characteristics.

### **Procedure**

To determine whether to use a procedure, function, or method, do the following:

1. Determine what functionality you want the routine to encapsulate, what interface you want to invoke the routine from, and what routine implementation you want to use.
  - See the following topic:
    - “Comparison of functional types of routines” on page 16to determine what functional routine types support these requirements.
2. Determine what SQL statements you want to include in the routine.
  - See the following topic:
    - “SQL statements that can be executed in routines” on page 36
  - Determine what functional routines support the execution of the required SQL statements.
3. If the routine will only include one or more queries, consider using SQL functions. SQL functions perform well in this situation because they are compiled in-line with the SQL statements that reference them, unlike procedures, which are compiled and invoked separately.
4. Determine whether in the future you might need to extend the functionality of the routine to include functionality of another routine type (for example, procedures support more SQL statements and in general more SQL features than do functions). To avoid having to rewrite a function into a procedure later, consider implementing a procedure now.

### **Results**

In general functional and SQL requirements motivate the choice of what functional type of routine to implement. However, there are cases where it is possible to create logically equivalent routines with different functional types. For example, it is possible to rewrite most basic procedures that return a single result-set as a table function. You can also easily rewrite basic procedures with only a single output parameter as scalar functions.

## What to do next

Once you have determined what functional type of routine to use, you might be interested in learning more about routine implementations or in determining what routine implementation to use.

## Implementations of routines

Routines can be implemented in a variety of ways. A routine implementation is essentially the underlying form of the routine that contains the logic that is run when a routine is invoked. Understanding the different supported routine implementations can help you understand how routines work and help you determine which routine implementation to choose when implementing user-defined routines.

The available routine implementations include:

- “Built-in routine implementation”
- “Sourced routine implementation”
- “SQL routine implementation” on page 21
- “External routine implementation” on page 21

“System-defined routines” on page 6 can be implemented as built-in routines, SQL routines, or external routines. However, their implementation is essentially invisible to the user and in general is of little concern to the user.

“User-defined routines” on page 7 can be implemented as sourced routines, SQL routines, or external routines.

The characteristics of each of the implementations differ and can result in more or less functionality support. Before deciding on a particular implementation, it is a good idea to review the supported functionality and restrictions associated with each implementation, by reading about each of the implementations and then by reading the topic:

- “Comparison of routine implementations” on page 28

A good understanding of the routine implementations can help you make good implementation decisions as well as help you to debug and troubleshoot existing routines.

### Built-in routine implementation

Built-in routines are built into the code of the DB2 database manager. These routines are strongly typed and perform well because their logic is native to the database code. These routines are found in the SYSIBM schema. Some examples of built-in scalar and aggregate functions include:

- Built-in scalar functions: +, -, \*, /, substr, concat, length, char, decimal, days
- Built-in aggregate functions: avg, count, min, max, stdev, sum, variance

Built-in functions comprise most of the commonly required casting, string manipulation, and arithmetic functionality. You can immediately use these functions in your SQL statements. For a complete list of available built-in functions, see the SQL Reference.

### Sourced routine implementation

A routine that is implemented with a sourced routine implementation is one that duplicates the semantics of another function, called its source function. Currently

only scalar and aggregate functions can be sourced functions. Sourced functions are particularly useful for allowing a distinct type to selectively inherit the semantics of its source type. Sourced functions are essentially a special form of an SQL implementation for a function.

### **SQL routine implementation**

A SQL routine implementation is composed entirely of SQL statements. SQL routine implementations are characterized by the fact that the SQL statements that define the logic of the routines are included within the CREATE statement used to create the routine in the database. SQL routines are quick and easy to implement because of their simple syntax, and perform well due to their close relationship with DB2.

The SQL Procedural Language (SQL PL) is a language extension of basic SQL that consists of statements and language elements that can be used to implement programming logic in SQL. SQL PL includes a set of statements for declaring variables and condition handlers (DECLARE statement) assigning values to variables (assignment-statement), and for implementing procedural logic (control-statements) such as IF, WHILE, FOR, GOTO, LOOP, SIGNAL, and others. SQL and SQL PL can be used to create SQL procedures, functions, triggers, and compound SQL statements. SQL procedures and functions, along with SQL global variables, user-defined conditions, and data-types, can be grouped together in modules.

### **External routine implementation**

An external routine implementation is one in which the routine logic is defined by programming language code that resides external to the database. As with other routine implementations, routines with external implementations are created in the database by executing a CREATE statement.

The routine logic stored in a compiled library resides on the database server in a special directory path. The association of the routine name with the external code application is asserted by the specification of the EXTERNAL clause in the CREATE statement.

External routines can be written in any of the “Supported APIs and programming languages for external routine development” on page 22.

External routine implementation can be somewhat more complex than SQL routine implementation. However, they are extremely powerful because they allow you to harness the full functionality and performance of the chosen implementation programming language. External functions also have the advantage of being able to access and manipulate entities that reside outside of the database, such as the network or file system. For routines that require a smaller degree of interaction with the DB2 database, but that must contain a lot of logic or very complex logic, an external routine implementation is a good choice.

As an example, external routines are ideal to use to implement new functions that operate on and enhance the utility of built-in data types, such as a new string function that operate on a VARCHAR data type or a complicated mathematical function that operates on a DOUBLE data type. External routine implementations are also ideal for logic that might involve an external action, such as sending an email.

If you are already comfortable programming in one of the supported external routine programming languages, and need to encapsulate logic with a greater

emphasis on programming logic than data access, once you learn the steps involved in creating routines with external implementation, you will soon discover just how powerful they can be.

**Supported APIs and programming languages for external routine development:**

You can develop DB2 external routines (procedures and functions) using the following APIs and associated programming languages:

- ADO.NET
  - .NET Common Language Runtime programming languages
- CLI
- Embedded SQL
  - C
  - C++
  - COBOL (Only supported for procedures)
- JDBC
  - Java
- OLE
  - Visual Basic
  - Visual C++
  - Any other programming language that supports this API.
- OLE DB (Only supported for table functions)
  - Any programming language that supports this API.
- SQLJ
  - Java

**Comparison of supported APIs and programming languages for external routine development:**

It is important to consider the characteristics and limitations of the various supported external routine application programming interfaces (APIs) and programming languages before you start implementing external routines. This will ensure that you choose the right implementation from the start and that the routine features that you require are available.



Table 3. Comparison of external routine APIs and programming languages

API and programming language	Feature support	Performance	Security	Scalability	Limitations
SQL (includes SQL PL)	<ul style="list-style-type: none"> <li>• SQL is a high level language that is easy to learn and use, which makes implementation go quickly.</li> <li>• SQL Procedural Language (SQL PL) elements allow for control-flow logic around SQL operations and queries.</li> </ul>	<ul style="list-style-type: none"> <li>• Very good.</li> <li>• SQL routines perform better than Java routines.</li> <li>• SQL routines perform as well as C and C++ external routines created with the NOT FENCED clause.</li> </ul>	<ul style="list-style-type: none"> <li>• Very safe.</li> <li>• SQL procedures always run in the same memory as the database manager. This corresponds to the routine being created by default with the keywords NOT FENCED.</li> </ul>	<ul style="list-style-type: none"> <li>• Highly scalable.</li> </ul>	<ul style="list-style-type: none"> <li>• Cannot access the database server file system.</li> <li>• Cannot invoke applications that reside outside of the database.</li> </ul>

Table 3. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<p>Embedded SQL (includes C and C++)</p>	<ul style="list-style-type: none"> <li>• Low level, but powerful programming language.</li> </ul>	<ul style="list-style-type: none"> <li>• Very good.</li> <li>• C and C++ routines perform better than Java routines.</li> <li>• C and C++ routines created with the NOT FENCED clause perform as well as SQL routines.</li> </ul>	<ul style="list-style-type: none"> <li>• C and C++ routines are prone to programming errors.</li> <li>• Programmers must be proficient in C to avoid making common memory and pointer manipulation errors which make routine implementation more tedious and time consuming.</li> <li>• C and C++ routines should be created with the FENCED clause and the NOT THREADSAFE clause to avoid the disruption of the database manager should an exception occur in the routine at run time. These are default clauses. The use of these clauses can somewhat negatively impact performance, but ensure safe execution. See: Security of routines.</li> </ul>	<ul style="list-style-type: none"> <li>• Scalability is reduced when C and C++ routines are created with the FENCED and NOT THREADSAFE clauses. These routines are run in an isolated <i>db2fmp</i> process apart from the database manager process. One <i>db2fmp</i> process is required per concurrently executed routine.</li> </ul>	<ul style="list-style-type: none"> <li>• There are multiple supported parameter passing styles which can be confusing. Users should use parameter style SQL as much as possible.</li> </ul>

Table 3. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
Embedded SQL (COBOL)	<ul style="list-style-type: none"> <li>• High-level programming language good for developing business, typically file oriented, applications.</li> <li>• Pervasively used in the past for production business applications, although its popularity is decreasing.</li> <li>• COBOL does not contain pointer support and is a linear iterative programming language.</li> </ul>	<ul style="list-style-type: none"> <li>• COBOL routines do not perform as well as routines created with any of the other external routine implementation options.</li> </ul>	<ul style="list-style-type: none"> <li>• No information at this time.</li> </ul>	<ul style="list-style-type: none"> <li>• No information at this time.</li> </ul>	<ul style="list-style-type: none"> <li>• You can create and invoke 32-bit COBOL procedures in 64-bit DB2 instances, however these routines will not perform as well as 64-bit COBOL procedures within a 64-bit DB2 instance.</li> </ul>
JDBC (Java) and SQLJ (Java)	<ul style="list-style-type: none"> <li>• High-level object-oriented programming language suitable for developing standalone applications, applets, and servlets.</li> <li>• Java objects and data types facilitate the establishment of database connections, execution of SQL statements, and manipulation of data.</li> </ul>	<ul style="list-style-type: none"> <li>• Java routines do not perform as well as C and C++ routines or SQL routines.</li> </ul>	<ul style="list-style-type: none"> <li>• Java routines are safer than C and C++ routines, because the control of dangerous operations is handled by the Java Virtual Machine (JVM). This increases reliability and makes it very difficult for the code of one Java routine to harm another routine running in the same process.</li> </ul>	<ul style="list-style-type: none"> <li>• Good scalability</li> <li>• Java routines created with the FENCED THREADSAFE clause (the default) scale well. All fenced Java routines will share a few JVMs. More than one JVM might be in use on the system if the Java heap of a particular db2fmp process is approaching exhaustion.</li> </ul>	<ul style="list-style-type: none"> <li>• To avoid potentially dangerous operations, Java Native Interface (JNI) calls from Java routines are not permitted.</li> </ul>

Table 3. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<p>.NET common language runtime supported languages (includes C#, Visual Basic, and others)</p>	<ul style="list-style-type: none"> <li>• Part of the Microsoft .NET model of managed code.</li> <li>• Source code is compiled into intermediate language (IL) byte code that can be interpreted by the Microsoft .NET Framework common language runtime.</li> <li>• CLR assemblies can be built up from sub-assemblies that were compiled from different .NET programming language source code, which allows users to re-use and integrate code modules written in various languages.</li> </ul>	<ul style="list-style-type: none"> <li>• CLR routines can only be created with the FENCED NOT THREADSAFE clause so as to minimize the possibility of database manager interruption at runtime. This can somewhat negatively impact performance</li> <li>• Use of the default clause values minimizes the possibility of database manager interruption at runtime; however because CLR routines must run as FENCED, they might perform slightly more slowly than other external routines that can be specified as NOT FENCED.</li> </ul>	<ul style="list-style-type: none"> <li>• CLR routines can only be created with the FENCED NOT THREADSAFE clause. They are therefore safe because they will be run outside of the database manager in a separate db2fmp process.</li> </ul>	<ul style="list-style-type: none"> <li>• No information available.</li> </ul>	<ul style="list-style-type: none"> <li>• Refer to the topic, "Restrictions on .NET CLR routines".</li> </ul>

Table 3. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<ul style="list-style-type: none"> <li>OLE</li> </ul>	<ul style="list-style-type: none"> <li>OLE routines can be implemented in Visual C++, Visual Basic, and other languages supported by OLE.</li> </ul>	<ul style="list-style-type: none"> <li>The speed of OLE automated routines depends on the language used to implement them. In general they are slower than non-OLE C/C++ routines.</li> <li>OLE routines can only run in FENCED NOT THREADSAFE mode, and therefore OLE automated routines do not scale well.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>

Table 3. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<ul style="list-style-type: none"> <li>OLE DB</li> </ul>	<ul style="list-style-type: none"> <li>OLE DB can be used to create user-defined table functions.</li> <li>OLE DB functions connect to external OLE DB data sources.</li> </ul>	<ul style="list-style-type: none"> <li>Performance of OLE DB functions depends on the OLE DB provider, however in general OLE DB functions perform better than logically equivalent Java functions, but slower than logically equivalent C, C++, or SQL functions. However some predicates from the query where the function is invoked might be evaluated at the OLE DB provider, therefore reducing the number of rows that DB2 has to process which can frequently result in improved performance.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>OLE DB can only be used to create user-defined table functions.</li> </ul>

### Comparison of routine implementations

Understanding the differences between the supported routine implementations can help you determine which routine implementation to use when building your own routines. This can save you time and effort as well as ensure that you are maximizing the functionality and performance of routines.

Built-in, sourced, SQL, and external routine implementations differ in a variety of ways. These differences are outlined in the following table:

Table 4. Comparison of routine implementations

Characteristic	Built-in	Sourced	SQL	External
Features and uses	<ul style="list-style-type: none"> <li>• Perform very well because their logic is native to the database manager code.</li> <li>• Many common casting, string manipulation, and arithmetic built-in functions are located in the SYSIBM schema.</li> </ul>	<ul style="list-style-type: none"> <li>• Used to provide basic extensions to the functionality of built-in functions.</li> <li>• SQL and SQL PL provide high level programming language support that makes implementing routine logic fast and easy.</li> </ul>	<ul style="list-style-type: none"> <li>• Used to extend the set of built-in functions with more complex functions that can execute SQL statements.</li> </ul>	<ul style="list-style-type: none"> <li>• Developers can program logic in the supported programming language of their choice.</li> <li>• Complicated logic can be implemented.</li> <li>• External actions, actions with impact outside of the database, are directly supported. This can include reading from or writing to the server file system, invoking an application or script on the server, and issuing SQL statements that are not supported in the SQL, sourced, or built-in implementations.</li> </ul>
Implementation is built into the database manager code?	<ul style="list-style-type: none"> <li>• Yes</li> </ul>	<ul style="list-style-type: none"> <li>• No</li> </ul>	<ul style="list-style-type: none"> <li>• No</li> </ul>	<ul style="list-style-type: none"> <li>• No</li> </ul>
Supported functional routine types that can have this implementation	<ul style="list-style-type: none"> <li>• Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>• Functions                             <ul style="list-style-type: none"> <li>– Scalar functions</li> <li>– Aggregate functions</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Procedures</li> <li>• Functions</li> <li>• Methods</li> </ul>	<ul style="list-style-type: none"> <li>• Procedures</li> <li>• Functions</li> <li>• Methods</li> </ul>
Supported SQL statements	<ul style="list-style-type: none"> <li>• Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>• Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>• Most SQL statements, including all SQL PL statements, can be executed in routines.</li> <li>• Refer to the topic, "SQL statements that can be executed in routines".</li> </ul>	<ul style="list-style-type: none"> <li>• Many SQL statements, including a sub-set of SQL PL statements, can be executed in routines.</li> <li>• Refer to the topic, "SQL statements that can be executed in routines".</li> </ul>

Table 4. Comparison of routine implementations (continued)

Characteristic	Built-in	Sourced	SQL	External
Performance	<ul style="list-style-type: none"> <li>Very fast</li> </ul>	<ul style="list-style-type: none"> <li>In general, about as fast as built-in functions.</li> </ul>	<ul style="list-style-type: none"> <li>Very good performance if the SQL is efficiently written, database operations are emphasized more than programming logic, and SQL routine best practices are adopted.</li> <li>Refer to the topic, "SQL routine best practices".</li> </ul>	<ul style="list-style-type: none"> <li>Very good performance if the programming logic is efficiently written and external routine best practices are adopted.</li> <li>Refer to the topic, "External routine best practices".</li> </ul>
Portability	<ul style="list-style-type: none"> <li>Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>Sourced functions can easily be dropped and recreated in other DB2 databases.</li> </ul>	<ul style="list-style-type: none"> <li>SQL functions can be easily dropped and re-created in other databases.</li> </ul>	<ul style="list-style-type: none"> <li>External functions can be dropped and re-created in other databases, however care must be taken to ensure that the environment is compatible and that the required supported software is available.</li> <li>Refer to the topic, "Deploying external routines".</li> </ul>
Interoperability	<ul style="list-style-type: none"> <li>Not applicable</li> </ul>	<ul style="list-style-type: none"> <li>They can be referenced wherever built-in functions can be referenced. Sourced functions cannot invoke other functions.</li> </ul>	<ul style="list-style-type: none"> <li>SQL routines can be referenced in many parts of SQL statements. A SQL routine can invoke other SQL and external routines with SQL access levels that are equal to or less than the SQL access level of the SQL routine.</li> </ul>	<ul style="list-style-type: none"> <li>External routines can invoke external routines and other SQL routines with SQL access levels that are equal to or less than the SQL access level of the external routine.</li> </ul>

In general the functional characteristics and applications of routines determine what routine type should be used. However, performance and the supported routine implementations also play an important role in determining what routine type should be used.



## Determining what routine implementation to use

### About this task

The choice of using or creating a routine with a built-in, sourced, SQL, or external routine implementation can influence what functionality the routine can provide, the performance of the routine, and the likelihood of runtime problems that might require debugging.

Whenever possible, if there is an existing system-defined routine that provides the support that you require, use it. Use existing built-in routines whenever possible. If the functionality you require is very similar to that of an existing built-in function, consider creating a sourced function that extends it.

If you must create a routine, follow the procedure below. It is important to determine what routine implementation to use before proceeding too far with routine design.

To determine whether to use a sourced, SQL, or external routine implementation when creating a routine, do the following:

### Procedure

1. Determine whether you want to create a procedure, function, or method. This should always be your first step when developing a routine. Also determine what are the support implementations for that routine type. See:
  - “Comparison of functional types of routines” on page 16
2. Determine what SQL statements you want to include in the routine. The set of SQL statements that you want to execute in a routine can limit your choice of routine implementation. See:
  - “Determining what SQL statements can be executed in routines” on page 42
3. Determine if now or in the future the routine logic must access data, files, or applications that reside external to the database. The data, files, or applications might reside in the file system of the database server or in the available network.
  - If the routine logic must access entities outside of the database, you must use an external routine implementation.
4. Determine the number of queries to be included in the routine relative to the quantity of procedural flow logic.
  - If the routine logic contains primarily procedural flow logic and very few queries, create an external routine.
  - If the routine logic contains many queries and a minimal amount of procedural flow logic, create an SQL routine.

### Results

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## Usage of routines

Routines can be used to solve many common problems faced by database architects, database administrators, and application developers alike. They can help improve the structure, maintenance, and performance of your applications.

Some examples of scenarios in which you might use routines are listed below:

- Administering databases with routines
- Extending SQL function support with user-defined functions

- Auditing data changes using routines and other SQL features

## Administration of databases with system-defined routines

Administering databases through applications is possible and has become easier with the introduction of system-defined routines for the explicit purpose of doing administrative functions.

### About this task

As of Version 8.1, DB2 provides a set of system-defined procedures and functions in the SYSPROC, SYSFUN, and SYSTOOLS schemas that are ready-to-use for doing administrative tasks, including the execution of DB2 commands through an SQL interface, modification of configuration parameters, package management, snapshot related tasks, and more. You might choose to use system-defined administrative routines if you require an application to perform administrative tasks or if you want to access the results of administrative tasks through an SQL interface so that you filter, sort, modify, or reuse the results in another query and if you don't want to create your own routines to do this.

Beginning with DB2 for Linux, UNIX, and Windows Version 9.1, there is a new system-defined administrative routine, named the ADMIN\_CMD. It along with the many other system-defined routines provide comprehensive administration support.

### ADMIN\_CMD for invoking DB2 commands through a SQL interface

As of Version 9.1, there is a new system-defined administrative routine called the ADMIN\_CMD that allows you to execute DB2 commands through an SQL interface. Essentially this routine allows you to pass in as an argument a DB2 command with appropriate flags and values as a string parameter. The routine executes the string containing the DB2 command and returns the results in a tabular or scalar format that can be used as part of a larger query or operation. This functionality makes it easier than ever to write administrative database applications.

### System-defined administrative routines

Examples of other system-defined routines include: SNAPSHOT\_TABLE, HEALTH\_DB\_HI, SNAPSHOT\_FILEW, REBIND\_ROUTINE\_PACKAGE. These and many more system-defined routines can be used from the CLP or in database applications wherever invocation of the specified routine is supported.

The ADMIN\_CMD routine and the other system-defined routines are available for use provided that you have the SYSPROC schema and SYSFUN schema names included in your CURRENT PATH value, which they are by default.

For examples of how to use the system-defined routines, refer to system-defined routine specific reference documentation.

## Extension of SQL function support with user-defined functions

### About this task

If no system-defined functions encapsulate the logic that you require, you can create your own user-defined functions. User-defined functions are a great way of extending the basic set of SQL functions. Whether you or a group of users need a

function to implement a complex mathematical formula, specific string manipulation, or to do some semantic transformations of values, you can easily create a high-performance SQL function to do this that can be referenced like any existing built-in SQL function.

For example, consider a user that requires a function that converts a value in one monetary currency to another monetary currency. Such a function is not available within the set of system-defined routines. This function can be created however as a user-defined SQL scalar function. Once created this function can be referenced wherever scalar functions are supported within an SQL statement.

Another user might require a more complex function that sends an email whenever a change is made to a particular column in a table. Such a function is not available within the set of system-defined routines. This function can be created however as a user-defined external procedure with a C programming language implementation. Once created, this procedure can be referenced wherever procedures are supported, including from within triggers.

These examples demonstrate how easily you can extend the SQL language by creating user-defined routines.

## Auditing using SQL table functions

### Before you begin

Database administrators interested in monitoring table data accesses and table data modifications made by database users can audit transactions on a table by creating and using SQL table functions that modify SQL data.

Any table function that encapsulates SQL statements that perform a business task, such as updating an employee's personal information, can additionally include SQL statements that record, in a separate table, details about the table accesses or modifications made by the user that invoked the function. An SQL table function can even be written so that it returns a result set of table rows that were accessed or modified in the body of the table function. The returned result set of rows can be inserted into and stored in a separate table as a history of the changes made to the table.

For the list of privileges required to create and register an SQL table function, see the following statements:

- CREATE FUNCTION (SQL Scalar, Table, or Row) statement

The definer of the SQL table function must also have authority to run the SQL statements encapsulated in the SQL table function body. Refer to the list of privileges required for each encapsulated SQL statement. To grant INSERT, UPDATE, DELETE privileges on a table to a user, see the following statement:

- GRANT (Table, View, or Nickname Privileges) statement

The tables accessed by the SQL table function must exist prior to invocation of the SQL table function.

### Example

#### Example 1: Auditing accesses of table data using an SQL table function

This function accesses the salary data of all employees in a department specified by input argument deptno. It also records in an audit table, named audit\_table, the user ID that invoked the function, the name of the

table that was read from, a description of what information was accessed, and the current time. Note that the table function is created with the keywords `MODIFIES SQL DATA` because it contains an `INSERT` statement that modifies SQL data.

```
CREATE FUNCTION sal_by_dept (deptno CHAR(3))
  RETURNS TABLE (lastname VARCHAR(10),
                 firstname VARCHAR(10),
                 salary INTEGER)

LANGUAGE SQL
MODIFIES SQL DATA
NO EXTERNAL ACTION
NOT DETERMINISTIC
BEGIN ATOMIC
  INSERT INTO audit_table(user, table, action, time)
    VALUES (USER,
            'EMPLOYEE',
            'Read employee salaries in department: ' || deptno,
            CURRENT_TIMESTAMP);
RETURN
  SELECT lastname, firstname, salary
     FROM employee as E
     WHERE E.dept = deptno;
END
```

### Example 2: Auditing updates to table data using an SQL table function

This function updates the salary of an employee specified by `updEmpNum`, by the amount specified by `amount`, and also records in an audit table named `audit_table`, the user that invoked the routine, the name of the table that was modified, and the type of modification made by the user. A `SELECT` statement that references a data change statement (here an `UPDATE` statement) in the `FROM` clause is used to return the updated row values. Note that the table function is created with the keywords `MODIFIES SQL DATA` because it contains both an `INSERT` statement and a `SELECT` statement that references the data change statement, `UPDATE`.

```
CREATE FUNCTION update_salary(updEmpNum CHAR(4), amount INTEGER)
  RETURNS TABLE (emp_lastname VARCHAR(10),
                 emp_firstname VARCHAR(10),
                 newSalary INTEGER)

LANGUAGE SQL
MODIFIES SQL DATA
NO EXTERNAL ACTION
NOT DETERMINISTIC
BEGIN ATOMIC
  INSERT INTO audit_table(user, table, action, time)
    VALUES (USER,
            'EMPLOYEE',
            'Update emp salary. Values: '
            || updEmpNum || ' ' || char(amount),
            CURRENT_TIMESTAMP);
RETURN
  SELECT lastname, firstname, salary
     FROM FINAL TABLE(UPDATE employee
                       SET salary = salary + amount
                       WHERE employee.empnum = updEmpNum);
END
```

### Example 3: Invoking an SQL table function used for auditing transactions

The following shows how a user might invoke the routine to update an employee's salary by 500 yen:

```
SELECT emp_lastname, emp_firstname, newsalary
   FROM TABLE(update_salary(CHAR('1136'), 500)) AS T
```

A result set is returned with the last name, first name, and new salary for the employee. The invoker of the function will not know that the audit record was made.

EMP_LASTNAME	EMP_FIRSTNAME	NEWSALARY
JONES	GWYNETH	90500

The audit table would include a new record such as the following:

USER	TABLE	ACTION	TIME
MBROOKS	EMPLOYEE	Update emp salary. Values: 1136 500	2003-07-24-21.01.38.459255

#### Example 4: Retrieving rows modified within the body of an SQL table function

This function updates the salary of an employee, specified by an employee number EMPNUM, by an amount specified by amount, and returns the original values of the modified row or rows to the caller. This example makes use of a SELECT statement that references a data change statement in the FROM clause. Specifying OLD TABLE within the FROM clause of this statement flags the return of the original row data from the table employee that was the target of the UPDATE statement. Using FINAL TABLE, instead of OLD TABLE, would flag the return of the row values subsequent to the update of table employee.

```
CREATE FUNCTION update_salary (updEmpNum CHAR(4), amount DOUBLE)
  RETURNS TABLE (empnum CHAR(4),
                 emp_lastname VARCHAR(10),
                 emp_firstname VARCHAR(10),
                 dept CHAR(4),
                 newsalary integer)

LANGUAGE SQL
MODIFIES SQL DATA
NO EXTERNAL ACTION
DETERMINISTIC
BEGIN ATOMIC
RETURN
  SELECT empnum, lastname, firstname, dept, salary
  FROM OLD TABLE(UPDATE employee
                  SET salary = salary + amount
                  WHERE employee.empnum = updEmpNum);

END
```

---

## Tools for developing routines

There are various development environments and tools available for developing procedures and functions. Some of these tools are provided with DB2 Database for Linux, UNIX, and Windows whereas others are integrated components within popular integrated development environments. There are graphical and non-graphical interfaces and tools that can be used to develop procedures and functions.

The following graphical user-interface (GUI) tool, provided with DB2, is available for developing routines in DB2 database servers:

- IBM® Data Studio

The following command line interface, provided with DB2, is available for developing routines in DB2 database servers:

- DB2 Command Line Processor (DB2 CLP)

Several IBM software products provide graphical tools for developing routines in DB2 database servers including, but not limited to:

- IBM Distributed Unified Debugger
- IBM Optim™ Development Studio
- IBM Rational® Application Developer
- IBM Rational Web Developer
- IBM WebSphere® Studio

Several open source software products provide graphical tools for developing routines in DB2 database servers including, but not limited to:

- DB2 Web Tools for the Eclipse Framework

Some DB2 features can be used to add graphical tool support for developing routines from within software provided by other vendors, including:

- IBM Database Add-Ins for Microsoft Visual Studio

## IBM Data Studio routine development support

IBM Data Studio provides an easy-to-use development environment for creating, building, debugging, testing, and deploying stored procedures. IBM Data Studio provides graphical tools which simplify the process of creating routines by allowing you to focus on the stored procedure logic rather than the details of generating the basic CREATE statement, building, and installing stored procedures on a DB2 server. Additionally, you can develop stored procedures on one operating system and build them on other server operating systems.

IBM Data Studio is a graphical application that supports rapid development. You can use it to perform the following tasks:

- Create new stored procedures.
- Build stored procedures on local and remote DB2 servers.
- Modify and rebuild existing stored procedures.
- Test and debug the execution of installed stored procedures.

IBM Data Studio allows you to manage your work in projects. Each IBM Data Studio project saves your connections to specific databases, such as DB2 for z/OS servers. In addition, you can create filters to display subsets of the stored procedures on each database. When opening a new or existing Data Studio project, you can filter stored procedures so that you view them based on their name, schema, language, or collection ID (for DB2 for z/OS servers).

For more information about IBM Data Studio, visit the IDM information center: <http://publib.boulder.ibm.com/infocenter/idm/v2r2/index.jsp>

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## SQL statements that can be executed in routines

Successful execution of SQL statements in routines is subject to restrictions and conditional on certain prerequisites being met. However, it is possible to execute many SQL statements in routines.

If a statement invokes a routine, the effective SQL data access level for the statement will be the greater of:

- The SQL data access level of the statement from the following table.
- The SQL data access level of the routine specified when the routine was created.

For example, the CALL statement has an SQL data access level of CONTAINS SQL. However, if a stored procedure defined as READS SQL DATA is called, the effective SQL data access level for the CALL statement is READS SQL DATA.

The following table lists all supported SQL statements, including SQL PL control-statements, and identifies if each SQL statement may be executed within the various types of routines. For each SQL statement listed in the first column, each of the subsequent columns shows an X to indicate if the statement is executable within the routine. The final column identifies the minimum SQL access level required to allow the statement execution to succeed. Unless otherwise noted in a footnote, all of the SQL statements may be executed either statically or dynamically.

Table 5. SQL statements that can be executed in routines

SQL statement	Executable in compound SQL (compiled) statements(1)	Executable in compound SQL (inlined) statements(2)	Executable in external procedures	Executable in external functions	Minimum required SQL data access level
ALLOCATE CURSOR	X		X	X	MODIFIES SQL DATA
ALTER {BUFFERPOOL, DATABASE PARTITION GROUP, FUNCTION, METHOD, NICKNAME, PROCEDURE, SEQUENCE, SERVER, TABLE, TABLESPACE, TYPE, USER MAPPING, VIEW}			X	X	MODIFIES SQL DATA
ASSOCIATE LOCATORS	X				
AUDIT			X	X	MODIFIES SQL DATA
BEGIN DECLARE SECTION			X	X	NO SQL(3)
CALL	X	X	X	X	READS SQL DATA
CASE	X	X			CONTAINS SQL
CLOSE	X		X	X	READS SQL DATA
COMMENT ON	X		X	X	MODIFIES SQL DATA
COMMIT	X(6)		X(6)		MODIFIES SQL DATA
Compound SQL	X	X	X	X	CONTAINS SQL
CONNECT(2)					

Table 5. SQL statements that can be executed in routines (continued)

SQL statement	Executable in compound SQL (compiled) statements(1)	Executable in compound SQL (inlined) statements(2)	Executable in external procedures	Executable in external functions	Minimum required SQL data access level
CREATE {ALIAS, BUFFERPOOL, DATABASE PARTITION GROUP, DISTINCT TYPE, EVENT MONITOR, FUNCTION, FUNCTION MAPPING, GLOBAL TEMPORARY TABLE(11), INDEX(11), INDEX EXTENSION, METHOD, NICKNAME, PROCEDURE, SCHEMA, SEQUENCE, SERVER, TABLE(11), TABLESPACE, TRANSFORM, TRIGGER, TYPE, TYPE MAPPING, USER MAPPING, VIEW(11), WRAPPER }	X (8)		X		MODIFIES SQL DATA
DECLARE CURSOR	X	X	X		NO SQL(3)
DECLARE TEMPORARY TABLE	X		X	X	MODIFIES SQL DATA
DELETE	X	X	X	X	MODIFIES SQL DATA
DESCRIBE(9)			X	X	READS SQL DATA
DISCONNECT(4)					
DROP	X(8)		X	X	MODIFIES SQL DATA
END DECLARE SECTION			X	X	NO SQL(3)
EXECUTE	X		X	X	CONTAINS SQL(5)
EXECUTE IMMEDIATE	X		x	X	CONTAINS SQL(5)



Table 5. SQL statements that can be executed in routines (continued)

SQL statement	Executable in compound SQL (compiled) statements(1)	Executable in compound SQL (inlined) statements(2)	Executable in external procedures	Executable in external functions	Minimum required SQL data access level
EXPLAIN	X		X	X	MODIFIES SQL DATA
FETCH	X		X	X	READS SQL DATA
FREE LOCATOR			X	X	CONTAINS SQL
FLUSH EVENT MONITOR			X	X	MODIFIES SQL DATA
FLUSH PACKAGE CACHE			X	X	MODIFIES SQL DATA
FOR	X	X			READS SQL DATA
FREE LOCATOR	X		X	X	CONTAINS SQL
GET DIAGNOSTICS	X	X			READS SQL DATA
GOTO	X	X			CONTAINS SQL
GRANT	X		X	X	MODIFIES SQL DATA
IF	X	X			CONTAINS SQL
INCLUDE			X	X	NO SQL
INSERT	X	X	X	X	MODIFIES SQL DATA
ITERATE	X	X			CONTAINS SQL
LEAVE	X	X			CONTAINS SQL
LOCK TABLE	X		X	X	CONTAINS SQL
LOOP	X	X			CONTAINS SQL
MERGE	X	X	X	X	MODIFIES SQL DATA
OPEN	X		X	X	READS SQL DATA(7)
PREPARE	X		X	X	CONTAINS SQL
REFRESH TABLE			X	X	MODIFIES SQL DATA
RELEASE(4)					
RELEASE SAVEPOINT	X		X	X	MODIFIES SQL DATA
RENAME TABLE			X	X	MODIFIES SQL DATA
RENAME TABLESPACE			X	X	MODIFIES SQL DATA
REPEAT	X	X			CONTAINS SQL
RESIGNAL	X				MODIFIES SQL DATA

Table 5. SQL statements that can be executed in routines (continued)

SQL statement	Executable in compound SQL (compiled) statements(1)	Executable in compound SQL (inlined) statements(2)	Executable in external procedures	Executable in external functions	Minimum required SQL data access level
RETURN	X				CONTAINS SQL
REVOKE			X	X	MODIFIES SQL DATA
ROLLBACK(6)	X		X		
ROLLBACK TO SAVEPOINT	X		X	X	MODIFIES SQL DATA
SAVEPOINT	X				MODIFIES SQL DATA
select-statement	X		X	X	READS SQL DATA
SELECT INTO	X		X(10)	X(10)	READS SQL DATA(7)
SET CONNECTION(4)					
SET INTEGRITY			X		MODIFIES SQL DATA
SET special register	X	X	X	X	CONTAINS SQL
SET variable	X	X			CONTAINS SQL
SIGNAL	X	X			MODIFIES SQL DATA
TRANSFER OWNERSHIP			X	X	MODIFIES SQL DATA
TRUNCATE			X	X	MODIFIES SQL DATA
UPDATE	X	X	X		MODIFIES SQL DATA
VALUES INTO	X		X	X	READS SQL DATA
WHENEVER	X		X		NO SQL(3)
WHILE	X	X			

**Note:**

1. Compound SQL (compiled) statements can be used as the body of SQL procedures, SQL functions, triggers, or as stand-alone statements.
2. Compound SQL (inline) statements can be used as the body of SQL functions, SQL methods, triggers, or as stand-alone statements.
3. Although the NO SQL option implies that no SQL statements can be specified, non-executable statements are not restricted.
4. Connection management statements are not allowed in any routine execution context.
5. This situation depends on the statement being executed. The statement specified for the EXECUTE statement must be allowed in the context of the

particular SQL access level in effect. For example, if the SQL access level READS SQL DATA is in effect, the statement cannot be INSERT, UPDATE, or DELETE.

6. The COMMIT statement and the ROLLBACK statement (without the TO SAVEPOINT clause) can be used in a stored procedure, but only if the stored procedure is called directly from an application, or indirectly through nested stored procedure calls from an application. If any trigger, function, method, or atomic compound statement is in the call chain to the stored procedure, a COMMIT or a ROLLBACK of a unit of work is not allowed.
7. If the SQL access level READS SQL DATA is in effect, no SQL data change statement can be embedded in the SELECT INTO statement, or in the cursor referenced by the OPEN statement.
8. SQL procedures can only issue CREATE and DROP statements for indexes, tables, and views.
9. The DESCRIBE SQL statement has a different syntax than that of the CLP DESCRIBE command.
10. This is only supported for embedded SQL routines.
11. When referenced in an SQL procedure, the statement can only be executed statically.

## Errors

Table 5 on page 37 indicates whether the SQL statement specified by the first column is allowed to execute inside a routine that has the specified SQL data access level. If the statement exceeds the data access level, an error is returned when the routine is executed.

- If an executable SQL statement is encountered inside a routine defined with the NO SQL data access level, then SQLSTATE 38001 is returned.
- For other execution contexts, the SQL statements that are unsupported in any context return an SQLSTATE 38003 error.
- For other SQL statements that are not allowed in a CONTAINS SQL context, SQLSTATE 38004 is returned.
- In a READS SQL DATA context, SQLSTATE 38002 is returned.
- During creation of an SQL routine, a statement that does not match the SQL data access level returns an SQLSTATE 42985 error.

## SQL access levels in routines

The degree to which routines can execute SQL statements is determined by the SQL access level of the routine. The SQL access level for a routine is determined by both what is permitted for the particular type of routine and what limitation is specified explicitly within the CREATE statement that defines a routine.

The SQL access levels follow:

- NO SQL
- CONTAINS SQL
- READS SQL
- MODIFIES SQL

This SQL access level clause is used to provide information to the database manager about the statement so that the statement can be executed safely by the database manager and with the best possible performance.

The default and maximal SQL access levels for different types of routines are shown below:

*Table 6. Default and maximum SQL access levels for routines*

Routine type	Default SQL access level	Maximum allowed SQL access level
SQL procedures	MODIFIES SQL DATA	MODIFIES SQL DATA
SQL functions (scalar functions)	READS SQL DATA	READS SQL DATA
SQL functions (table functions)	READS SQL DATA	MODIFIES SQL DATA
External procedures	MODIFIES SQL DATA	MODIFIES SQL DATA
External functions (scalar functions)	READS SQL DATA	READS SQL DATA
External functions (table functions)	READS SQL DATA	READS SQL DATA

Optimal performance of routines is achieved when the most restrictive SQL access clause that is valid is specified in the routine CREATE statement.

In the CREATE statement for a routine:

- If you explicitly specify READS SQL DATA, no SQL statement in the routine can modify data.
- If you explicitly specify CONTAINS SQL DATA, no SQL statement in the routine can modify or read data.
- If you explicitly specify NO SQL, there must be no executable SQL statements in the routine.

## Determining what SQL statements can be executed in routines

### Before you begin

Many, but not all SQL statements can be executed in routines. Execution of a particular SQL statement within a routine is dependent on the type of routine, the implementation of the routine, the maximum SQL access level specified for the routine, and the privileges of the routine definer and invoker.

Determining what SQL statements can be executed within a routine before you implement your routine can ensure that you make the right choice of routine type and implementation from the start.

To successfully execute a SQL statement in a routine, the following prerequisites must be met:

- The SQL access level of the routine must permit the execution of the particular SQL statement.
  - The SQL access level of a routine is specified in the CREATE statement for the routine.
  - Some SQL access levels are not supported for certain types of routines. Refer to the restrictions below.
- The routine definer must have the necessary privileges to execute the SQL statement.
  - The privileges required to execute every supported SQL statement are provided in the SQL Reference.
- No other separate restriction restricts the execution of the statement.
  - Refer to the SQL Reference for a list of restrictions specific to the given SQL statement.

The following restrictions limit the set of SQL statements that can be executed within routines. In particular these restrictions limit what SQL access levels can be specified for particular types of routines:

- External functions cannot be specified with the MODIFIES SQL DATA access level.
- External procedures that will be called from a trigger cannot be specified with a MODIFIES SQL DATA access level.

## Procedure

To determine what SQL statements can be invoked in a particular routine, do the following:

1. Determine the SQL access level of the routine. If it is an existing routine, examine the CREATE statement that was used to create the routine. The SQL access level clause might be explicitly defined in the DDL as one of: NO SQL, CONTAINS SQL, READS SQL DATA, or MODIFIES SQL DATA. If no such clause is explicitly specified, then the default value for the routine is implied.
  - For SQL procedures the default is MODIFIES SQL DATA.
  - For SQL functions the default is MODIFIES SQL DATA.
  - For external procedures the default is MODIFIES SQL DATA.
  - For external functions the default is READS SQL DATA.
2. Refer to the table in the topic, "SQL statements that can be executed in routines". Look up the SQL statement of interest by name.
3. Check if the SQL statement is supported for the specific type of routine and implementation.
4. Verify that the required SQL access level to execute the statement matches the SQL access level of the routine.
5. Carefully read any usage notes or footnotes to ensure that there are no other restrictions on the SQL statement execution.

## Results

If the SQL statement is indicated as being executable within a routine, the routine SQL access level meets the prerequisites for executing the statement within the routine, and all other prerequisites have been met, the SQL statement should be successfully executable from the routine.

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## Portability of routines

Routine portability refers to the ease with which a routine can be deployed. Portability comprises such factors as operating system compatibility, runtime environment compatibility, software compatibility, invocation interface compatibility as well as other routine implementation factors such as compatibility of support for the SQL statements executed within a routine.

Routine portability is essential if the environment to which you will deploy a routine is not identical to the environment in which the routine was developed. In general DB2 routines are highly portable between operating systems and even between the various DB2 database products and editions. It is a good idea to consider the potential portability problems before you begin developing routines so that you minimize the likelihood of rework later.

The following topics include information related to factors that can limit the portability of routines:

- Supported DB2 Database for Linux, UNIX, and Windows editions
- Supported development and compiler software
- SQL statements that can be executed in routines
- Restrictions on routines
- Deploying routines

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## Interoperability of routines

The interoperability of routines of different types and with different programming implementations ensures that routines can be highly re-useable modules throughout the life-span of a database system.

Because code modules are often implemented by different programmers with programming expertise in different programming languages, and because it is generally desirable to reuse code wherever possible to save on development time and costs, DB2 routine infrastructure is designed to support a high degree of routine interoperability. Interoperability of routines is characterized by the ability to reference and invoke routines of different types and implementations from other routines seamlessly and without any additional requirements. DB2 routines are interoperable in the following ways:

- A client application in one programming language can invoke routines that are implemented in a different programming language.
  - For example, C client applications can invoke .NET common language runtime routines.
- A routine can invoke another routine regardless of the routine type or the implementation language of the routine.
  - For example a Java procedure (one type of routine) can invoke an SQL scalar function (another type of routine with a different implementation language).
- A routine created in a database server on one operating system can be invoked from a DB2 client running on a different operating system.

There are various kinds of routines that address particular functional needs and various routine implementations. The choice of routine type and implementation can impact the degree to which the above benefits are exhibited. In general, routines are a powerful way of encapsulating logic so that you can extend your SQL and improve the structure, maintenance, and potentially the performance of your applications.

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## Performance of routines

The performance of routines is impacted by a variety of factors including the type and implementation of the routine, the number of SQL statements within the routine, the degree of complexity of the SQL in the routine, the number of parameters to the routine, the efficiency of the logic within the routine implementation, the error handling within the routines and more.

Because users often choose to implement routines to improve the performance of applications, it is important to get the most out of routine performance.

The following table outlines some of the general factors that impact routine performance and gives recommendations on how to improve routine performance

by altering each factor. For further details on performance factors that impact specific routine types, refer to the performance and tuning topics for the specific routine type.

*Table 7. Performance considerations and routine performance recommendations*

Performance consideration	Performance recommendation
Routine type: procedure, function, method	<ul style="list-style-type: none"> <li>• Procedures, functions, and methods serve different purposes and are referenced in different places. Their functional differences make it difficult to compare their performance directly.</li> <li>• In general procedures can sometimes be rewritten as functions (particularly if they return a scalar value and only query data) and enjoy slight performance improvements, however these benefits are generally a result of simplifying the SQL required to implement the SQL logic.</li> <li>• User-defined functions with complex initializations can make use of scratchpads to store any values required in the first invocation so that they can be used in subsequent invocations.</li> </ul>
Routine implementation: system-defined or user-defined	<ul style="list-style-type: none"> <li>• For equivalent logic, built-in routines perform the best, followed by system-defined routines, because they enjoy a closer relationship with the database engine than do user-defined routines.</li> <li>• User-defined routines can perform very well if they are well coded and follow best practices.</li> </ul>
Routine implementation: SQL or external routine implementation	<ul style="list-style-type: none"> <li>• SQL routines are more efficient than external routines because they are executed directly by the DB2 database server.</li> <li>• SQL procedures generally perform better than logically equivalent external procedures.</li> <li>• For simple logic, SQL function performance will be comparable to that of an equivalent external function.</li> <li>• For complex logic, such as math algorithms and string manipulation functions that require little SQL, it is better to use an external routine in a low level programming language such as C because there is less dependence on SQL support.</li> <li>• See Comparison of routine implementations for a comparison of the features, including performance, of the supported external routine programming language options.</li> </ul>

Table 7. Performance considerations and routine performance recommendations (continued)

Performance consideration	Performance recommendation
External routine implementation programming language	<ul style="list-style-type: none"> <li>• See: Comparison of external routine APIs and programming languages for a comparison of the performance features that you should consider when selecting an external routine implementation.</li> <li>• Java (JDBC and SQLJ APIs)               <ul style="list-style-type: none"> <li>– Java routines with very large memory requirements are best created with the FENCED NOT THREADSAFE clause specified. Java routines with average memory requirements can be specified with the FENCED THREADSAFE clause.</li> <li>– For fenced threadsafe Java routine invocations, DB2 attempts to choose a threaded Java fenced mode process with a Java heap that is large enough to run the routine. Failure to isolate large heap consumers in their own process can result in out-of-Java-heap errors in multi-threaded Java db2fmp processes. FENCED THREADSAFE routines, in contrast, perform better because they can share a small number of JVMs.</li> </ul> </li> <li>• C and C++               <ul style="list-style-type: none"> <li>– In general C and C++ routines perform better than other external routine implementations and as well as SQL routines.</li> <li>– To perform their best C and C++ routines should be compiled in 32-bit format if they will be deployed to a 32-bit DB2 instance and in 64-bit format if they will be deployed to a 64-bit DB2 instance.</li> </ul> </li> <li>• COBOL               <ul style="list-style-type: none"> <li>– In general COBOL performance is good, but COBOL is not a recommended routine implementation.</li> </ul> </li> </ul>
Number of SQL statements within the routine	<ul style="list-style-type: none"> <li>• Routines should contain more than one SQL statement, otherwise the overhead of routine invocation is not performance cost effective.</li> <li>• Logic that must make several database queries, process intermediate results, and ultimately return a subset of the data that was worked with is the best logic for routine encapsulation. Complex data mining, and large updates requiring lookups of related data are examples of this type of logic. Heavy SQL processing is done on the database server and only the smaller data result set is passed back to the caller.</li> </ul>
Complexity of SQL statements within the routine	<ul style="list-style-type: none"> <li>• It makes good sense to include very complex queries within your routines so that you capitalize on the greater memory and performance capabilities of the database server.</li> <li>• Do not worry about the SQL statements being overly complex.</li> </ul>
Static or dynamic SQL execution within routines	<ul style="list-style-type: none"> <li>• In general static SQL performs better than dynamic SQL. In routines there are no additional differences when you use static or dynamic SQL.</li> </ul>



Table 7. Performance considerations and routine performance recommendations (continued)

Performance consideration	Performance recommendation
Number of parameters to routines	<ul style="list-style-type: none"> <li>Minimizing the number of parameters to routines can improve routine performance as this minimizes the number of buffers to be passed between the routine and routine invoker.</li> </ul>
Data types of routine parameters	<ul style="list-style-type: none"> <li>You can improve the performance of routines by using VARCHAR parameters instead of CHAR parameters in the routine definition. Using VARCHAR data types instead of CHAR data types prevents DB2 from padding parameters with spaces before passing the parameter and decreases the amount of time required to transmit the parameter across a network.</li> </ul> <p>For example, if your client application passes the string "A SHORT STRING" to a routine that expects a CHAR(200) parameter, DB2 has to pad the parameter with 186 spaces, null-terminate the string, then send the entire 200 character string and null-terminator across the network to the routine.</p> <p>In comparison, passing the same string, "A SHORT STRING", to a routine that expects a VARCHAR(200) parameter results in DB2 simply passing the 14 character string and a null terminator across the network.</p>
Initialization of parameters to routines	<ul style="list-style-type: none"> <li>It is a good idea to always initialize input parameters to routines, particularly if the input routine parameter values are null. For null value routine parameters, a shorter or empty buffer can be passed to the routine instead of a full sized buffer, which can improve performance.</li> </ul>
Number of local variables in routines	<ul style="list-style-type: none"> <li>Minimizing the number of local variables declared within a routine can improve performance by minimizing the number of SQL statements executed within the routine.</li> <li>In general aim to use as few variables as possible. Re-use variables if this will not be semantically confusing.</li> </ul>
Initialization of local variables in routines	<ul style="list-style-type: none"> <li>If possible, it is a good practice to initialize multiple local variables within a single SQL statement as this saves on the total SQL execution time for the routine.</li> </ul>
Number of result sets returned by procedures	<ul style="list-style-type: none"> <li>If you can reduce the number of result sets returned by a routine you can improve routine performance.</li> </ul>
Size of result sets returned by routines	<ul style="list-style-type: none"> <li>Make sure that for each result set returned by a routine, the query defining the result filters the columns returned and the number of rows returned as much as possible. Returning unnecessary columns or rows of data is not efficient and can result in sub-optimal routine performance.</li> </ul>

Table 7. Performance considerations and routine performance recommendations (continued)

Performance consideration	Performance recommendation
Efficiency of logic within routines	<ul style="list-style-type: none"> <li>• As with any application, the performance of a routine can be limited by a poorly implemented algorithm. Aim to be as efficient as possible when programming routines and apply generally recommended coding best practices as much as possible.</li> <li>• Analyze your SQL and wherever possible reduce your query to its simplest form. This can often be done by using CASE expressions instead of CASE statements or by collapsing multiple SQL statements into a single statement that uses a CASE expression as a switch.</li> </ul>
Run-time mode of routine (FENCED or NOT FENCED clause specification)	<p><b>NOT FENCED clause usage:</b></p> <ul style="list-style-type: none"> <li>• In general, creating your routine with the NOT FENCED clause, which makes it runs in the same process as the DB2 database manager, is preferable over creating it with the FENCED clause, which makes it run in a special DB2 process outside of the engine's address space.</li> <li>• While you can expect improved routine performance when running routines as not fenced, user code in unfenced routines can accidentally or maliciously corrupt the database or damage the database control structures. You should only use the NOT FENCED clause when you need to maximize performance benefits, and if you deem the routine to be secure. (For information on assessing and mitigating the risks of registering C/C++ routines as NOT FENCED, refer to Security of routines. If the routine is not safe enough to run in the database manager's process, use the FENCED clause when creating the routine. To limit the creation and running of potentially unsafe code, DB2 requires that a user have a special privilege, CREATE_NOT_FENCED_ROUTINE in order to create NOT FENCED routines.</li> <li>• If an abnormal termination occurs while you are running a NOT FENCED routine, the database manager will attempt an appropriate recovery if the routine is registered as NO SQL. However, for routines not defined as NO SQL, the database manager will fail.</li> <li>• NOT FENCED routines must be precompiled with the WCHARTYPE NOCONVERT option if the routine uses GRAPHIC or DBCLOB data.</li> </ul>

Table 7. Performance considerations and routine performance recommendations (continued)

Performance consideration	Performance recommendation
Run-time mode of routine (FENCED or NOT FENCED clause specification)	<p><b>FENCED THREADSAFE clause usage</b></p> <ul style="list-style-type: none"> <li>• Routines created with the FENCED THREADSAFE clause run in the same process as other routines. More specifically, non-Java routines share one process, while Java(TM) routines share another process, separate from routines written in other languages. This separation protects Java routines from the potentially more error prone routines written in other languages. Also, the process for Java routines contains a JVM, which incurs a high memory cost and is not used by other routine types. Multiple invocations of FENCED THREADSAFE routines share resources, and therefore incur less system overhead than FENCED NOT THREADSAFE routines, which each run in their own dedicated process.</li> <li>• If you feel your routine is safe enough to run in the same process as other routines, use the THREADSAFE clause when registering it. As with NOT FENCED routines, information on assessing and mitigating the risks of registering C/C++ routines as FENCED THREADSAFE is in the topic, "Security considerations for routines".</li> <li>• If a FENCED THREADSAFE routine abnormally ends, only the thread running this routine is terminated. Other routines in the process continue running. However, the failure that caused this thread to abnormally end can adversely affect other routine threads in the process, causing them to trap, hang, or have damaged data. After one thread abends, the process is no longer used for new routine invocations. Once all the active users complete their jobs in this process, it is terminated.</li> <li>• When you register Java routines, they are deemed THREADSAFE unless you indicate otherwise. All other LANGUAGE types are NOT THREADSAFE by default. Routines using LANGUAGE OLE and OLE DB cannot be specified as THREADSAFE.</li> <li>• NOT FENCED routines must be THREADSAFE. It is not possible to register a routine as NOT FENCED NOT THREADSAFE (SQLCODE -104).</li> <li>• Users on UNIX(R) can see their Java and C THREADSAFE processes by looking for db2fmp (Java) or db2fmp (C).</li> </ul>

Table 7. Performance considerations and routine performance recommendations (continued)

Performance consideration	Performance recommendation
Run-time mode of routine (FENCED or NOT FENCED clause specification)	<p><b>FENCED NOT THREADSAFE mode</b></p> <ul style="list-style-type: none"> <li>FENCED NOT THREADSAFE routines each run in their own dedicated process. If you are running numerous routines, this can have a detrimental effect on database system performance. If the routine is not safe enough to run in the same process as other routines, use the NOT THREADSAFE clause when registering the routine.</li> <li>On UNIX, NOT THREADSAFE processes appear as db2fmp (pid) (where pid is the process id of the agent using the fenced mode process) or as db2fmp (idle) for a pooled NOT THREADSAFE db2fmp.</li> </ul>
Level of SQL access in routine: NO SQL, CONTAINS SQL, READS SQL DATA, MODIFIES SQL DATA	<ul style="list-style-type: none"> <li>Routines that are created with a lower level of SQL access clause will perform better than routines created with a higher level of SQL access clause. Therefore you should declare your routines with the most restrictive level of SQL access clause. For example, if your routine only reads SQL data, do not create it with the MODIFIES SQL DATA clause, but rather create it with the more restrictive READS SQL DATA clause.</li> </ul>
Determinism of routine (DETERMINISTIC or NOT DETERMINISTIC clause specification)	<ul style="list-style-type: none"> <li>Declaring a routine with the DETERMINISTIC or NOT DETERMINISTIC clause has no impact on routine performance.</li> </ul>
Number and complexity of external actions made by routine (EXTERNAL ACTION clause specification)	<ul style="list-style-type: none"> <li>Depending on the number of external actions and the complexity of external actions performed by an external routine, routine performance can be hindered. Factors that contribute to this are network traffic, access to files for writing or reading, the time required to execute the external action, and the risk associated with hangs in external action code or behaviors.</li> </ul>
Routine invocation when input parameters are null (CALLED ON NULL INPUT clause specification)	<ul style="list-style-type: none"> <li>If receiving null input parameter values results in no logic being executed and an immediate return by the routine, you can modify your routine so that it is not fully invoked when null input parameter values are detected. To create a routine that ends invocation early if routine input parameters are received, create the routine and specify the CALLED ON NULL INPUT clause.</li> </ul>
Procedure parameters of type XML	<ul style="list-style-type: none"> <li>The passing of parameters of data type XML is significantly less efficient in external procedures implemented in either the C or JAVA programming language than in SQL procedures. When passing one or more parameters of data type XML, consider using SQL procedures instead of external procedures.</li> <li>XML data is materialized when passed to stored procedures as IN, OUT, or INOUT parameters. If you are using Java stored procedures, the heap size (JAVA_HEAP_SZ configuration parameter) might need to be increased based on the quantity and size of XML arguments, and the number of external stored procedures that are being executed concurrently.</li> </ul>

Once routines are created and deployed, it might be harder to determine what environmental and routine specific factors are impacting routine performance, and hence it is important to design routines with performance in mind.

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## Security of routines

The security of routines is paramount to ensure their continued functioning, to minimize the risk of tampering, and to protect the database system environment. There are a few categories of routine security considerations each with varying levels of risk. One must be aware of these risks when developing or maintaining routines so as to mitigate unfortunate outcomes as much as possible.

### Security control of who can create routines

The security of routines begins when users are given the necessary privileges to execute the CREATE statement required to create routines in the database. When granting these privileges, it is important to understand the corresponding risks:

- Users with the privilege to execute the CREATE statement for a routine can create multiple routines.
- Users with the privilege to execute the CREATE statement for a routine can create routines that can modify the database layout or database data subject to the other privileges that user has.
- Users that successfully create routines are automatically granted the EXECUTE privilege required to invoke the routine.
- Users that successfully create routines are automatically granted the ALTER ROUTINE privilege required to modify the routine.

To minimize the risk of users modifying the database and data:

- Minimize the number of users that have the privilege to create routines.
- Ensure that the user IDs of departed employees are removed, or if they are re-used, be sure to assess the procedure related privileges.

Refer to the topics on controlling access to database objects and data for more on how to grant and revoke privileges from one, many, or all database users.

### Security control of who can invoke routines

It is easy to determine when users require privileges: they are unable to do something. It is harder to determine when users no longer require these privileges. This is particularly true when it comes to users with privileges to invoke routines, as allowing them to retain their privileges can introduce risks:

- Users that have been granted the EXECUTE privilege to invoke a routine will continue to be able to invoke the routine until this privilege is removed. If the routine contains sensitive logic or acts on sensitive data this can be a business risk.

To minimize the risk of users modifying the database and data:

- Minimize the number of users that have the privilege to invoke routines.
- Ensure that the user IDs of departed employees are removed, or if they are re-used, be sure to assess the procedure related privileges.
- If you suspect that someone is maliciously invoking routines, you should revoke the EXECUTE privilege for each of those routines.

## Security control of routines defined with FENCED or NOT FENCED clauses

When formulating the CREATE statement for a routine, you must determine whether you want to specify the FENCED clause or NOT FENCED clause. Once you understand the benefits of creating a routine as fenced or unfenced it is important to assess the risks associated with running routines with external implementations as NOT FENCED.

- Routines created with the NOT FENCED clause can accidentally or maliciously corrupt the database manager's shared memory, damage the database control structures, or access database manager resources which can cause the database manager to fail. There is also the risk that they will corrupt databases and their tables.

To ensure the integrity of the database manager and its databases:

- Thoroughly screen routines you intend to create that specify the NOT FENCED clause. These routines must be fully tested, debugged, and not exhibit any unexpected side-effects. In the examination of the routine code, pay close attention to memory management and the use of static variables. The greatest potential for corruption arises when code does not properly manage memory or incorrectly uses static variables. These problems are prevalent in languages other than Java and .NET programming languages.

In order to register a NOT FENCED routine, the CREATE\_NOT\_FENCED\_ROUTINE authority is required. When granting the CREATE\_NOT\_FENCED\_ROUTINE authority, be aware that the recipient can potentially gain unrestricted access to the database manager and all its resources.

**Note:** NOT FENCED routines are not supported in Common Criteria compliant configurations.

## Securing routines

### Before you begin

When creating routines it is important to ensure that the routines, routine libraries (in the case of external routines), and the privileges of the users that will interact with the routines are managed with routine security in mind.

Although it might not be necessary to have anything as elaborate as a routine security strategy, it helps to be mindful of the factors contributing to the security of routines and to follow a disciplined approach when securing routines.

- Read the topic, "Security of routines".
- To fully secure routines within the database system you must have:
  - Root user access on the database server operating system.
  - One of the SECADM or ACCESSCTRL authorities.

### About this task

Whether you are creating a routine, or assessing an existing routine, the procedure for securing a routine is similar.

## Procedure

1. Limit the number of user IDs with the privileges required to create routines and ensure that these users are allowed to have these privileges.
  - Upon successful execution of the CREATE statement for a routine, this user ID will automatically be granted other privileges including the EXECUTE privilege, which allows the user to invoke the routine, and the GRANT EXECUTE privilege, which allows the user to grant the ability to invoke the routine to other users.
  - Ensure that the users with this privilege are few and that the right users get this privilege.
2. Assess the routine for potentially malicious or inadequately reviewed or tested code.
  - Consider the origin of the routine. Is the party that supplied the routine reliable?
  - Look for malicious code such as code that attempts to read or write to the database server file system and or replace files there.
  - Look for poorly implemented code related to memory management, pointer manipulation, and the use of static variables that might cause the routine to fail.
  - Verify that the code has been adequately tested.
3. Reject routines that appear to be excessively unsafe or poorly coded - the risk is not always worth it.
4. Contain the risks associated with only somewhat potentially risky routines.
  - SQL user-defined SQL routines are by default created as NOT FENCED THREADSAFE routines, because they are safe to run within the database manager memory space. For these routines you do not need to do anything.
  - Specify the FENCED clause in the CREATE statement for the routine. This will ensure that the routine operation does not affect the database manager. This is a default clause.
  - If the routine is multi-threaded, specify the NOT THREADSAFE clause in the CREATE statement for the routine. This will ensure that any failures or malicious code in the routine do not impact other routines that might run in a shared thread process.
5. If the routine is an external routine, you must put the routine implementation library or class file on the database server. Follow the general recommendations for deploying routines and the specific recommendations for deploying external routine library or class files.

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## Authorizations and binding of routines that contain SQL

When discussing routine level authorization it is important to define some roles related to routines, the determination of the roles, and the privileges related to these roles:

### Package Owner

The owner of a particular package that participates in the implementation of a routine. The package owner is the user who executes the BIND command to bind a package with a database, unless the OWNER precompile/BIND option is used to override the package ownership and set it to an alternate user. Upon execution of the BIND command, the package owner is granted EXECUTE WITH GRANT privilege on the

package. A routine library or executable can be comprised of multiple packages and therefore can have multiple package owners associated with it.

### **Routine Definer**

The ID that issues the CREATE statement to register a routine. The routine definer is generally a DBA, but is also often the routine package owner. When a routine is invoked, at package load time, the authorization to run the routine is checked against the definer's authorization to execute the package or packages associated with the routine (not against the authorization of the routine invoker). For a routine to be successfully invoked, the routine definer must have one of:

- EXECUTE privilege on the package or packages of the routine and EXECUTE privilege on the routine
- DATAACCESS authority

If the routine definer and the routine package owner are the same user, then the routine definer will have the required EXECUTE privileges on the packages. If the definer is not the package owner, the definer must be explicitly granted EXECUTE privilege on the packages by any user with ACCESSCTRL or SECADM authority, CONTROL or EXECUTE WITH GRANT OPTION privilege on the package. (The creator of a package automatically receives CONTROL and EXECUTE WITH GRANT OPTION on the package.)

Upon issuing the CREATE statement that registers the routine, the definer is implicitly granted the EXECUTE WITH GRANT OPTION privilege on the routine.

The routine definer's role is to encapsulate under one authorization ID, the privileges of running the packages associated with a routine and the privilege of granting EXECUTE privilege on the routine to PUBLIC or to specific users that need to invoke the routine.

**Note:** For SQL routines the routine definer is also implicitly the package owner. Therefore the definer will have EXECUTE WITH GRANT OPTION on both the routine and on the routine package upon execution of the CREATE statement for the routine.

### **Routine Invoker**

The ID that invokes the routine. To determine which users will be invokers of a routine, it is necessary to consider how a routine can be invoked. Routines can be invoked from a command window or from within an embedded SQL application. In the case of methods and UDFs the routine reference will be embedded in another SQL statement. A procedure is invoked by using the CALL statement. For dynamic SQL in an application, the invoker is the runtime authorization ID of the immediately higher-level routine or application containing the routine invocation (however, this ID can also depend on the DYNAMICRULES option with which the higher-level routine or application was bound). For static SQL, the invoker is the value of the OWNER precompile/BIND option of the package that contains the reference to the routine. To successfully invoke the routine, these users will require EXECUTE privilege on the routine. This privilege can be granted by any user with EXECUTE WITH GRANT OPTION privilege on the routine (this includes the routine definer unless the privilege has been explicitly revoked), ACCESSCTRL, or SECADM authority, by explicitly issuing a GRANT statement.



As an example, if a package associated with an application containing dynamic SQL was bound with `DYNAMICRULES BIND`, then its runtime authorization ID will be its package owner, not the person invoking the package. Also, the package owner will be the actual binder or the value of the `OWNER precompile/bind` option. In this case, the invoker of the routine assumes this value rather than the ID of the user who is executing the application.

**Note:**

1. For static SQL within a routine, the package owner's privileges must be sufficient to execute the SQL statements in the routine body. These SQL statements might require table access privileges or execute privileges if there are any nested references to routines.
2. For dynamic SQL within a routine, the userid whose privileges will be validated are governed by the `DYNAMICRULES` option of the `BIND` of the routine body.
3. The routine package owner must `GRANT EXECUTE` on the package to the routine definer. This can be done before or after the routine is registered, but it must be done before the routine is invoked otherwise an error (`SQLSTATE 42051`) will be returned.

The steps involved in managing the execute privilege on a routine are detailed in the diagram and text that follows:

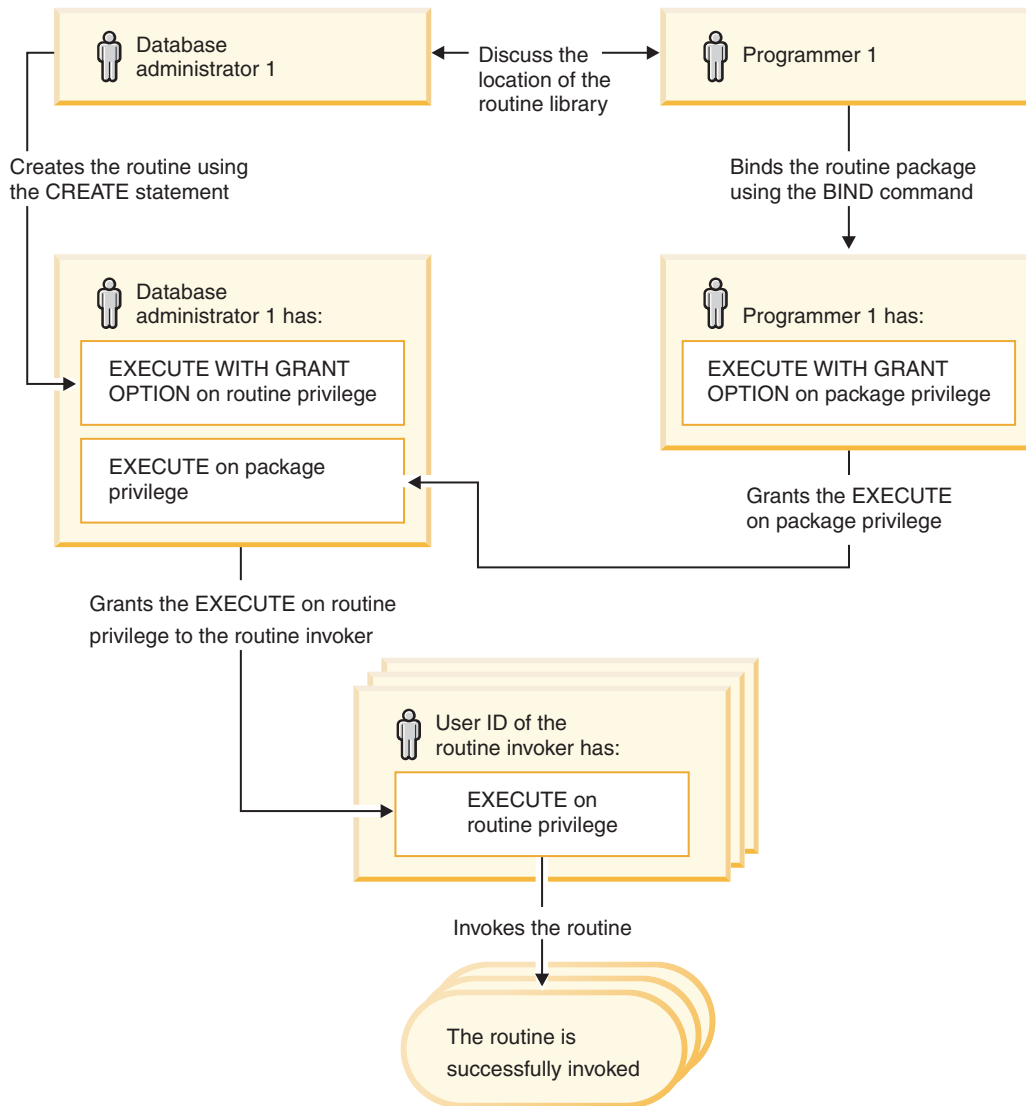


Figure 2. Managing the EXECUTE privilege on routines

1. Definer performs the appropriate CREATE statement to register the routine. This registers the routine in DB2 with its intended level of SQL access, establishes the routine signature, and also points to the routine executable. The definer, if not also the package owner, needs to communicate with the package owners and authors of the routine programs to be clear on where the routine libraries reside so that this can be correctly specified in the EXTERNAL clause of the CREATE statement. By virtue of a successful CREATE statement, the definer has EXECUTE WITH GRANT privilege on the routine, however the definer does not yet have EXECUTE privilege on the packages of the routine.
2. Definer must grant EXECUTE privilege on the routine to any users who are to be permitted use of the routine. (If the package for this routine will recursively call this routine, then this step must be done before the next step.)
3. Package owners precompile and bind the routine program, or have it done on their behalf. Upon a successful precompile and bind, the package owner is implicitly granted EXECUTE WITH GRANT OPTION privilege on the respective package. This step follows step one in this list only to cover the

possibility of SQL recursion in the routine. If such recursion does not exist in any particular case, the precompile/bind could precede the issuing of the CREATE statement for the routine.

4. Each package owner must explicitly grant EXECUTE privilege on their respective routine package to the definer of the routine. This step must come at some time after the previous step. If the package owner is also the routine definer, this step can be skipped.
5. Static usage of the routine: the bind owner of the package referencing the routine must have been given EXECUTE privilege on the routine, so the previous step must be completed at this point. When the routine executes, DB2 verifies that the definer has the EXECUTE privilege on any package that is needed, so step 3 must be completed for each such package.
6. Dynamic usage of the routine: the authorization ID as controlled by the DYNAMICRULES option for the invoking application must have EXECUTE privilege on the routine (step 4), and the definer of the routine must have the EXECUTE privilege on the packages (step 3).

---

## Data conflicts when procedures read from or write to tables

To preserve the integrity of the database, it is necessary to avoid conflicts when reading from and writing to tables. For example, suppose an application is updating the EMPLOYEE table, and the statement calls a routine. Suppose that the routine tries to read the EMPLOYEE table and encounters the row being updated by the application. The row is in an indeterminate state from the perspective of the routine- perhaps some columns of the row have been updated while other have not. If the routine acts on this partially updated row, it can take incorrect actions. To avoid this sort of problem, DB2 does not allow operations that conflict on any table.

To describe how DB2 avoids conflicts when reading from and writing to tables from routines, the following two terms are needed:

### top-level statement

A top-level statement is any SQL statement issued from an application, or from a stored procedure that was invoked as a top-level statement. If a procedure is invoked within a dynamic compound statement or a trigger, the compound statement or the statement that causes the firing of the trigger is the top-level statement. If an SQL function or an SQL method contains a nested CALL statement, the statement invoking the function or the method is the top-level statement.

### table access context

A table access context refers to the scope where conflicting operations on a table are allowed. A table access context is created whenever:

- A top-level statement issues an SQL statement.
- A UDF or method is invoked.
- A procedure is invoked from a trigger, a dynamic compound statement, an SQL function or an SQL method.

For example, when an application calls a stored procedure, the CALL is a top-level statement and therefore gets a table access context. If the stored procedure does an UPDATE, the UPDATE is also a top-level statement (because the stored procedure was invoked as a top-level statement) and therefore gets a table access context. If the UPDATE invokes a UDF, the UDF gets a separate table access context and SQL statements inside the UDF are not top-level statements.

Once a table has been accessed for reading or writing, it is protected from conflicts within the top-level statement that made the access. The table can be read or written from a different top-level statement or from a routine invoked from a different top-level statement.

The following rules are applied:

1. Within a table access context, a given table can be both read from and written to without causing a conflict.
2. If a table is being read within a table access context then other contexts can also read the table. If any other context attempts to write to the table, however, a conflict occurs.
3. If a table is being written within a table access context, then no other context can read or write to the table without causing a conflict.

If a conflict occurs, an error (SQLCODE -746, SQLSTATE 57053) is returned to the statement that caused the conflict.

The following is an example of table read and write conflicts:

Suppose an application issues the statement:

```
UPDATE t1 SET c1 = udf1(c2)
```

UDF1 contains the statements:

```
DECLARE cur1 CURSOR FOR SELECT c1, c2 FROM t1  
OPEN cur1
```

This will result in a conflict because rule 3 is violated. This form of conflict can only be resolved by redesigning the application or UDF.

The following does not result in a conflict:

Suppose an application issues the statements:

```
DECLARE cur2 CURSOR FOR SELECT udf2(c1) FROM t2  
OPEN cur2  
FETCH cur2 INTO :hv  
UPDATE t2 SET c2 = 5
```

UDF2 contains the statements:

```
DECLARE cur3 CURSOR FOR SELECT c1, c2 FROM t2  
OPEN cur3  
FETCH cur3 INTO :hv
```

With the cursor, UDF2 is allowed to read table T2 because two table access contexts can read the same table. The application is allowed to update T2 even though UDF2 is reading the table because UDF2 was invoked in a different application level statement than the update.

---

## Chapter 3. External routines

External routines are routines that have their logic implemented in a programming language application that resides outside of the database, in the file system of the database server. The association of the routine with the external code application is asserted by the specification of the EXTERNAL clause in the CREATE statement of the routine.

You can create external procedures, external functions, and external methods. Although they are all implemented in external programming languages, each routine functional type has different features. Before deciding to implement an external routine, it is important that you first understand what external routines are, and how they are implemented and used, by reading the topic, "Overview of external routines". With that knowledge you can then learn more about external routines from the topics targeted by the related links so that you can make informed decisions about when and how to use them in your database environment.

---

### External routine features

External routines provide support for most of the common routine features as well as support for additional features not supported by SQL routines.

The following features are unique to external routines:

#### **Access to files, data, and applications residing outside of the database**

External routines can access and manipulate data or files that reside outside of the database itself. They can also invoke applications that reside outside of the database. The data, files, or applications might, for example, reside in the database server file system or within the available network.

#### **Variety of external routine parameter style options**

The implementation of external routines in a programming language can be done using a choice of parameter styles. Although there might be a preferred parameter style for a chosen programming language, there is sometimes choice. Some parameter styles provide support for the passing of additional database and routine property information to and from the routine in a structure named dbinfo structure that might be useful within the routine logic.

#### **Preservation of state between external function invocations with a scratchpad**

External user-defined functions provide support for state preservation between function invocations for a set of values. This is done with a structure called a scratchpad. This can be useful both for functions that return aggregated values and for functions that require initial setup logic such as initialization of buffers.

#### **Call-types identify individual external function invocations**

External user-defined functions are invoked multiple times for a set of values. Each invocation is identified with a call-type value that can be referenced within the function logic. For example there are special call-types for the first invocation of a function, for data fetching calls, and for the final invocation. Call-types are useful, because specific logic can be associated with a particular call-type.

## External function and method features

External functions and external methods provide support for functions that, for a given set of input data, might be invoked multiple times and produce a set of output values.

To learn more about the features of external functions and methods, see the following topics:

- “External scalar functions”
- “External scalar function and method processing model” on page 61
- “External table functions” on page 62
- “External table function processing model” on page 63
- “Table function execution model for Java” on page 64
- “Scratchpads for external functions and methods” on page 65
- “Scratchpads on 32-bit and 64-bit operating systems” on page 68

These features are unique to external functions and methods and do not apply to SQL functions and SQL methods.

### External scalar functions

External scalar functions are scalar functions that have their logic implemented in an external programming language.

These functions can be developed and used to extend the set of existing SQL functions and can be invoked in the same manner as DB2 built-in functions such as LENGTH and COUNT. That is, they can be referenced in SQL statements wherever an expression is valid.

The execution of external scalar function logic takes place on the DB2 database server, however unlike built-in or user-defined SQL scalar functions, the logic of external functions can access the database server filesystem, perform system calls or access a network.

External scalar functions can read SQL data, but cannot modify SQL data.

External scalar functions can be repeatedly invoked for a single reference of the function and can maintain state between these invocations by using a scratchpad, which is a memory buffer. This can be powerful if a function requires some initial, but expensive, setup logic. The setup logic can be done on a first invocation using the scratchpad to store some values that can be accessed or updated in subsequent invocations of the scalar function.

### Features of external scalar functions

- Can be referenced as part of an SQL statement anywhere an expression is supported.
- The output of a scalar function can be used directly by the invoking SQL statement.
- For external scalar user-defined functions, state can be maintained between the iterative invocations of the function by using a scratchpad.
- Can provide a performance advantage when used in predicates, because they are executed at the server. If a function can be applied to a candidate row at the server, it can often eliminate the row from consideration before transmitting it to the client machine, reducing the amount of data that must be passed from server to client.

## Limitations

- Cannot do transaction management within a scalar function. That is, you cannot issue a COMMIT or a ROLLBACK within a scalar function.
- Cannot return result sets.
- Scalar functions are intended to return a single scalar value per set of inputs.
- External scalar functions are not intended to be used for a single invocation. They are designed such that for a single reference to the function and a given set of inputs, that the function be invoked once per input, and return a single scalar value. On the first invocation, scalar functions can be designed to do some setup work, or store some information that can be accessed in subsequent invocations. SQL scalar functions are better suited to functionality that requires a single invocation.
- In a single partition database external scalar functions can contain SQL statements. These statements can read data from tables, but cannot modify data in tables. If the database has more than one partition then there must be no SQL statements in an external scalar function. SQL scalar functions can contain SQL statements that read or modify data.

## Common uses

- Extend the set of DB2 built-in functions.
- Perform logic inside an SQL statement that SQL cannot natively perform.
- Encapsulate a scalar query that is commonly reused as a subquery in SQL statements. For example, given a postal code, search a table for the city where the postal code is found.

## Supported languages

- C
- C++
- Java
- OLE
- .NET common language runtime languages

## Note:

1. There is a limited capability for creating aggregate functions. Also known as column functions, these functions receive a set of like values (a column of data) and return a single answer. A user-defined aggregate function can only be created if it is sourced upon a built-in aggregate function. For example, if a distinct type SHOESIZE exists that is defined with base type INTEGER, you could define a function, AVG(SHOESIZE), as an aggregate function sourced on the existing built-in aggregate function, AVG(INTEGER).
2. You can also create function that return a row. These are known as row functions and can only be used as a transform function for structured types. The output of a row function is a single row.

## External scalar function and method processing model

The processing model for methods and scalar UDFs that are defined with the FINAL CALL specification is as follows:

### FIRST call

This is a special case of the NORMAL call, identified as FIRST to enable the function to perform any initial processing. Arguments are evaluated

and passed to the function. Normally, the function will return a value on this call, but it can return an error, in which case no NORMAL or FINAL call is made. If an error is returned on a FIRST call, the method or UDF must clean up before returning, because no FINAL call will be made.

#### **NORMAL call**

These are the second through second-last calls to the function, as dictated by the data and the logic of the statement. The function is expected to return a value with each NORMAL call after arguments are evaluated and passed. If NORMAL call returns an error, no further NORMAL calls are made, but the FINAL call is made.

#### **FINAL call**

This is a special call, made at end-of-statement processing (or CLOSE of a cursor), provided that the FIRST call succeeded. No argument values are passed on a FINAL call. This call is made so that the function can clean up any resources. The function does not return a value on this call, but can return an error.

For methods or scalar UDFs not defined with FINAL CALL, only NORMAL calls are made to the function, which normally returns a value for each call. If a NORMAL call returns an error, or if the statement encounters another error, no more calls are made to the function.

**Note:** This model describes the ordinary error processing for methods and scalar UDFs. In the event of a system failure or communication problem, a call indicated by the error processing model cannot be made. For example, for a FENCED UDF, if the `db2udf fenced` process is somehow prematurely terminated, DB2 cannot make the indicated calls.

### **External table functions**

A user-defined table function delivers a table to the SQL in which it is referenced. A table UDF reference is only valid in a FROM clause of a SELECT statement. When using table functions, observe the following:

- Even though a table function delivers a table, the physical interface between DB2 and the UDF is one-row-at-a-time. There are five types of calls made to a table function: OPEN, FETCH, CLOSE, FIRST, and FINAL. The existence of FIRST and FINAL calls depends on how you define the UDF. The same *call-type* mechanism that can be used for scalar functions is used to distinguish these calls.
- Not every result column defined in the RETURNS clause of the CREATE FUNCTION statement for the table function has to be returned. The DBINFO keyword of CREATE FUNCTION, and corresponding *dbinfo* argument enable the optimization that only those columns needed for a particular table function reference need be returned.
- The individual column values returned conform in format to the values returned by scalar functions.
- The CREATE FUNCTION statement for a table function has a CARDINALITY specification. This specification enables the definer to inform the DB2 optimizer of the approximate size of the result so that the optimizer can make better decisions when the function is referenced.

Regardless of what has been specified as the CARDINALITY of a table function, exercise caution against writing a function with infinite cardinality, that is, a function that always returns a row on a FETCH call. There are many situations where DB2 expects the end-of-table condition, as a catalyst within its query processing. Using GROUP BY or ORDER BY are examples where this is the case.



DB2 cannot form the groups for aggregation until end-of-table is reached, and it cannot sort until it has all the data. So a table function that never returns the end-of-table condition (SQL-state value '02000') can cause an infinite processing loop if you use it with a GROUP BY or ORDER BY clause.

## External table function processing model

The processing model for table UDFs that are defined with the FINAL CALL specification is as follows:

### FIRST call

This call is made before the first OPEN call, and its purpose is to enable the function to perform any initial processing. The scratchpad is cleared prior to this call. Arguments are evaluated and passed to the function. The function does not return a row. If the function returns an error, no further calls are made to the function.

### OPEN call

This call is made to enable the function to perform special OPEN processing specific to the scan. The scratchpad (if present) is not cleared prior to the call. Arguments are evaluated and passed. The function does not return a row on an OPEN call. If the function returns an error from the OPEN call, no FETCH or CLOSE call is made, but the FINAL call will still be made at end of statement.

### FETCH call

FETCH calls continue to be made until the function returns the SQLSTATE value signifying end-of-table. It is on these calls that the UDF develops and returns a row of data. Argument values can be passed to the function, but they are pointing to the same values that were passed on OPEN. Therefore, the argument values might not be current and should not be relied upon. If you do need to maintain current values between the invocations of a table function, use a scratchpad. The function can return an error on a FETCH call, and the CLOSE call will still be made.

### CLOSE call

This call is made at the conclusion of the scan or statement, provided that the OPEN call succeeded. Any argument values will not be current. The function can return an error.

### FINAL call

The FINAL call is made at the end of the statement, provided that the FIRST call succeeded. This call is made so that the function can clean up any resources. The function does not return a value on this call, but can return an error.

For table UDFs not defined with FINAL CALL, only OPEN, FETCH, and CLOSE calls are made to the function. Before each OPEN call, the scratchpad (if present) is cleared.

The difference between table UDFs that are defined with FINAL CALL and those defined with NO FINAL CALL can be seen when examining a scenario involving a join or a subquery, where the table function access is the "inner" access. For example, in a statement such as:

```
SELECT x,y,z,... FROM table_1 as A,  
       TABLE(table_func_1(A.col1,...)) as B  
WHERE ...
```

In this case, the optimizer would open a scan of table\_func\_1 for each row of table\_1. This is because the value of table\_1's col1, which is passed to table\_func\_1, is used to define the table function scan.

For NO FINAL CALL table UDFs, the OPEN, FETCH, FETCH, ..., CLOSE sequence of calls repeats for each row of table\_1. Note that each OPEN call will get a clean scratchpad. Because the table function does not know at the end of each scan whether there will be more scans, it must clean up completely during CLOSE processing. This could be inefficient if there is significant one-time open processing that must be repeated.

FINAL CALL table UDFs, provide a one-time FIRST call, and a one-time FINAL call. These calls are used to amortize the expense of the initialization and termination costs across all the scans of the table function. As before, the OPEN, FETCH, FETCH, ..., CLOSE calls are made for each row of the outer table, but because the table function knows it will get a FINAL call, it does not need to clean everything up on its CLOSE call (and reallocate on subsequent OPEN). Also note that the scratchpad is not cleared between scans, largely because the table function resources will span scans.

At the expense of managing two additional call types, the table UDF can achieve greater efficiency in these join and subquery scenarios. Deciding whether to define the table function as FINAL CALL depends on how it is expected to be used.

### Table function execution model for Java

For table functions written in Java and using PARAMETER STYLE DB2GENERAL, it is important to understand what happens at each point in DB2's processing of a given statement. The following table details this information for a typical table function. Covered are both the NO FINAL CALL and the FINAL CALL cases, assuming SCRATCHPAD in both cases.

Point in scan time	NO FINAL CALL LANGUAGE JAVA SCRATCHPAD	FINAL CALL LANGUAGE JAVA SCRATCHPAD
Before the first OPEN for the table function	<ul style="list-style-type: none"> <li>No calls.</li> </ul>	<ul style="list-style-type: none"> <li>Class constructor is called (means new scratchpad). UDF method is called with FIRST call.</li> <li>Constructor initializes class and scratchpad variables. Method connects to Web server.</li> </ul>
At each OPEN of the table function	<ul style="list-style-type: none"> <li>Class constructor is called (means new scratchpad). UDF method is called with OPEN call.</li> <li>Constructor initializes class and scratchpad variables. Method connect to Web server, and opens the scan for Web data.</li> </ul>	<ul style="list-style-type: none"> <li>UDF method is opened with OPEN call.</li> <li>Method opens the scan for whatever Web data it wants. (Might be able to avoid reopen after a CLOSE reposition, depending on what is saved in the scratchpad.)</li> </ul>
At each FETCH for a new row of table function data	<ul style="list-style-type: none"> <li>UDF method is called with FETCH call.</li> <li>Method fetches and returns next row of data, or EOT.</li> </ul>	<ul style="list-style-type: none"> <li>UDF method is called with FETCH call.</li> <li>Method fetches and returns new row of data, or EOT.</li> </ul>

Point in scan time	NO FINAL CALL LANGUAGE JAVA SCRATCHPAD	FINAL CALL LANGUAGE JAVA SCRATCHPAD
At each CLOSE of the table function	<ul style="list-style-type: none"> <li>UDF method is called with CLOSE call. <code>close()</code> method if it exists for class.</li> <li>Method closes its Web scan and disconnects from the Web server. <code>close()</code> does not need to do anything.</li> </ul>	<ul style="list-style-type: none"> <li>UDF method is called with CLOSE call.</li> <li>Method might reposition to the top of the scan, or close the scan. It can save any state in the scratchpad, which will persist.</li> </ul>
After the last CLOSE of the table function	<ul style="list-style-type: none"> <li>No calls.</li> </ul>	<ul style="list-style-type: none"> <li>UDF method is called with FINAL call. <code>close()</code> method is called if it exists for class.</li> <li>Method disconnects from the Web server. <code>close()</code> method does not need to do anything.</li> </ul>

**Note:**

- The term "UDF method" refers to the Java class method that implements the UDF. This is the method identified in the EXTERNAL NAME clause of the CREATE FUNCTION statement.

### Scratchpads for external functions and methods

A *scratchpad* enables a user-defined function or method to save its state from one invocation to the next.

For example, here are two situations where saving state between invocations is beneficial:

- Functions or methods that, to be correct, depend on saving state.

An example of such a function or method is a simple counter function that returns a '1' the first time it is called, and increments the result by one each successive call. Such a function could, in some circumstances, be used to number the rows of a SELECT result:

```
SELECT counter(), a, b+c, ...
FROM tablex
WHERE ...
```

The function needs a place to store the current value for the counter between invocations, where the value will be guaranteed to be the same for the following invocation. On each invocation, the value can then be incremented and returned as the result of the function.

This type of routine is NOT DETERMINISTIC. Its output does not depend solely on the values of its SQL arguments.

- Functions or methods where the performance can be improved by the ability to perform some initialization actions.

An example of such a function or method, which might be a part of a document application, is a *match* function, which returns 'Y' if a given document contains a given string, and 'N' otherwise:

```
SELECT docid, doctitle, docauthor
FROM docs
WHERE match('myocardial infarction', docid) = 'Y'
```

This statement returns all the documents containing the particular text string value represented by the first argument. What *match* would like to do is:

- First time only.  
Retrieve a list of all the document IDs that contain the string 'myocardial infarction' from the document application, that is maintained outside of DB2. This retrieval is a costly process, so the function would like to do it only one time, and save the list somewhere handy for subsequent calls.
- On each call.  
Use the list of document IDs saved during the first call to see if the document ID that is passed as the second argument is contained in the list. This type of routine is DETERMINISTIC. Its answer only depends on its input argument values. What is shown here is a function whose performance, not correctness, depends on the ability to save information from one call to the next.

Both of these needs are met by the ability to specify a SCRATCHPAD in the CREATE statement:

```
CREATE FUNCTION counter()
  RETURNS int ... SCRATCHPAD;

CREATE FUNCTION match(varchar(200), char(15))
  RETURNS char(1) ... SCRATCHPAD 10000;
```

The SCRATCHPAD keyword tells DB2 to allocate and maintain a scratchpad for a routine. The default size for a scratchpad is 100 bytes, but you can determine the size (in bytes) for a scratchpad. The *match* example is 10000 bytes long. DB2 initializes the scratchpad to binary zeros before the first invocation. If the scratchpad is being defined for a table function, and if the table function is also defined with NO FINAL CALL (the default), DB2 refreshes the scratchpad before each OPEN call. If you specify the table function option FINAL CALL, DB2 does not examine or change the content of the scratchpad after its initialization. For scalar functions defined with scratchpads, DB2 also does not examine or change the scratchpad's content after its initialization. A pointer to the scratchpad is passed to the routine on each invocation, and DB2 preserves the routine's state information in the scratchpad.

So for the *counter* example, the last value returned could be kept in the scratchpad. And the *match* example could keep the list of documents in the scratchpad if the scratchpad is big enough, otherwise it could allocate memory for the list and keep the address of the acquired memory in the scratchpad. Scratchpads can be variable length: the length is defined in the CREATE statement for the routine.

The scratchpad only applies to the individual reference to the routine in the statement. If there are multiple references to a routine in a statement, each reference has its own scratchpad, thus scratchpads cannot be used to communicate between references. The scratchpad only applies to a single DB2 agent (an agent is a DB2 entity that performs processing of all aspects of a statement). There is no "global scratchpad" to coordinate the sharing of scratchpad information between the agents. This is especially important for situations where DB2 establishes multiple agents to process a statement (in either a single partition or multiple partition database). In these cases, even though there might only be a single reference to a routine in a statement, there could be multiple agents doing the work, and each would have its own scratchpad. In a multiple partition database, where a statement referencing a UDF is processing data on multiple partitions, and invoking the UDF on each partition, the scratchpad would only apply to a single partition. As a result, there is a scratchpad on each partition where the UDF is executed.

If the correct execution of a function depends on there being a single scratchpad per reference to the function, then register the function as `DISALLOW PARALLEL`. This will force the function to run on a single partition, thereby guaranteeing that only a single scratchpad will exist per reference to the function.

Because it is recognized that a UDF or method might require system resources, the UDF or method can be defined with the `FINAL CALL` keyword. This keyword tells DB2 to call the UDF or method at end-of-statement processing so that the UDF or method can release its system resources. It is vital that a routine free any resources it acquires; even a small leak can become a big leak in an environment where the statement is repetitively invoked, and a big leak can cause a DB2 crash.

As the scratchpad is of a fixed size, the UDF or method can itself include a memory allocation and thus, can make use of the final call to free the memory. For example, the preceding `match` function cannot predict how many documents will match the given text string. So a better definition for `match` is:

```
CREATE FUNCTION match(varchar(200), char(15))
  RETURNS char(1) ... SCRATCHPAD 10000 FINAL CALL;
```

For UDFs or methods that use a scratchpad and are referenced in a subquery, DB2 might make a final call, if the UDF or method is so specified, and refresh the scratchpad between invocations of the subquery. You can protect yourself against this possibility, if your UDFs or methods are ever used in subqueries, by defining the UDF or method with `FINAL CALL` and using the call-type argument, or by always checking for the *binary zero* state of the scratchpad.

If you do specify `FINAL CALL`, note that your UDF or method receives a call of type `FIRST`. This could be used to acquire and initialize some persistent resource.

Following is a simple Java example of a UDF that uses a scratchpad to compute the sum of squares of entries in a column. This example takes in a column and returns a column containing the cumulative sum of squares from the top of the column to the current row entry:

```
CREATE FUNCTION SumOfSquares(INTEGER)
  RETURNS INTEGER
  EXTERNAL NAME 'UDFsrv!SumOfSquares'
  DETERMINISTIC
  NO EXTERNAL ACTION
  FENCED
  NOT NULL CALL
  LANGUAGE JAVA
  PARAMETER STYLE DB2GENERAL
  NO SQL
  SCRATCHPAD 10
  FINAL CALL
  DISALLOW PARALLEL
  NO DBINFO@
```

```
// Sum Of Squares using Scratchpad UDF
public void SumOfSquares(int inColumn,
                        int outSum)
  throws Exception
{
  int sum = 0;
  byte[] scratchpad = getScratchpad();

  // variables to read from SCRATCHPAD area
  ByteArrayInputStream byteArrayIn = new ByteArrayInputStream(scratchpad);
  DataInputStream dataIn = new DataInputStream(byteArrayIn);
```

```

// variables to write into SCRATCHPAD area
byte[] byteArrayCounter;
int i;
ByteArrayOutputStream byteArrayOut = new ByteArrayOutputStream(10);
DataOutputStream dataOut = new DataOutputStream(byteArrayOut);

switch(getCallType())
{
    case SQLUDF_FIRST_CALL:
        // initialize data
        sum = (inColumn * inColumn);
        // save data into SCRATCHPAD area
        dataOut.writeInt(sum);
        byteArrayCounter = byteArrayOut.toByteArray();
        for(i = 0; i < byteArrayCounter.length; i++)
        {
            scratchpad[i] = byteArrayCounter[i];
        }
        setScratchpad(scratchpad);
        break;
    case SQLUDF_NORMAL_CALL:
        // read data from SCRATCHPAD area
        sum = dataIn.readInt();
        // work with data
        sum = sum + (inColumn * inColumn);
        // save data into SCRATCHPAD area
        dataOut.writeInt(sum);
        byteArrayCounter = byteArrayOut.toByteArray();
        for(i = 0; i < byteArrayCounter.length; i++)
        {
            scratchpad[i] = byteArrayCounter[i];
        }
        setScratchpad(scratchpad);
        break;
}
//set the output value
set(2, sum);
} // SumOfSquares UDF

```

Please note that there is a built-in DB2 function that performs the same task as the SumOfSquares UDF. This example was chosen to demonstrate the use of a scratchpad.

## Scratchpads on 32-bit and 64-bit operating systems

To make your UDF or method code portable between 32-bit and 64-bit operating systems, you must take care in the way you create and use scratchpads that contain 64-bit values. It is recommended that you do not declare an explicit length variable for a scratchpad structure that contains one or more 64-bit values, such as 64-bit pointers or `sqlint64` BIGINT variables.

Following is a sample structure declaration for a scratchpad:

```

struct sql_scratchpad
{
    sqlint32 length;
    char data[100];
};

```

When defining its own structure for the scratchpad, a routine has two choices:

1. Redefine the entire scratchpad `sql_scratchpad`, in which case it needs to include an explicit length field. For example:

```

struct sql_spad
{
    sqlint32 length;
    sqlint32 int_var;
    sqlint64 bigint_var;
};
void SQL_API_FN routine( ..., struct sql_spad* scratchpad, ... )
{
    /* Use scratchpad */
}

```

2. Redefine just the data portion of the scratchpad `sql_scratchpad`, in which case no length field is needed.

```

struct spaddata
{
    sqlint32 int_var;
    sqlint64 bigint_var;
};
void SQL_API_FN routine( ..., struct sql_scratchpad* spad, ... )
{
    struct spaddata* scratchpad = (struct spaddata*)spad->data;
    /* Use scratchpad */
}

```

As the application cannot change the value in the length field of the scratchpad, there is no significant benefit to coding the routine as shown in the first example. The second example is also portable between computers with different word sizes, so it is the preferred way of writing the routine.

## SQL in external routines

All routines written in an external programming language (such as C, Visual Basic, C#, Java, and others) can contain SQL.

The CREATE statement for a routine (stored procedure, UDF), or the CREATE TYPE statement, in the case of a method, contains a clause that defines the level of SQL access for the routine or method. Based on the nature of the SQL included in your routine, you must choose the applicable clause:

### **NO SQL**

the routine contains no SQL at all

### **CONTAINS SQL**

Contains SQL, but neither reads nor writes data (for example: SET SPECIAL REGISTER).

### **READS SQL DATA**

Contains SQL that can read from tables (SELECT, VALUES statements), but does not modify table data.

### **MODIFIES SQL DATA**

Contains SQL that updates tables, either user tables directly (INSERT, UPDATE, DELETE statements) or DB2's catalog tables implicitly (DDL statements). This clause is only applicable to stored procedures and SQL-bodied table functions.

DB2 will validate at execution time that a routine does not exceed its defined level. For example, if a routine defined as CONTAINS SQL tries to SELECT from a table, an error (SQLCODE -579, SQLSTATE 38004) will result because it is attempting a read of SQL data. Also note that nested routine references, must be of the same or of a more restrictive SQL level that contains the reference. For example, routines

that modify SQL data can invoke routines that read SQL data, but routines that can only read SQL data, that are defined with the READS SQL DATA clause, cannot invoke routines that modify SQL data.

A routine executes SQL statements within the database connection scope of the calling application. A routine cannot establish its own connection, nor can it reset the calling application's connection (SQLCODE -751, SQLSTATE 38003).

Only a stored procedure defined as MODIFIES SQL DATA can issue COMMIT and ROLLBACK statements. Other types of routines (UDFs and methods) cannot issue COMMITs or ROLLBACKs (SQLCODE -751, SQLSTATE 38003). Even though a stored procedure defined as MODIFIES SQL DATA can attempt to COMMIT or ROLLBACK a transaction, it is recommended that a COMMIT or ROLLBACK be done from the calling application so changes are not unexpectedly committed. Stored procedures cannot issue COMMIT or ROLLBACK statements if the stored procedure was invoked from an application that established a type 2 connection to the database.

Also, only stored procedures defined as MODIFIES SQL DATA can establish their own savepoints, and rollback their own work within the savepoint. Other types of routines (UDFs and methods) cannot establish their own savepoints. A savepoint created within a stored procedure is not released when the stored procedure completes. The application will be able to roll back the savepoint. Similarly, a stored procedure could roll back a savepoint defined in the application. DB2 will implicitly release any savepoints established by the routine when it returns.

A routine can inform DB2 about whether it has succeeded by assigning an SQLSTATE value to the sqlstate argument that DB2 passes to it. Some parameter styles (PARAMETER STYLEs JAVA, GENERAL, and GENERAL WITH NULLS) do not support the exchange of SQLSTATE values.

If, in handling the SQL issued by a routine, DB2 encounters an error, it returns that error to the routine, just as it does for any application. For normal user errors, the routine has an opportunity to take alternative or corrective action. For example, if a routine is trying to INSERT to a table and gets a duplicate key error (SQLCODE -813), it can instead UPDATE the existing row of the table.

There are, however, certain more serious errors that can occur that make it impossible for DB2 to proceed in a normal fashion. Examples of these include deadlock, or database partition failure, or user interrupt. Some of these errors are propagated up to the calling application. Other severe errors that are unit of work related go all the way out to either (a) the application, or (b) a stored procedure that is permitted to issue transaction control statements (COMMIT or ROLLBACK), whichever occurs first in backing out.

If one of these errors occurs during the execution of SQL issued by a routine, the error is returned to the routine, but DB2 remembers that a serious error has occurred. Additionally, in this case, DB2 will automatically fail (SQLCODE -20139, SQLSTATE 51038) any subsequent SQL issued by this routine and by any calling routines. The only exception to this is if the error only backs out to the outermost stored procedure that is permitted to issue transaction control statements. In this case, this stored procedure can continue to issue SQL.

Routines can issue both static and dynamic SQL, and in either case they must be precompiled and bound if embedded SQL is used. For static SQL, the information used in the precompile/bind process is the same as it is for any client application



using embedded SQL. For dynamic SQL, you can use the DYNAMICRULES precompile/bind option to control the current schema and current authentication ID for embedded dynamic SQL. This behavior is different for routines and applications.

The isolation level defined for the routine packages or statements is respected. This can result in a routine running at a more restrictive, or a more generous, isolation level than the calling application. This is important to consider when calling a routine that has a less restrictive isolation level than the calling statement. For example, if a cursor stability function is called from a repeatable read application, the UDF can exhibit non-repeatable read characteristics.

The invoking application or routine is not affected by any changes made by the routine to special register values. Updatable special registers are inherited by the routine from the invoker. Changes to updatable special registers are not passed back to the invoker. Non-updatable special registers get their default value. For further details on updatable and non-updatable special registers, see the related topic, "Special registers".

Routines can OPEN, FETCH, and CLOSE cursors in the same manner as client applications. Multiple invocations (for example, in the case of recursion) of the same function each get their own instance of the cursor. UDFs and methods must close their cursors before the invoking statement completes, otherwise an error will occur (SQLCODE -472, SQLSTATE 24517). The final call for a UDF or method is a good time to close any cursors that remain open. Any opened cursors not closed before completion in a stored procedure are returned to the client application or calling routine as result sets.

Arguments passed to routines are not automatically treated as host variables. This means for a routine to use a parameter as a host variable in its SQL, it must declare its own host variable and copy the parameter value to this host variable.

**Note:** Embedded SQL routines must be precompiled and bound with the DATETIME option set to ISO.

## External routine parameter styles

External routine implementations must conform to a particular convention for the exchange of routine parameter values. These conventions are known as *parameter styles*. An external routine parameter style is specified when the routine is created by specifying the PARAMETER STYLE clause. Parameter styles characterize the specification and order in which parameter values will be passed to the external routine implementation. They also specify what if any additional values will be passed to the external routine implementation. For example, some parameter styles specify that for each routine parameter value that an additional separate null-indicator value be passed to the routine implementation to provide information about the parameters nullability which cannot otherwise be easily determined with a native programming language data type.

The table below provides a list of the available parameter styles, the routine implementations that support each parameter style, the functional routine types that support each parameter style, and a description of the parameter style:

Table 8. Parameter styles

Parameter style	Supported language	Supported routine type	Description
SQL <sup>1</sup>	<ul style="list-style-type: none"> <li>• C/C++</li> <li>• OLE</li> <li>• .NET common language runtime languages</li> <li>• COBOL <sup>2</sup></li> </ul>	<ul style="list-style-type: none"> <li>• UDFs</li> <li>• stored procedures</li> <li>• methods</li> </ul>	<p>In addition to the parameters passed during invocation, the following arguments are passed to the routine in the following order:</p> <ul style="list-style-type: none"> <li>• A null indicator for each parameter or result declared in the CREATE statement.</li> <li>• The SQLSTATE to be returned to DB2.</li> <li>• The qualified name of the routine.</li> <li>• The specific name of the routine.</li> <li>• The SQL diagnostic string to be returned to DB2.</li> </ul> <p>Depending on options specified in the CREATE statement and the routine type, the following arguments can be passed to the routine in the following order:</p> <ul style="list-style-type: none"> <li>• A buffer for the scratchpad.</li> <li>• The call type of the routine.</li> <li>• The dbinfo structure (contains information about the database).</li> </ul>
DB2SQL <sup>1</sup>	<ul style="list-style-type: none"> <li>• C/C++</li> <li>• OLE</li> <li>• .NET common language runtime languages</li> <li>• COBOL</li> </ul>	<ul style="list-style-type: none"> <li>• stored procedures</li> </ul>	<p>In addition to the parameters passed during invocation, the following arguments are passed to the stored procedure in the following order:</p> <ul style="list-style-type: none"> <li>• A vector containing a null indicator for each parameter on the CALL statement.</li> <li>• The SQLSTATE to be returned to DB2.</li> <li>• The qualified name of the stored procedure.</li> <li>• The specific name of the stored procedure.</li> <li>• The SQL diagnostic string to be returned to DB2.</li> </ul> <p>If the DBINFO clause is specified in the CREATE PROCEDURE statement, a dbinfo structure (it contains information about the database) is passed to the stored procedure.</p>
JAVA	<ul style="list-style-type: none"> <li>• Java</li> </ul>	<ul style="list-style-type: none"> <li>• UDFs</li> <li>• stored procedures</li> </ul>	<p>PARAMETER STYLE JAVA routines use a parameter passing convention that conforms to the Java language and SQLJ Routines specification.</p> <p>For stored procedures, INOUT and OUT parameters will be passed as single entry arrays to facilitate the returning of values. In addition to the IN, OUT, and INOUT parameters, Java method signatures for stored procedures include a parameter of type ResultSet[] for each result set specified in the DYNAMIC RESULT SETS clause of the CREATE PROCEDURE statement.</p> <p>For PARAMETER STYLE JAVA UDFs and methods, no additional arguments to those specified in the routine invocation are passed.</p> <p>PARAMETER STYLE JAVA routines do not support the DBINFO or PROGRAM TYPE clauses. For UDFs, PARAMETER STYLE JAVA can only be specified when there are no structured data types specified as parameters and no structured type, CLOB, DBCLOB, or BLOB data types specified as return types (SQLSTATE 429B8). Also, PARAMETER STYLE JAVA UDFs do not support table functions, call types, or scratchpads.</p>

Table 8. Parameter styles (continued)

Parameter style	Supported language	Supported routine type	Description
DB2GENERAL	<ul style="list-style-type: none"> <li>Java</li> </ul>	<ul style="list-style-type: none"> <li>UDFs</li> <li>stored procedures</li> <li>methods</li> </ul>	<p>This type of routine will use a parameter passing convention that is defined for use with Java methods. Unless you are developing table UDFs, UDFs with scratchpads, or need access to the dbinfo structure, it is recommended that you use PARAMETER STYLE JAVA.</p> <p>For PARAMETER STYLE DB2GENERAL routines, no additional arguments to those specified in the routine invocation are passed.</p>
GENERAL	<ul style="list-style-type: none"> <li>C/C++</li> <li>.NET common language runtime languages</li> <li>COBOL</li> </ul>	<ul style="list-style-type: none"> <li>stored procedures</li> </ul>	<p>A PARAMETER STYLE GENERAL stored procedure receives parameters from the CALL statement in the invoking application or routine. If the DBINFO clause is specified in the CREATE PROCEDURE statement, a dbinfo structure (it contains information about the database) is passed to the stored procedure.</p> <p>GENERAL is the equivalent of SIMPLE stored procedures for DB2 for z/OS.</p>
GENERAL WITH NULLS	<ul style="list-style-type: none"> <li>C/C++</li> <li>.NET common language runtime languages</li> <li>COBOL</li> </ul>	<ul style="list-style-type: none"> <li>stored procedures</li> </ul>	<p>A PARAMETER STYLE GENERAL WITH NULLS stored procedure receives parameters from the CALL statement in the invoking application or routine. Also included is a vector containing a null indicator for each parameter on the CALL statement. If the DBINFO clause is specified in the CREATE PROCEDURE statement, a dbinfo structure (it contains information about the database) is passed to the stored procedure.</p> <p>GENERAL WITH NULLS is the equivalent of SIMPLE WITH NULLS stored procedures for DB2 for z/OS.</p>

**Note:**

1. For UDFs and methods, PARAMETER STYLE SQL is equivalent to PARAMETER STYLE DB2SQL.
2. COBOL can only be used to develop stored procedures.
3. .NET common language runtime methods are not supported.

**Parameter handling in PROGRAM TYPE MAIN or PROGRAM TYPE SUB procedures**

Procedures can accept parameters in the style of main routines or subroutines. This is determined when you register your procedure with the CREATE PROCEDURE statement.

C or C++ procedures of PROGRAM TYPE SUB accept arguments in the same manner as C or C++ subroutines. Pass parameters as pointers. For example, the following C procedure signature accepts parameters of type INTEGER, SMALLINT, and CHAR(3):

```
int storproc (sqlint32 *arg1, sqlint16 *arg2, char *arg3)
```

Java procedures can only accept arguments as subroutines. Pass IN parameters as simple arguments. Pass OUT and INOUT parameters as arrays with a single element. The following parameter-style Java procedure signature accepts an IN parameter of type INTEGER, an OUT parameter of type SMALLINT, and an INOUT parameter of type CHAR(3):

```
int storproc (int arg1, short arg2[], String arg[])
```

To write a C procedure that accepts arguments like a main function in a C program, specify PROGRAM TYPE MAIN in the CREATE PROCEDURE statement. You must write procedures of PROGRAM TYPE MAIN to conform to the following specifications:

- The procedure accepts parameters through two arguments:
  - a parameter counter variable; for example, *argc*
  - an array of pointers to the parameters; for example, *char \*\*argv*
- The procedure must be built as a shared library

In PROGRAM TYPE MAIN procedures, DB2 sets the value of the first element in the *argv* array, (*argv[0]*), to the name of the procedure. The remaining elements of the *argv* array correspond to the parameters as defined by the PARAMETER STYLE of the procedure. For example, the following embedded C procedure passes in one IN parameter as *argv[1]* and returns two OUT parameters as *argv[2]* and *argv[3]*.

The CREATE PROCEDURE statement for the PROGRAM TYPE MAIN example is as follows:

```
CREATE PROCEDURE MAIN_EXAMPLE (IN job CHAR(8),
    OUT salary DOUBLE, OUT errorcode INTEGER)
    DYNAMIC RESULT SETS 0
    LANGUAGE C
    PARAMETER STYLE GENERAL
    NO DBINFO
    FENCED
    READS SQL DATA
    PROGRAM TYPE MAIN
    EXTERNAL NAME 'spserver!mainexample'
```

The following code for the procedure copies the value of *argv[1]* into the CHAR(8) host variable *injob*, then copies the value of the DOUBLE host variable *outsalary* into *argv[2]* and returns the SQLCODE as *argv[3]*:

```
SQL_API_RC SQL_API_FN main_example (int argc, char **argv)
{
    EXEC SQL INCLUDE SQLCA;

    EXEC SQL BEGIN DECLARE SECTION;
        char injob[9];
        double outsalary;
    EXEC SQL END DECLARE SECTION;

    /* argv[0] contains the procedure name. */
    /* Parameters start at argv[1]          */
    strcpy (injob, (char *)argv[1]);

    EXEC SQL SELECT AVG(salary)
        INTO :outsalary
        FROM employee
        WHERE job = :injob;

    memcpy ((double *)argv[2], (double *)&outsalary, sizeof(double));

    memcpy ((sqlint32 *)argv[3], (sqlint32 *)&SQLCODE, sizeof(sqlint32));

    return (0);
} /* end main_example function */
```

---

## Supported routine programming languages

In general, routines are used to improve overall performance of the database management system by enabling application functionality to be performed on the database server. The amount of gain realized by these efforts is limited, to some degree, by the language chosen to write a routine.

Some of the issues you should consider before implementing routines in a certain language are:

- The available skills for developing a routine in a particular language and environment.
- The reliability and safety of a language's implemented code.
- The scalability of routines written in a particular language.

To help assess the preceding criteria, here are some characteristics of various supported languages:

### SQL

- SQL routines are faster than Java routines, and roughly equivalent in performance to NOT FENCED C/C++ routines.
- SQL routines are written completely in SQL, and can include elements of SQL Procedural Language (SQL PL), which contains SQL control-statements that can be used to implement logic.
- SQL routines are considered 'safe' by DB2 as they consist entirely of SQL statements. SQL routines always run directly in the database engine, giving them good performance, and scalability.

### C/C++

- Both C/C++ embedded SQL and DB2 CLI routines are faster than Java routines. They are roughly equivalent in performance to SQL routines when run in NOT FENCED mode.
- C/C++ routines are prone to error. It is recommended that you register C/C++ routines as FENCED NOT THREADSAFE, because routines in these languages are the most likely to disrupt the functioning of DB2's database engine by causing memory corruption. Running in FENCED NOT THREADSAFE mode, while safer, incurs performance overhead. For information on assessing and mitigating the risks of registering C/C++ routines as NOT FENCED or FENCED THREADSAFE, see the topic, "Security considerations for routines".
- By default, C/C++ routines run in FENCED NOT THREADSAFE mode to isolate them from damaging the execution of other routines. Because of this, you will have one db2fmp process per concurrently executing C/C++ routine on the database server. This can result in scalability problems on some systems.

### Java

- Java routines are slower than C/C++ or SQL routines.
- Java routines are safer than C/C++ routines because control of dangerous operations is handled by the JVM. Because of this, reliability is increased, as it is difficult for a Java routine to damage another routine running in the same process.

**Note:** To avoid potentially dangerous operations, Java Native Interface (JNI) calls from Java routines are not permitted. If you need to invoke C/C++ code from a Java routine, you can do so by invoking a separately cataloged C/C++ routine.

- When run in FENCED THREADSAFE mode (the default), Java routines scale well. All FENCED Java routines will share a few JVMs (more than one JVM might be in use on the system if the Java heap of a particular db2fmp process is approaching exhaustion).
- NOT FENCED Java routines are currently not supported. A Java routine defined as NOT FENCED will be invoked as if it had been defined as FENCED THREADSAFE.

#### **.NET common language runtime languages**

- .NET common language runtime (CLR) routines are routines that are compiled into intermediate language (IL) byte code that can be interpreted by the CLR of the .NET Framework. The source code for a CLR routine can be written in any .NET Framework supported language.
- Working with .NET CLR routines allows the user the flexibility to code in the .NET CLR supported programming language of their choice.
- CLR assemblies can be built up from sub-assemblies that were compiled from different .NET programming language source code, which allows the user to re-use and integrate code modules written in various languages.
- CLR routines can only be created as FENCED NOT THREADSAFE routines. This minimizes the possibility of engine corruption, but also means that these routines cannot benefit from the performance opportunity that can be had with NOT FENCED routines.

#### **OLE**

- OLE routines can be implemented in Visual C++, Visual Basic and other languages supported by OLE.
- The speed of OLE automated routines depends on the language used to implement them. In general, they are slower than non-OLE C/C++ routines.
- OLE routines can only run in FENCED NOT THREADSAFE mode. This minimizes the chance of engine corruption. This also means that OLE automated routines do not scale well.

#### **OLE DB**

- OLE DB can only be used to define table functions.
- OLE DB table functions connect to a external OLE DB data source.
- Depending on the OLE DB provider, OLE DB table functions are generally faster than Java table functions, but slower than C/C++ or SQL-bodied table functions. However, some predicates from the query where the function is invoked might be evaluated at the OLE DB provider, therefore reducing the number of rows that DB2 has to process. This frequently results in improved performance.
- OLE DB routines can only run in FENCED NOT THREADSAFE mode. This minimizes the chance of engine corruption. This also means that OLE DB automated table functions do not scale well.

## Comparison of supported APIs and programming languages for external routine development

It is important to consider the characteristics and limitations of the various supported external routine application programming interfaces (APIs) and programming languages before you start implementing external routines. This will ensure that you choose the right implementation from the start and that the routine features that you require are available.

Table 9. Comparison of external routine APIs and programming languages

API and programming language	Feature support	Performance	Security	Scalability	Limitations
SQL (includes SQL PL)	<ul style="list-style-type: none"> <li>• SQL is a high level language that is easy to learn and use, which makes implementation go quickly.</li> <li>• SQL Procedural Language (SQL PL) elements allow for control-flow logic around SQL operations and queries.</li> </ul>	<ul style="list-style-type: none"> <li>• Very good.</li> <li>• SQL routines perform better than Java routines.</li> <li>• SQL routines perform as well as C and C++ external routines created with the NOT FENCED clause.</li> </ul>	<ul style="list-style-type: none"> <li>• Very safe.</li> <li>• SQL procedures always run in the same memory as the database manager. This corresponds to the routine being created by default with the keywords NOT FENCED.</li> </ul>	<ul style="list-style-type: none"> <li>• Highly scalable.</li> </ul>	<ul style="list-style-type: none"> <li>• Cannot access the database server file system.</li> <li>• Cannot invoke applications that reside outside of the database.</li> </ul>

Table 9. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<p>Embedded SQL (includes C and C++)</p>	<ul style="list-style-type: none"> <li>• Low level, but powerful programming language.</li> </ul>	<ul style="list-style-type: none"> <li>• Very good.</li> <li>• C and C++ routines perform better than Java routines.</li> <li>• C and C++ routines created with the NOT FENCED clause perform as well as SQL routines.</li> </ul>	<ul style="list-style-type: none"> <li>• C and C++ routines are prone to programming errors.</li> <li>• Programmers must be proficient in C to avoid making common memory and pointer manipulation errors which make routine implementation more tedious and time consuming.</li> <li>• C and C++ routines should be created with the FENCED clause and the NOT THREADSAFE clause to avoid the disruption of the database manager should an exception occur in the routine at run time. These are default clauses. The use of these clauses can somewhat negatively impact performance, but ensure safe execution. See: Security of routines.</li> </ul>	<ul style="list-style-type: none"> <li>• Scalability is reduced when C and C++ routines are created with the FENCED and NOT THREADSAFE clauses. These routines are run in an isolated <i>db2fmp</i> process apart from the database manager process. One <i>db2fmp</i> process is required per concurrently executed routine.</li> </ul>	<ul style="list-style-type: none"> <li>• There are multiple supported parameter passing styles which can be confusing. Users should use parameter style SQL as much as possible.</li> </ul>



Table 9. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
Embedded SQL (COBOL)	<ul style="list-style-type: none"> <li>• High-level programming language good for developing business, typically file oriented, applications.</li> <li>• Pervasively used in the past for production business applications, although its popularity is decreasing.</li> <li>• COBOL does not contain pointer support and is a linear iterative programming language.</li> </ul>	<ul style="list-style-type: none"> <li>• COBOL routines do not perform as well as routines created with any of the other external routine implementation options.</li> </ul>	<ul style="list-style-type: none"> <li>• No information at this time.</li> </ul>	<ul style="list-style-type: none"> <li>• No information at this time.</li> </ul>	<ul style="list-style-type: none"> <li>• You can create and invoke 32-bit COBOL procedures in 64-bit DB2 instances, however these routines will not perform as well as 64-bit COBOL procedures within a 64-bit DB2 instance.</li> </ul>
JDBC (Java) and SQLJ (Java)	<ul style="list-style-type: none"> <li>• High-level object-oriented programming language suitable for developing standalone applications, applets, and servlets.</li> <li>• Java objects and data types facilitate the establishment of database connections, execution of SQL statements, and manipulation of data.</li> </ul>	<ul style="list-style-type: none"> <li>• Java routines do not perform as well as C and C++ routines or SQL routines.</li> </ul>	<ul style="list-style-type: none"> <li>• Java routines are safer than C and C++ routines, because the control of dangerous operations is handled by the Java Virtual Machine (JVM). This increases reliability and makes it very difficult for the code of one Java routine to harm another routine running in the same process.</li> </ul>	<ul style="list-style-type: none"> <li>• Good scalability</li> <li>• Java routines created with the FENCED THREADSAFE clause (the default) scale well. All fenced Java routines will share a few JVMs. More than one JVM might be in use on the system if the Java heap of a particular db2fmp process is approaching exhaustion.</li> </ul>	<ul style="list-style-type: none"> <li>• To avoid potentially dangerous operations, Java Native Interface (JNI) calls from Java routines are not permitted.</li> </ul>

Table 9. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<p>.NET common language runtime supported languages (includes C#, Visual Basic, and others)</p>	<ul style="list-style-type: none"> <li>• Part of the Microsoft .NET model of managed code.</li> <li>• Source code is compiled into intermediate language (IL) byte code that can be interpreted by the Microsoft .NET Framework common language runtime.</li> <li>• CLR assemblies can be built up from sub-assemblies that were compiled from different .NET programming language source code, which allows users to re-use and integrate code modules written in various languages.</li> </ul>	<ul style="list-style-type: none"> <li>• CLR routines can only be created with the FENCED NOT THREADSAFE clause so as to minimize the possibility of database manager interruption at runtime. This can somewhat negatively impact performance</li> <li>• Use of the default clause values minimizes the possibility of database manager interruption at runtime; however because CLR routines must run as FENCED, they might perform slightly more slowly than other external routines that can be specified as NOT FENCED.</li> </ul>	<ul style="list-style-type: none"> <li>• CLR routines can only be created with the FENCED NOT THREADSAFE clause. They are therefore safe because they will be run outside of the database manager in a separate db2fmp process.</li> </ul>	<ul style="list-style-type: none"> <li>• No information available.</li> </ul>	<ul style="list-style-type: none"> <li>• Refer to the topic, "Restrictions on .NET CLR routines".</li> </ul>

Table 9. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<ul style="list-style-type: none"> <li>OLE</li> </ul>	<ul style="list-style-type: none"> <li>OLE routines can be implemented in Visual C++, Visual Basic, and other languages supported by OLE.</li> </ul>	<ul style="list-style-type: none"> <li>The speed of OLE automated routines depends on the language used to implement them. In general they are slower than non-OLE C/C++ routines.</li> <li>OLE routines can only run in FENCED NOT THREADSAFE mode, and therefore OLE automated routines do not scale well.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>

Table 9. Comparison of external routine APIs and programming languages (continued)

API and programming language	Feature support	Performance	Security	Scalability	Limitations
<ul style="list-style-type: none"> <li>OLE DB</li> </ul>	<ul style="list-style-type: none"> <li>OLE DB can be used to create user-defined table functions.</li> <li>OLE DB functions connect to external OLE DB data sources.</li> </ul>	<ul style="list-style-type: none"> <li>Performance of OLE DB functions depends on the OLE DB provider, however in general OLE DB functions perform better than logically equivalent Java functions, but slower than logically equivalent C, C++, or SQL functions. However some predicates from the query where the function is invoked might be evaluated at the OLE DB provider, therefore reducing the number of rows that DB2 has to process which can frequently result in improved performance.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>No information available.</li> </ul>	<ul style="list-style-type: none"> <li>OLE DB can only be used to create user-defined table functions.</li> </ul>

## Performance considerations for developing routines

One of the most significant benefits of developing routines, instead of expanding client applications, is performance. Consider the following performance impacts when choosing an approach for routine implementation.

### NOT FENCED mode

A NOT FENCED routine runs in the same process as the database manager. In general, running your routine as NOT FENCED results in better performance as compared with running it in FENCED mode, because FENCED routines run in a special DB2 process outside of the engine's address space.

While you can expect improved routine performance when running routines in NOT FENCED mode, user code can accidentally or maliciously corrupt the database or damage the database control structures. You should only use NOT FENCED routines when you need to maximize the

performance benefits, and if you deem the routine to be secure. (For information on assessing and mitigating the risks of registering C/C++ routines as NOT FENCED, see the topic, "Security considerations for routines".) If the routine is not safe enough to run in the database manager's process, use the FENCED clause when registering the routine. To limit the creation and running of potentially unsafe code, DB2 requires that a user have a special privilege, CREATE\_NOT\_FENCED\_ROUTINE in order to create NOT FENCED routines.

If an abnormal termination occurs while you are running a NOT FENCED routine, the database manager will attempt an appropriate recovery if the routine is registered as NO SQL. However, for routines not defined as NO SQL, the database manager will fail.

NOT FENCED routines must be precompiled with the WCHARTYPE NOCONVERT option if the routine uses GRAPHIC or DBCLOB data.

### **FENCED THREADSAFE mode**

FENCED THREADSAFE routines run in the same process as other routines. More specifically, non-Java routines share one process, while Java routines share another process, separate from routines written in other languages. This separation protects Java routines from the potentially more error prone routines written in other languages. Also, the process for Java routines contains a JVM, which incurs a high memory cost and is not used by other routine types. Multiple invocations of FENCED THREADSAFE routines share resources, and therefore incur less system overhead than FENCED NOT THREADSAFE routines, which each run in their own dedicated process.

If you feel your routine is safe enough to run in the same process as other routines, use the THREADSAFE clause when registering it. As with NOT FENCED routines, information on assessing and mitigating the risks of registering C/C++ routines as FENCED THREADSAFE is in the topic, "Security considerations for routines".

If a FENCED THREADSAFE routine abends, only the thread running this routine is terminated. Other routines in the process continue running. However, the failure that caused this thread to abend can adversely affect other routine threads in the process, causing them to trap, hang, or have damaged data. After one thread abends, the process is no longer used for new routine invocations. Once all the active users complete their jobs in this process, it is terminated.

When you register Java routines, they are deemed THREADSAFE unless you indicate otherwise. All other LANGUAGE types are NOT THREADSAFE by default. Routines using LANGUAGE OLE and OLE DB cannot be specified as THREADSAFE.

NOT FENCED routines must be THREADSAFE. It is not possible to register a routine as NOT FENCED NOT THREADSAFE (SQLCODE -104).

Users on UNIX can see their Java and C THREADSAFE processes by looking for db2fmp (Java) or db2fmp (C).

### **FENCED NOT THREADSAFE mode**

FENCED NOT THREADSAFE routines each run in their own dedicated process. If you are running numerous routines, this can have a detrimental effect on database system performance. If the routine is not safe enough to run in the same process as other routines, use the NOT THREADSAFE clause when registering the routine.

On UNIX, NOT THREADSAFE processes appear as db2fmp (pid) (where pid is the process id of the agent using the fenced mode process) or as db2fmp (idle) for a pooled NOT THREADSAFE db2fmp.

### **Java routines**

If you intend to run a Java routine with large memory requirements, it is recommended that you register it as FENCED NOT THREADSAFE. For FENCED THREADSAFE Java routine invocations, DB2 attempts to choose a threaded Java fenced mode process with a Java heap that is large enough to run the routine. Failure to isolate large heap consumers in their own process can result in-out-of-Java-heap errors in multithreaded Java db2fmp processes. If your Java routine does not fall into this category, FENCED routines will run better in threadsafe mode where they can share a small number of JVMs.

NOT FENCED Java routines are currently not supported. A Java routine defined as NOT FENCED will be invoked as if it had been defined as FENCED THREADSAFE.

### **C/C++ routines**

C or C++ routines are generally faster than Java routines, but are more prone to errors, memory corruption, and crashing. For these reasons, the ability to perform memory operations makes C or C++ routines risky candidates for THREADSAFE or NOT FENCED mode registration. These risks can be mitigated by adhering to programming practices for secure routines (see the topic, "Security considerations for routines"), and thoroughly testing your routine.

### **SQL routines**

SQL routines, particularly SQL procedures, are also generally faster than Java routines, and usually share comparable performance with C routines. SQL routines always run in NOT FENCED mode, providing a further performance benefit over external routines. UDFs that contain complex logic will generally run more quickly if written in C than in SQL. If the logic is simple, than an SQL UDF will be comparable to any external UDF.

### **Scratchpads**

A scratchpad is a block of memory that can be assigned to UDFs and methods. The scratchpad only applies to the individual reference to the routine in an SQL statement. If there are multiple references to a routine in a statement, each reference has its own scratchpad. A scratchpad enables a UDF or method to save its state from one invocation to the next.

For UDFs and methods with complex initializations, you can use scratchpads to store any values required in the first invocation for use in all future invocations. The logic of other UDFs and methods might also require that intermediate values be saved from invocation to invocation.

### **Use VARCHAR parameters instead of CHAR parameters**

You can improve the performance of your routines by using VARCHAR parameters instead of CHAR parameters in the routine definition. Using VARCHAR data types instead of CHAR data types prevents DB2 from padding parameters with spaces before passing the parameter and decreases the amount of time required to transmit the parameter across a network.

For example, if your client application passes the string "A SHORT STRING" to a routine that expects a CHAR(200) parameter, DB2 has to pad

the parameter with 186 spaces, null-terminate the string, then send the entire 200 character string and null-terminator across the network to the routine.

In comparison, passing the same string, "A SHORT STRING," to a routine that expects a VARCHAR(200) parameter results in DB2 simply passing the 14 character string and a null terminator across the network.

---

## Security considerations for routines

Developing and deploying routines provides you with an opportunity to greatly improve the performance and effectiveness of your database applications. There can, however, be security risks if the deployment of routines is not managed correctly by the database administrator.

The following sections describe security risks and means by which you can mitigate these risks. The security risks are followed by a section on how to safely deploy routines whose security is unknown.

### Security risks

#### **NOT FENCED routines can access database manager resources**

NOT FENCED routines run in the same process as the database manager. Because of their close proximity to the database engine, NOT FENCED routines can accidentally or maliciously corrupt the database manager's shared memory, or damage the database control structures. Either form of damage will cause the database manager to fail. NOT FENCED routines can also corrupt databases and their tables.

To ensure the integrity of the database manager and its databases, you must thoroughly screen routines you intend to register as NOT FENCED. These routines must be fully tested, debugged, and exhibit no unexpected side-effects. In the examination of the routine, pay close attention to memory management and the use of static variables. The greatest potential for corruption arises when code does not properly manage memory or incorrectly uses static variables. These problems are prevalent in languages other than Java and .NET programming languages.

In order to register a NOT FENCED routine, the CREATE\_NOT\_FENCED\_ROUTINE authority is required. When granting the CREATE\_NOT\_FENCED\_ROUTINE authority, be aware that the recipient can potentially gain unrestricted access to the database manager and all its resources.

**Note:** NOT FENCED routines are not supported in Common Criteria compliant configurations.

#### **FENCED THREADSAFE routines can access memory in other FENCED THREADSAFE routines**

FENCED THREADSAFE routines run as threads inside a shared process. Each of these routines are able to read the memory used by other routine threads in the same process. Therefore, it is possible for one threaded routine to collect sensitive data from other routines in the threaded process. Another risk inherent in the sharing of a single process, is that one routine thread with flawed memory management can corrupt other routine threads, or cause the entire threaded process to crash.

To ensure the integrity of other FENCED THREADSAFE routines, you must thoroughly screen routines you intend to register as FENCED

THREADSAFE. These routines must be fully tested, debugged, and exhibit no unexpected side-effects. In the examination of the routine, pay close attention to memory management and the use of static variables. This is where the greatest potential for corruption exists, particularly in languages other than Java.

In order to register a FENCED THREADSAFE routine, the CREATE\_EXTERNAL\_ROUTINE authority is required. When granting the CREATE\_EXTERNAL\_ROUTINE authority, be aware that the recipient can potentially monitor or corrupt the memory of other FENCED THREADSAFE routines.

### **Write access to the database server by the owner of fenced processes can result in database manager corruption**

The user ID under which fenced processes run is defined by the **db2icrt** (create instance) or **db2iupdt** (update instance) system commands. This user ID must not have write access to the directory where routine libraries and classes are stored (in UNIX environments, `sqllib/function`; in Windows environments, `sqllib\function`). This user ID must also not have read or write access to any database, operating system, or otherwise critical files and directories on the database server.

If the owner of fenced processes does have write access to various critical resources on the database server, the potential for system corruption exists. For example, a database administrator registers a routine received from an unknown source as FENCED NOT THREADSAFE, thinking that any potential harm can be averted by isolating the routine in its own process. However, the user ID that owns fenced processes has write access to the `sqllib/function` directory. Users invoke this routine, and unbeknownst to them, it overwrites a library in `sqllib/function` with an alternate version of a routine body that is registered as NOT FENCED. This second routine has unrestricted access to the entire database manager, and can thereby distribute sensitive information from database tables, corrupt the databases, collect authentication information, or crash the database manager.

Ensure the user ID that owns fenced processes does not have write access to critical files or directories on the database server (especially `sqllib/function` and the database data directories).

### **Vulnerability of routine libraries and classes**

If access to the directory where routine libraries and classes are stored is not controlled, routine libraries and classes can be deleted or overwritten. As discussed in the previous item, the replacement of a NOT FENCED routine body with a malicious (or poorly coded) routine can severely compromise the stability, integrity, and privacy of the database server and its resources.

To protect the integrity of routines, you must manage access to the directory containing the routine libraries and classes. Ensure that the fewest possible number of users can access this directory and its files. When assigning write access to this directory, be aware that this privilege can provide the owner of the user ID unrestricted access to the database manager and all its resources.

## **Deploying potentially insecure routines**

If you happen to acquire a routine from an unknown source, be sure you know exactly what it does before you build, register, and invoke it. It is recommended



that you register it as FENCED and NOT THREADSAFE unless you have tested it thoroughly, and it exhibits no unexpected side-effects.

If you need to deploy a routine that does not meet the criteria for secure routines, register the routine as FENCED and NOT THREADSAFE. To ensure that database integrity is maintained, FENCED and NOT THREADSAFE routines:

- Run in a separate DB2 process, shared with no other routines. If they abnormally terminate, the database manager will be unaffected.
- Use memory that is distinct from memory used by the database. An inadvertent mistake in a value assignment will not affect the database manager.

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## Routine code page considerations

Character data is passed to external routines in the code page implied by the PARAMETER CCSID option used when the routine was created. Similarly, a character string that is output from the routine is assumed by the database to use the code page implied by the PARAMETER CCSID option.

When a client program (using, for example, code page C) accesses a section with a different code page (for example, code page S) that invokes a routine using a different code page (for example, code page R), the following events occur:

1. When an SQL statement is invoked, input character data is converted from the code page of the client application (C) to the one associated with the section (S). Conversion does not occur for BLOBs or data that will be used as FOR BIT DATA.
2. If the code page of the routine is not the same as the code page of the section, then before the routine is invoked, input character data (except for BLOB and FOR BIT DATA) is converted to the code page of the routine (R).

It is strongly recommended that you precompile, compile, and bind the server routine using the code page that the routine will be invoked under (R). This might not be possible in all cases. For example, you can create a Unicode database in a Windows environment. However, if the Windows environment does not have the Unicode code page, you have to precompile, compile, and bind the application that creates the routine in a Windows code page. The routine will work if the application has no special delimiter characters that the precompiler does not understand.

3. When the routine finishes, the database manager converts all output character data from the routine code page (R) to the section code page (S) if necessary. If the routine raised an error during its execution, the SQLSTATE and diagnostic message from the routine will also be converted from the routine code page to the section code page. Conversion does not happen for BLOB or FOR BIT DATA character strings.
4. When the statement finishes, output character data is converted from the section code page (S) back to code page of the client application (C). Conversion does not occur for BLOBs or for data that was used as FOR BIT DATA.

By using the DBINFO option on the CREATE FUNCTION, CREATE PROCEDURE, and CREATE TYPE statements, the routine code page is passed to the routine. Using this information, a routine that is sensitive to the code page can be written to operate in many different code pages.

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## 32-bit and 64-bit application and routine support

DB2 Database for Linux, UNIX, and Windows provides support for the development and deployment of applications and routines, including procedures and user-defined functions (UDFs), on various platforms. For your applications and routines to work properly it is important to review and understand DB2 database support for 32-bit and 64-bit considerations.

To start off, it is good to first clarify a few points:

- A 32-bit hardware platform is running a 32-bit operating system, and that a 64 bit hardware platform is running a 64-bit operating system.
- You can install a 32-bit instance of the DB2 database on either a 32-bit operating system or a 64 bit operating system, but that you can only install a 64-bit instance of DB2 database on a 64-bit operating system.
- A 32-bit application is an application that was built on a 32 bit operating system.
- A 64-bit application is an application that was built on a 64-bit operating system.

The following tables outline DB2 database 32-bit and 64-bit support for client applications and routines, with the following presumptions:

*Table 10. Support for running 32-bit and 64-bit applications on 32-bit or 64-bit hardware platforms*

	<b>32 bit hardware + operating system</b>	<b>64 bit hardware + operating system</b>
32 bit application	YES	YES
64 bit application	NO	YES

The following table indicates the support for creating a connection to a DB2 database server from a DB2 client application.

*Table 11. Support for connections from 32-bit and 64-bit clients to 32-bit and 64-bit servers*

	<b>32 bit server</b>	<b>64 bit server</b>
32 bit client	YES	YES
64 bit application	YES	YES

*Table 12. Support for running 32-bit and 64-bit applications on 32-bit or 64-bit hardware platforms*

	<b>32 bit hardware and operating system</b>	<b>64 bit hardware and operating system</b>
32 bit application	YES	YES
64 bit application	NO	YES

The following table indicates the support for creating a connection to a DB2 database server from a DB2 client application.

*Table 13. Support for connections from 32-bit and 64-bit clients to 32-bit and 64-bit servers*

	<b>32 bit server</b>	<b>64 bit server</b>
32 bit client	YES	YES
64 bit application	YES	YES

Table 14. Support for running fenced and unfenced procedures and UDFs on 32-bit and 64-bit servers

	32 bit server	64 bit server
32 bit fenced procedure or UDF	YES	YES <sup>1,2,3</sup>
64 bit fenced procedure or UDF	NO	YES
32 bit unfenced procedure or UDF	YES	NO <sup>2</sup>
64 bit unfenced procedure or UDF	NO	YES

**Note:**

1. Running a 32-bit procedure on a 64-bit server can be slow.
2. 32-bit routines must be created as FENCED and NOT THREADSAFE to work on a 64 bit server.
3. It is not possible to invoke 32-bit routines on a Linux/IA-64 database server.

### 32-bit and 64-bit support for external routines

Support for 32-bit and 64-bit external routines is determined by the specification of one of the following two clauses in the CREATE statement for the routines: FENCED clause or NOT FENCED clause.

The routine-body of an external routine is written in a programming language and compiled into a library or class file that is loaded and run when the routine is invoked. The specification of the FENCED or NOT FENCED clause determines whether the external routine runs in a fenced environment distinct from the database manager or in the same addressing space as the database manager which can yield better performance through the use of shared memory instead of TCPIP for communications. By default routines are always created as fenced regardless of the other clauses selected.

The following table illustrates DB2's support for running fenced and unfenced 32-bit and 64-bit routines on 32-bit and 64-bit database servers that are running the same operating system.

Table 15. Support for 32-bit and 64-bit external routines

Bit-width of routine	32-bit server	64-bit server
32-bit fenced procedure or UDF	Supported	Supported <sup>1</sup>
64-bit fenced procedure or UDF	Not supported <sup>3</sup>	Supported
32-bit unfenced procedure or UDF	Supported	Supported <sup>1,2</sup>
64-bit unfenced procedure or UDF	Not supported <sup>3</sup>	Supported

**Note:**

1. Running a 32-bit routine on a 64-bit server is not as fast as running a 64-bit routine on a 64-bit server.
2. 32-bit routines must be created as FENCED and NOT THREADSAFE to work on a 64-bit server.
3. 64-bit applications and routines cannot be run in 32-bit addressing spaces.

The important thing to note in the table is that 32-bit unfenced procedures cannot run on a 64-bit DB2 server. If you must deploy 32-bit unfenced routines to 64-bit platforms, remove the NOT FENCED clause from the CREATE statements for these routines before you catalog them.

## Performance of routines with 32-bit libraries on 64-bit database servers

It is possible to call routines with 32-bit routine libraries on 64-bit DB2 database servers. However, this does not perform as well as calling a 64-bit routine on a 64-bit server. The reason for the performance degradation is that before each attempt to execute a 32-bit routine on a 64-bit server, an attempt is first made to call it as a 64-bit library. If this fails, the library is then called as a 32-bit library. A failed attempt to call a 32-bit library as a 64-bit library produces an error message (SQLCODE -444) in the db2diag log files.

Java classes are bit-width independent. Only Java virtual machines (JVMs) are classified as 32-bit or 64-bit. DB2 only supports the use of JVMs that are the same bit width as the instance in which they are used. In other words, in a 32-bit DB2 instance only a 32-bit JVM can be used, and in a 64-bit DB2 instance only a 64-bit JVM can be used. This ensures proper functioning of Java routines and the best possible performance.

---

## XML data type support in external routines

External procedures and functions written in the following programming languages support parameters and variables of data type XML:

- C
- C++
- COBOL
- Java
- .NET CLR languages

External OLE and OLEDB routines do not support parameters of data type XML.

XML data type values are represented in external routine code in the same way as CLOB data types.

When declaring external routine parameters of data type XML, the CREATE PROCEDURE and CREATE FUNCTION statements that will be used to create the routines in the database must specify that the XML data type is to be stored as a CLOB data type. The size of the CLOB value should be close to the size of the XML document represented by the XML parameter.

The CREATE PROCEDURE statement below shows a CREATE PROCEDURE statement for an external procedure implemented in the C programming language with an XML parameter named parm1:

```
CREATE PROCEDURE myproc(IN parm1 XML AS CLOB(2M), IN parm2 VARCHAR(32000))
LANGUAGE C
FENCED
PARAMETER STYLE SQL
EXTERNAL NAME 'mylib!myproc';
```

Similar considerations apply when creating external UDFs, as shown in the example below:

```

CREATE FUNCTION myfunc (IN parm1 XML AS CLOB(2M))
RETURNS SMALLINT
LANGUAGE C
PARAMETER STYLE SQL
DETERMINISTIC
NOT FENCED
NULL CALL
NO SQL
NO EXTERNAL ACTION
EXTERNAL NAME 'mylib1!myfunc'

```

XML data is materialized when passed to stored procedures as IN, OUT, or INOUT parameters. If you are using Java stored procedures, the heap size (**java\_heap\_sz** configuration parameter) might need to be increased based on the quantity and size of XML arguments, and the number of external stored procedures that are being executed concurrently.

Within external routine code, XML parameter and variable values are accessed, set, and modified in the same way as in database applications.

---

## Restrictions on external routines

The following restrictions apply to external routines and should be considered when developing or debugging external routines.

### Restrictions that apply to all external routines:

- New threads cannot be created in external routines.
- Connection level APIs cannot be called from within external functions or external methods.
- Receiving inputs from the keyboard and displaying outputs to standard output is not possible from external routines. Do not use standard input-output streams. For example:
  - In external Java routine code, do not issue the `System.out.println()` methods.
  - In external C or C++ routine code, do not issue `printf()`.
  - In external COBOL routine code, do not issue `display`

Although external routines cannot display data to standard output, they can include code that writes data to a file on the database server file system.

For fenced routines that run in UNIX environments, the target directory where the file is to be created, or the file itself, must have the appropriate permissions such that the owner of the `sql1ib/adm/.fenced` file can create it or write to it. For not fenced routines, the instance owner must have create, read, and write permissions for the directory in which the file is opened.

**Note:** DB2 does not attempt to synchronize any external input or output performed by a routine with DB2's own transactions. So, for example, if a UDF writes to a file during a transaction, and that transaction is later backed out for some reason, no attempt is made to discover or undo the writes to the file.

- Connection-related statements or commands cannot be executed in external routines. This restriction applies to the following statements, including:
  - BACKUP
  - CONNECT
  - CONNECT TO

- CONNECT RESET
- CREATE DATABASE
- DROP DATABASE
- FORWARD RECOVERY
- RESTORE
- Operating system function usage within routines is not recommended. The use of these functions is not restricted except in the following cases:
  - User-defined signal handlers must not be installed for external routines. Failure to adhere to this restriction can result in unexpected external routine run-time failures, database abends, or other problems. Installing signal handlers can also interfere with operation of the JVM for Java routines.
  - System calls that terminate a process can abnormally terminate one of DB2's processes and result in database system or database application failure. Other system calls can also cause problems if they interfere with the normal operation of the DB2; database manager. For example, a function that attempts to unload a library containing a user-defined function from memory could cause severe problems. Be careful in coding and testing external routines containing system calls.
- External routines must not contain commands that would terminate the current process. An external routine must always return control to the DB2 database manager without terminating the current process.
- External routine libraries, classes, or assemblies must not be updated while the database is active except in special cases. If an update is required while the DB2 database manager is active, and stopping and starting the instance is not an option, create the new library, class, or assembly for the routine with a different. Then, use the ALTER statement to change the external routine's EXTERNAL NAME clause value so that it references the name of the new library, class, or assembly file.
- Environment variable **DB2CKPTR** is not available in external routines. All other environment variables with names beginning with 'DB2' are captured at the time the database manager is started and are available for use in external routines.
- Some environment variables with names that do not start with 'DB2' are not available to external routines that are fenced. For example, the **LIBPATH** environment variable is not available for use. However these variables are available to external routines that are not fenced.
- Environment variable values that were set after the DB2 database manager is started are not available to external routines.
- Use of protected resources, resources that can only be accessed by one process at a time, within external routines should be limited. If used, try to reduce the likelihood of deadlocks when two external routines try to access the protected resource. If two or more external routines deadlock while attempting to access the protected resource, the DB2 database manager will not be able to detect or resolve the situation. This will result in hung external routine processes.
- Memory for external routine parameters should not be explicitly allocated on the DB2 database server. The DB2 database manager automatically allocates storage based upon the parameter declaration in the CREATE statement for the routine. Do not alter any storage pointers for parameters in external routines. Attempting to change a pointer with a locally created storage pointer can result in memory leaks, data corruption, or abends.
- Do not use static or global data in external routines. DB2 cannot guarantee that the memory used by static or global variables will be untouched between

external routine invocations. For UDFs and methods, you can use scratchpads to store values for use between invocations.

- All SQL parameter values are buffered. This means that a copy of the value is made and passed to the external routine. If there are changes made to the input parameters of an external routine, these changes will have no effect on SQL values or processing. However, if an external routine writes more data to an input or output parameter than is specified by the CREATE statement, memory corruption has occurred, and the routine can abend.
- The **LOAD** utility does not support loading into tables that contain columns that reference fenced procedures. If you issue the **LOAD** command on such table, you will receive error message SQL1376N. To work around this restriction, you can redefine the routine to be unfenced, or use the import utility.

### **Restrictions that apply to external procedures only**

- When returning result sets from nested stored procedures, you can open a cursor with the same name on multiple nesting levels. However, pre-version 8 applications will only be able to access the first result set that was opened. This restriction does not apply to cursors that are opened with a different package level.

### **Restrictions that apply to external functions only**

- External functions cannot return result sets. All cursors opened within an external function must be closed by the time the final-call invocation of the function completes.
- Dynamic allocations of memory in an external routine should be freed before the external routine returns. Failure to do so will result in a memory leak and the continuous growth in memory consumption of a DB2 process that could result in the database system running out of memory.

For external user-defined functions and external methods, scratchpads can be used to allocate dynamic memory required for multiple function invocations. When scratchpads are used in this way, specify the FINAL CALL attribute in the CREATE FUNCTION or CREATE METHOD statement. This ensures that allocated memory is freed before the routine returns.

---

## **Creating external routines**

External routines including procedures and functions are created in a similar way as routines with other implementations, however there are a few more steps required, because the routine implementation requires the coding, compilation, and deployment of source code.

### **Before you begin**

- The IBM Data Server Client must be installed.
- The database server must be running an operating system that supports the chosen implementation programming language compilers and development software.
- The required compilers and runtime support for the chosen programming language must be installed on the database server
- Authority to execute the CREATE PROCEDURE, CREATE FUNCTION, or CREATE METHOD statement.

### **Restrictions**

For a list of restrictions associated with external routines see:

- “Restrictions on external routines” on page 91

## About this task

You would choose to implement an external routine if:

- You want to encapsulate complex logic into a routine that accesses the database or that performs an action outside of the database.
- You require the encapsulated logic to be invoked from any of: multiple applications, the CLP, another routine (procedure, function (UDF), or method), or a trigger.
- You are most comfortable coding this logic in a programming language rather than using SQL and SQL PL statements.
- You require the routine logic to perform operations external to the database such as writing or reading to a file on the database server, the running of another application, or logic that cannot be represented with SQL and SQL PL statements.

## Procedure

1. Code the routine logic in the chosen programming language.
  - For general information about external routines, routine features, and routine feature implementation, see the topics referenced in the Prerequisites section.
  - Use or import any required header files required to support the execution of SQL statements.
  - Declare variables and parameters correctly using programming language data types that map to DB2 SQL data types.
2. Parameters must be declared in accordance with the format required by the parameter style for the chosen programming language. For more on parameters and prototype declarations see:
  - “External routine parameter styles” on page 71
3. Build your code into a library or class file.
4. Copy the library or class file into the DB2 *function directory* on the database server. It is recommended that you store assemblies or libraries associated with DB2 routines in the function directory. To find out more about the function directory, see the EXTERNAL clause of either of the following statements: CREATE PROCEDURE or CREATE FUNCTION.

You can copy the assembly to another directory on the server if you wish, but to successfully invoke the routine you must note the fully qualified path name of your assembly as you will require it for the next step.

5. Execute either dynamically or statically the appropriate SQL language CREATE statement for the routine type: CREATE PROCEDURE or CREATE FUNCTION.
  - Specify the LANGUAGE clause with the appropriate value for the chosen API or programming language. Examples include: CLR, C, JAVA.
  - Specify the PARAMETER STYLE clause with the name of the supported parameter style that was implemented in the routine code.
  - Specify the EXTERNAL clause with the name of the library, class, or assembly file to be associated with the routine using one of the following values:
    - the fully qualified path name of the routine library, class, or assembly file .
    - the relative path name of the routine library, class, or assembly file relative to the function directory.



By default DB2 will look for the library, class, or assembly file by name in the function directory unless a fully qualified or relative path name for it is specified in the EXTERNAL clause.

- Specify DYNAMIC RESULT SETS with a numeric value if your routine is a procedure and it will return one or more result sets to the caller.
- Specify any other clauses required to characterize the routine.

## Results

To invoke your external routine, see Routine invocation

## Writing routines

### Before you begin

The three types of routines (procedures, UDFs, and methods) have much in common with regards to how they are written. For instance, the three routine types employ some of the same parameter styles, support the use of SQL through various client interfaces (embedded SQL, CLI, and JDBC), and can all invoke other routines. To this end, the following steps represent a single approach for writing routines.

There are some routine features that are specific to a routine type. For example, result sets are specific to stored procedures, and scratchpads are specific to UDFs and methods. When you come across a step not applicable to the type of routine you are developing, go to the step that follows it.

Before writing a routine, you must decide the following:

- The type of routine you need.
- The programming language you will use to write it.
- Which interface to use if you require SQL statements in your routine.

See also the topics on Security, Library and Class Management, and Performance considerations.

### Procedure

To create a routine body, you must:

1. *Applicable only to external routines.* Accept input parameters from the invoking application or routine and declare output parameters. How a routine accepts parameters is dependent on the parameter style you will create the routine with. Each parameter style defines the set of parameters that are passed to the routine body and the order that the parameters are passed.

For example, the following is a signature of a UDF body written in C (using `sqludf.h`) for PARAMETER STYLE SQL:

```
SQL_API_RC SQL_API_FN product ( SQLUDF_DOUBLE *in1,  
                                SQLUDF_DOUBLE *in2,  
                                SQLUDF_DOUBLE *outProduct,  
                                SQLUDF_NULLIND *in1NullInd,  
                                SQLUDF_NULLIND *in2NullInd,  
                                SQLUDF_NULLIND *productNullInd,  
                                SQLUDF_TRAIL_ARGS )
```

2. Add the logic that the routine is to perform. Some features that you can employ in the body of your routines are as follows:
  - Calling other routines (nesting), or calling the current routine (recursion).

- In routines that are defined to have SQL (CONTAINS SQL, READS SQL, or MODIFIES SQL), the routine can issue SQL statements. The types of statements that can be invoked is controlled by how routines are registered.
  - In external UDFs and methods, use scratchpads to save state from one call to the next.
  - In SQL procedures, use condition handlers to determine the SQL procedure's behavior when a specified condition occurs. You can define conditions based on SQLSTATES.
3. *Applicable only to stored procedures.* Return one or more result sets. In addition to individual parameters that are exchanged with the calling application, stored procedures have the capability to return multiple result sets. Only SQL routines and CLI, ODBC, JDBC, and SQLJ routines and clients can accept result sets.

## Results

In addition to writing your routine, you also need to register it before you can invoke it. This is done with the CREATE statement that matches the type of routine you are developing. In general, the order in which you write and register your routine does not matter. However, the registration of a routine must precede its being built if it issues SQL that references itself. In this case, for a bind to be successful, the routine's registration must have already occurred.

## Debugging routines

### Before you begin

Before deploying routines on a production server you must thoroughly test and debug them on a test server. This is especially important for routines that need to be registered as NOT FENCED because they have unrestricted access to the database manager's memory, its databases, and database control structures. FENCED THREADSAFE routines also demand close attention because they share memory with other routines.

### About this task

#### Checklist of common routine problems

To ensure that a routine executes properly, check that:

- The routine is registered properly. The parameters provided in the CREATE statement must match the arguments handled by the routine body. With this in mind, check the following specific items:
  - The data types of the arguments used by the routine body are appropriate for the parameter types defined in the CREATE statement.
  - The routine does not write more bytes to an output variable than were defined for the corresponding result in the CREATE statement.
  - The routine arguments for SCRATCHPAD, FINAL CALL, DBINFO are present if the routine was registered with corresponding CREATE options.
  - For external routines, the value for the EXTERNAL NAME clause in the CREATE statement must match the routine library and entry point (case sensitivity varies by operating system).
  - For C++ routines, the C++ compiler applies type decoration to the entry point name. Either the type decorated name needs to be specified in the EXTERNAL NAME clause, or the entry point should be defined as extern "C" in the user code.

- The routine name specified during invocation must match the registered name (defined in the CREATE statement) of the routine. By default, routine identifiers are folded to uppercase. This does not apply to delimited identifiers, which are not folded to uppercase, and are therefore case sensitive.

The routine must be placed in the directory path specified in the CREATE statement, or if no path is given, where DB2 looks for it by default. For UDFs, methods, and fenced procedures, this is: `sqllib/function` (UNIX) or `sqllib\function` (Windows). For unfenced procedures, this is: `sqllib/function/unfenced` (UNIX) or `sqllib\function\unfenced` (Windows).

- The routine is built using the correct calling sequence, precompile (if embedded SQL), compile, and link options.
- The application is bound to the database, except if it is written using CLI, ODBC, or JDBC. The routine must also be bound if it contains SQL and does not use any of these interfaces.
- The routine accurately returns any error information to the client application.
- All applicable call types are accounted for if the routine was defined with FINAL CALL.
- The system resources used by routines are returned.
- If you attempt to invoke a routine and receive an error (SQLCODE -551, SQLSTATE 42501) indicating that you have insufficient privileges to perform this operation, this is likely because you do not have the EXECUTE privilege on the routine. This privilege can be granted to any invoker of a routine by a user with SECADM authority, ACCESSCTRL authority, or by any user with EXECUTE WITH GRANT OPTION privilege on the routine. The related topic on authorizations and routines provides details on how to effectively manage the use of this privilege.

### **Routine debugging techniques**

To debug a routine, use the following techniques:

- The Development Center provides extensive debugging tools for SQL-bodied and Java procedures.
- It is not possible to write diagnostic data to screen from a routine. If you intend to write diagnostic data to a file, ensure that you write to a globally accessible directory such as `\tmp`. Do not write to directories used by database managers or databases.

For procedures, a safe alternative is to write diagnostic data to an SQL table. The procedure you are testing must be registered with the MODIFIES SQL DATA clause in order to be able to write to an SQL table. If you need an existing procedure to write data (or no longer write data) to an SQL table, you must drop and re-register the procedure with (or without) the MODIFIES SQL DATA clause. Before dropping and re-registering the procedure, be aware of its dependencies.

- You can debug your routine locally by writing a simple application that invokes the routine entry point directly. Consult your compiler documentation for information on using the supplied debugger.

## **Returning error messages from SQL procedures**

When you issue a CREATE PROCEDURE statement for an SQL procedure, DB2 might accept the syntax of the SQL procedure body but fail to create the SQL

procedure at the precompile or compile stage. In these situations, DB2 normally creates a log file that contains the error messages.

## Procedure

To retrieve the error messages generated by DB2 and the C compiler for an SQL procedure, display the message log file in the following directory on your database server:

```
UNIX instance/function/routine/sqlproc/db_name/schema_name/tmp
```

where *instance* represents the path of the DB2 instance, *db\_name* represents the database alias, and *schema\_name* represents the schema with which the CREATE PROCEDURE statement was issued.

## Windows

```
instance\function\routine\sqlproc\db_name\schema_name\tmp
```

where *instance* represents the path of the DB2 instance, *db\_name* represents the database alias, and *schema\_name* represents the schema with which the CREATE PROCEDURE statement was issued.

**Note:** If the SQL procedure schema name is not issued as part of the CREATE PROCEDURE statement, DB2 uses the value of the CURRENT SCHEMA special register. To display the value of the CURRENT SCHEMA special register, issue the following statement at the CLP:

```
VALUES CURRENT SCHEMA
```

---

## External routine library and class management

To successfully develop and invoke external routines, external routine library and class files must be deployed and managed properly.

External routine library and class file management can be minimal if care is taken when external routines are first created and library and class files deployed.

The main external routine management considerations are the following:

- Deployment of external routine library and class files
- Security of external routine library and class files
- Resolution of external routine libraries and classes
- Modifications to external routine library and class files
- Backup and restore of external routine library and class files

System administrators, database administrators and database application developers should all take responsibility to ensure that external routine library and class files are secure and correctly preserved during routine development and database administration tasks.

## Deployment of external routine libraries and classes

Deployment of external routine libraries and classes refers to the copying of external routine libraries and classes to the database server once they have been built from source code.

External routine library, class, or assembly files must be copied into the DB2 *function directory* or a sub-directory of this directory on the database server. This is the recommended external routine deployment location. To find out more about

the function directory, see the description of the EXTERNAL clause for either of the following SQL statements: CREATE PROCEDURE or CREATE FUNCTION.

You can copy the external routine class, library, or assembly to other directory locations on the server, depending on the API and programming language used to implement the routine, however this is generally discouraged. If this is done, to successfully invoke the routine you must take particular note of the fully qualified path name and ensure that this value is used with the EXTERNAL NAME clause.

Library and class files can be copied to the database server file system using most generally available file transfer tools. Java routines can be copied from a computer where a DB2 client is installed to a DB2 database server using special system-defined procedures designed specifically for this purpose. See the topics on Java routines for more details.

When executing the appropriate SQL language CREATE statement for the routine type: CREATE PROCEDURE or CREATE FUNCTION, be sure to specify the appropriate clauses, paying particular attention to the EXTERNAL NAME clause.

- Specify the LANGUAGE clause with the appropriate value for the chosen API or programming language. Examples include: CLR, C, JAVA.
- Specify the PARAMETER STYLE clause with the name of the supported parameter style that was implemented in the routine code.
- Specify the EXTERNAL clause with the name of the library, class, or assembly file to be associated with the routine using one of the following values:
  - the fully qualified path name of the routine library, class, or assembly file.
  - the relative path name of the routine library, class, or assembly file relative to the function directory.

By default DB2 will look for the library, class, or assembly file by name in the function directory unless a fully qualified or relative path name for it is specified in the EXTERNAL clause.

## Security of external routine library or class files

External routine libraries are stored in the file system on the database server and are not backed up or protected in any way by the DB2 database manager. For routines to continue to successfully be invoked, it is imperative that the library associated with the routine continue to exist in the location specified in the EXTERNAL clause of the CREATE statement used to create the routine.

Do not move or delete routine libraries after creating routines; doing so will cause routine invocations to fail.

To prevent routine libraries from being accidentally or intentionally deleted or replaced, you must restrict access to the directories on the database server that contain routine libraries and restrict access to the routine library files. This can be done by using operating system commands to set directory and file permissions.

## Resolution of external routine libraries and classes

DB2 external routine library resolution is performed at the DB2 instance level. This means that in DB2 instances containing multiple DB2 databases, external routines can be created in one database that use external routine libraries already being used for a routine in another database.

Instance level external routine resolution supports code re-use by allowing multiple routine definitions to be associated with a single library. When external routine libraries are not re-used in this way, and instead copies of the external routine library exist in the file system of the database server, library name conflicts can happen. This can specifically happen when there are multiple databases in a single instance and the routines in each database are associated with their own copies of libraries and classes of routine bodies. A conflict arises when the name of a library or class used by a routine in one database is identical to the name of a library or class used by a routine in another database (in the same instance).

To minimize the likelihood of this happening, it is recommended that a single copy of a routine library be stored in the instance level function directory (`sqllib/function` directory) and that the `EXTERNAL` clause of all of the routine definitions in each of the databases reference the unique library.

If two functionally different routine libraries must be created with the same name, it is important to take additional steps to minimize the likelihood of library name conflicts.

**For C, C++, COBOL, and ADO.NET routines:**

Library name conflicts can be minimized or resolved by:

1. Storing the libraries with routine bodies in separate directories for each database.
2. Creating the routines with an `EXTERNAL NAME` clause value that specifies the full path of the given library (instead of a relative path).

**For Java routines:**

Class name conflicts cannot be resolved by moving the class files in question into different directories, because the `CLASSPATH` environment variable is instance-wide. The first class encountered in the `CLASSPATH` is the one that is used. Therefore, if you have two different Java routines that reference a class with the same name, one of the routines will use the incorrect class. There are two possible solutions: either rename the affected classes, or create a separate instance for each database.

## Modifications to external routine library and class files

Modifications to an existing external routine's logic might be necessary after an external routine has been deployed and it is in use in a production database system environment. Modifications to existing routines can be made, but it is important that they be done carefully so as to define a clear takeover point in time for the updates and to minimize the risk of interrupting any concurrent invocations of the routine.

If an external routine library requires an update, do not recompile and relink the routine to the same target file (for example, `sqllib/function/foo.a`) that the current routine is using while the database manager is running. If a current routine invocation is accessing a cached version of the routine process and the underlying library is replaced, this can cause the routine invocation to fail. If it is necessary to change the body of a routine without stopping and restarting DB2, complete the following steps:

1. Create the new external routine library with a different library or class file name.
2. If it is an embedded SQL routine, bind the routine package to the database using the `BIND` command.

3. Use the ALTER ROUTINE statement to change the routine definition so that the EXTERNAL NAME clause references the updated routine library or class. If the routine body to be updated is used by routines cataloged in multiple databases, the actions prescribed in this section must be completed for each affected database.
4. For updating Java routines that are built into JAR files, you must issue a CALL SQLJ.REFRESH\_CLASSES() statement to force DB2 to load the new classes. If you do not issue the CALL SQLJ.REFRESH\_CLASSES() statement after you update Java routine classes, DB2 continues to use the previous versions of the classes. DB2 refreshes the classes when a COMMIT or ROLLBACK occurs.

Once the routine definition has been updated, all subsequent invocations of the routine will load and run the new external routine library or class.

## Backup and restore of external routine library and class files

External routine libraries are not backed up with other database objects when a database backup is performed. They are similarly not restored when a database is restored.

If the purpose of a database backup and restore is to re-deploy a database, then external routine library files must be copied from the original database server file system to the target database server file system in such a way as to preserve the relative path names of the external routine libraries.

## External routine library management and performance

External routine library management can impact routine performance, because the DB2 database manager dynamically caches external routine libraries in an effort to improve performance in accordance with routine usage.

For optimal external routine performance consider the following:

- Keep the number of routines in each library as small as possible. It is better to have numerous small external routine libraries than a few large ones.
- Group together within source code the routine functions of routines that are commonly invoked together. When the code is compiled into an external routine library the entry points of commonly invoked routines will be closer together which allows the database manager to provide better caching support. The improved caching support is due to the efficiency that can be gained by loading a single external routine library once and then invoking multiple external routine functions within that library.

For external routines implemented in the C or C++ programming language, the cost of loading a library is paid only once for libraries that are consistently in use by C routines. After a routine is invoked once, all subsequent invocations from the same thread in the process, do not need to reload the routine's library.





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## Chapter 4. .NET common language runtime (CLR) routines

In DB2, a common language runtime (CLR) routine is an external routine created by executing a CREATE PROCEDURE or CREATE FUNCTION statement that references a .NET assembly as its external code body.

The following terms are important in the context of CLR routines:

### **.NET Framework**

A Microsoft application development environment comprised of the CLR and .NET Framework class library designed to provide a consistent programming environment for developing and integrating code pieces.

### **Common language runtime (CLR)**

The runtime interpreter for all .NET Framework applications.

### **intermediate language (IL)**

Type of compiled byte-code interpreted by the .NET Framework CLR. Source code from all .NET compatible languages compiles to IL byte-code.

### **assembly**

A file that contains IL byte-code. This can either be a library or an executable.

You can implement CLR routines in any language that can be compiled into an IL assembly. These languages include, but are not limited to: Managed C++, C#, Visual Basic, and J#.

Before developing a CLR routine, it is important to both understand the basics of routines and the unique features and characteristics specific to CLR routines. To learn more about routines and CLR routines see:

- “Benefits of using routines” on page 3
- “SQL data type representation in .NET CLR routines” on page 105
- “Parameters in .NET CLR routines” on page 107
- “Returning result sets from .NET CLR procedures” on page 109
- “Restrictions on .NET CLR routines” on page 111
- “Errors related to .NET CLR routines” on page 121

Developing a CLR routine is easy. For step-by-step instructions on how to develop a CLR routine and complete examples see:

- “Creating .NET CLR routines from DB2 Command Window” on page 113
- “Examples of C# .NET CLR procedures” on page 124
- “Examples of C# .NET CLR functions” on page 158

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## Support for external routine development in .NET CLR languages

To develop external routines in .NET CLR languages and successfully run them, you will need to use supported operating systems, versions of DB2 database servers and clients, and development software.

.NET CLR external routines can be implemented in any language that can be compiled into an IL assembly by the Microsoft .NET Framework. These languages include, but are not limited to: Managed C++, C#, Visual Basic, and J#.

You can develop .NET CLR routines on the following operating systems:

- Windows 2000
- Windows XP (32-bit edition and 64-bit edition)
- Windows Server 2003 (32-bit and 64-bit edition)
- Windows Server 2008 (32-bit and 64-bit edition)

A Version 9 or later data server client must be installed for .NET CLR routine development. The database server must be running DB2 Version 9 or later database products.

A supported version of the Microsoft .NET Framework software must also be installed on the same computer as the DB2 database server. The Microsoft .NET Framework is independently available or available as part of Microsoft .NET Framework Software Development Kit.

---

## Tools for developing .NET CLR routines

Tools can make the task of developing .NET CLR routines that interact with DB2 database faster and easier.

.NET CLR routines can be developed in Microsoft Visual Studio .NET using graphical tools available in:

- IBM Database Add-Ins for Microsoft Visual Studio

The following command line interfaces, provided with DB2, are also available for developing .NET CLR routines on DB2 database servers:

- DB2 Command Line Processor (DB2 CLP)
- DB2 Command Window

---

## Designing .NET CLR routines

When designing .NET CLR routines, you should take into account both general external routine design considerations and .NET CLR specific design considerations.

Knowledge and experience with .NET application development and general knowledge of external routines. The following topics can provide you with some of the required prerequisite information.

For more information on the features and uses of external routines see:

- “External routine implementation” on page 21

For more information on the characteristics of .NET CLR routines, see:

- Chapter 4, “.NET common language runtime (CLR) routines,” on page 103

With the prerequisite knowledge, designing embedded SQL routines consists mainly of learning about the unique features and characteristics of .NET CLR routines:

- Include assemblies that provide support for SQL statement execution in .NET CLR routines (IBM.Data.DB2)
- Supported SQL data types in .NET CLR routines
- Parameters to .NET CLR routines
- Returning result sets from .NET CLR routines

- Security and execution control mode settings for .NET CLR routines
- Restrictions on .NET CLR routines
- Returning result sets from .NET CLR procedures

After having learned about the .NET CLR characteristics, see: “Creating .NET CLR routines” on page 112.

## SQL data type representation in .NET CLR routines

.NET CLR routines can reference SQL data type values as routine parameters, parameter values to be used as part of SQL statement execution, and as variables, however the appropriate IBM SQL data type values, IBM Data Server Provider for .NET data type values, and .NET Framework data type values must be used to ensure that there is no truncation or loss of data when accessing or retrieving the values.

For routine parameter specifications within the CREATE PROCEDURE or CREATE FUNCTION statements used to create .NET CLR routines, DB2 SQL data type values are used. Most SQL data types can be specified for routine parameters, however there are some exceptions.

For specifying parameter values to be used as part of an SQL statement to be executed, IBM Data Server Provider for .NET objects must be used. The DB2Parameter object is used to represent a parameter to be added to a DB2Command object which represents a SQL statement. When specifying the data type value for the parameter, the IBM Data Server Provider for .NET data type values available in the IBM.Data.DB2Types namespace must be used. The IBM.Data.DB2Types namespace provides classes and structures to represent each of the supported DB2 SQL data types.

For parameters and local variables that might temporarily hold SQL data type values appropriate IBM Data Server Provider for .NET data types, as defined in the IBM.Data.DB2Types Namespace, must be used.

**Note:** The dbinfo structure is passed into CLR functions and procedures as a parameter. The scratchpad and call type for CLR UDFs are also passed into CLR routines as parameters. For information about the appropriate CLR data types for these parameters, see the related topic:

- Parameters in CLR routines

The following table shows mappings between DB2Type data types, DB2 data types, Informix® data types, Microsoft .NET Framework types, and DB2Types classes and structures.

Category	DB2Types Classes and Structures	DB2Type Data Type	DB2 Data Type	Informix Data Type	.NET Data Type
Numeric	DB2Int16	SmallInt	SMALLINT	BOOLEAN, SMALLINT	Int16
	DB2Int32	Integer	INT	INTEGER, INT, SERIAL	Int32
	DB2Int64	BigInt	BIGINT	BIGINT, BIGSERIAL, INT8, SERIAL8	Int64
	DB2Real, DB2Real370	Real	REAL	REAL, SMALLFLOAT	Single
	DB2Double	Double	DOUBLE PRECISION	DECIMAL (≤31), DOUBLE PRECISION	Double
	DB2Double	Float	FLOAT	DECIMAL (32), FLOAT	Double
	DB2Decimal	Decimal	DECIMAL	MONEY	Decimal
	DB2DecimalFloat	DecimalFloat	DECFLOAT (16 34) <sup>1,4</sup>		Decimal
	DB2Decimal	Numeric	DECIMAL	DECIMAL (≤31), NUMERIC	Decimal
Date/Time	DB2Date	Date	DATE	DATETIME (date precision)	Datetime
	DB2Time	Time	TIME	DATETIME (time precision)	TimeSpan
	DB2TimeStamp	Timestamp	TIMESTAMP	DATETIME (time and date precision)	DateTime
XML	DB2Xml	Xml <sup>2</sup>	XML		Byte[]
Character data	DB2String	Char	CHAR	CHAR	String
	DB2String	VarChar	VARCHAR	VARCHAR	String
	DB2String	LongVarChar <sup>1</sup>	LONG VARCHAR	LVARCHAR	String
Binary data	DB2Binary	Binary	CHAR FOR BIT DATA		Byte[]
	DB2Binary	Binary <sup>3</sup>	BINARY		Byte[]
	DB2Binary	VarBinary <sup>3</sup>	VARBINARY		Byte[]
	DB2Binary	LongVarBinary <sup>1</sup>	LONG VARCHAR FOR BIT DATA		Byte[]
Graphic data	DB2String	Graphic	GRAPHIC		String
	DB2String	VarGraphic	VARGRAPHIC		String
	DB2String	LongVarGraphic <sup>1</sup>	LONG VARGRAPHIC		String
LOB data	DB2Clob	Clob	CLOB	CLOB, TEXT	String
	DB2Blob	Blob	BLOB	BLOB, BYTE	Byte[]
	DB2Clob	DbClob	DBCLOB		String
Row ID	DB2RowId	RowId	ROWID		Byte[]

1. These data types are not supported as parameters in DB2 .NET common language runtime routines.
2. A DB2ParameterClass.ParameterName property of the type DB2Type.Xml can accept variables of the following types: String, byte[], DB2Xml, and XmlReader.
3. These data types are applicable only to DB2 for z/OS.
4. This data type is only supported for DB2 for z/OS, Version 9 and later releases and for DB2 for Linux, UNIX, and Windows Version 9.5 and later releases.

## Parameters in .NET CLR routines

Parameter declaration in .NET CLR routines must conform to the requirements of one of the supported parameter styles, and must respect the parameter keyword requirements of the particular .NET language used for the routine.

If the routine is to use a scratchpad, the dbinfo structure, or to have a PROGRAM TYPE MAIN parameter interface, there are additional details to consider. This topic addresses all CLR parameter considerations.

### Supported parameter styles for CLR routines

The parameter style of the routine must be specified at routine creation time in the EXTERNAL clause of the CREATE statement for the routine. The parameter style must be accurately reflected in the implementation of the external CLR routine code. The following DB2 parameter styles are supported for CLR routines:

- SQL (Supported for procedures and functions)
- GENERAL (Supported for procedures only)
- GENERAL WITH NULLS (Supported for procedures only)
- DB2SQL (Supported for procedures and functions)

For more information about these parameter styles see:

- “External routine parameter styles” on page 71

### CLR routine parameter null indicators

If the parameter style chosen for a CLR routine requires that null indicators be specified for the parameters, the null indicators are to be passed into the CLR routine as System.Int16 type values, or in a System.Int16[] value when the parameter style calls for a vector of null indicators.

When the parameter style dictates that the null indicators be passed into the routine as distinct parameters, as is required for parameter style SQL, one System.Int16 null indicator is required for each parameter.

In .NET languages distinct parameters must be prefaced with a keyword to indicate if the parameter is passed by value or by reference. The same keyword that is used for a routine parameter must be used for the associated null indicator parameter. The keywords used to indicate whether an argument is passed by value or by reference are discussed in more detail below.

For more information about parameter style SQL and other supported parameter styles, see:

- “External routine parameter styles” on page 71

### Passing CLR routine parameters by value or by reference

.NET language routines that compile into intermediate language (IL) byte-code require that parameters be prefaced with keywords that indicate the particular properties of the parameter such as whether the parameter is passed by value, by reference, is an input only, or an output only parameter.

Parameter keywords are .NET language specific. For example to pass a parameter by reference in C#, the parameter keyword is ref, whereas in Visual Basic, a by

reference parameter is indicated by the `byRef` keyword. The keywords must be used to indicate the SQL parameter usage (IN, OUT, INOUT) that was specified in the CREATE statement for the routine.

The following rules apply when applying parameter keywords to .NET language routine parameters in DB2 routines:

- IN type parameters must be declared *without* a parameter keyword in C#, and must be declared with the `byVal` keyword in Visual Basic.
- INOUT type parameters must be declared with the language specific keyword that indicates that the parameter is passed by reference. In C# the appropriate keyword is `ref`. In Visual Basic, the appropriate keyword is `byRef`.
- OUT type parameters must be declared with the language specific keyword that indicates that the parameter is an output only parameter. In C#, use the `out` keyword. In Visual Basic, the parameter must be declared with the `byRef` keyword. Output only parameters must always be assigned a value before the routine returns to the caller. If the routine does not assign a value to an output only parameter, an error will be raised when the .NET routine is compiled.

Here is what a C#, parameter style SQL procedure prototype looks like for a routine that returns a single output parameter language.

```
public static void Counter (out String language,  
                           out Int16 languageNullInd,  
                           ref String sqlState,  
                           String funcName,  
                           String funcSpecName,  
                           ref String sqlMsgString,  
                           Byte[] scratchPad,  
                           Int32 callType);
```

It is clear that the parameter style SQL is implemented because of the extra null indicator parameter, `languageNullInd` associated with the output parameter `language`, the parameters for passing the SQLSTATE, the routine name, the routine specific name, and optional user-defined SQL error message. Parameter keywords have been specified for the parameters as follows:

- In C# no parameter keyword is required for input only parameters.
- In C# the 'out' keyword indicates that the variable is an output parameter only, and that its value has not been initialized by the caller.
- In C# the 'ref' keyword indicates that the parameter was initialized by the caller, and that the routine can optionally modify this value.

See the .NET language specific documentation regarding parameter passing to learn about the parameter keywords in that language.

**Note:** DB2 controls allocation of memory for all parameters and maintains CLR references to all parameters passed into or out of a routine.

### **No parameter marker is required for procedure result sets**

No parameter markers is required in the procedure declaration of a procedure for a result set that will be returned to the caller. Any cursor statement that is not closed from inside of a CLR stored procedure will be passed back to its caller as a result set.

For more on result sets in CLR routines, see:

- “Returning result sets from .NET CLR procedures” on page 109

## **Dbinfo structure as CLR parameter**

The dbinfo structure used for passing additional database information parameters to and from a routine is supported for CLR routines through the use of an IL dbinfo class. This class contains all of the elements found in the C language sqludf\_dbinfo structure except for the length fields associated with the strings. The length of each string can be found using the .NET language Length property of the particular string.

To access the dbinfo class, simply include the IBM.Data.DB2 assembly in the file that contains your routine, and add a parameter of type sqludf\_dbinfo to your routine's signature, in the position specified by the parameter style used.

## **UDF scratchpad as CLR parameter**

If a scratchpad is requested for a user defined function, it is passed into the routine as a System.Byte[] parameter of the specified size.

## **CLR UDF call type or final call parameter**

For user-defined functions that have requested a final call parameter or for table functions, the call type parameter is passed into the routine as a System.Int32 data type.

## **PROGRAM TYPE MAIN supported for CLR procedures**

Program type MAIN is supported for .NET CLR procedures. Procedures defined as using Program Type MAIN must have the following signature:

```
void functionname(Int32 NumParams, Object[] Params)
```

## **Returning result sets from .NET CLR procedures**

You can develop CLR procedures that return result sets to a calling routine or application. Result sets cannot be returned from CLR functions (UDFs).

### **Before you begin**

The .NET representation of a result set is a DB2DataReader object which can be returned from one of the various execute calls of a DB2Command object. Any DB2DataReader object whose Close() method has not explicitly been called prior to the return of the procedure, can be returned. The order in which result sets are returned to the caller is the same as the order in which the DB2DataReader objects were instantiated. No additional parameters are required in the function definition in order to return a result set.

An understanding of how to create CLR routines will help you to follow the steps in the procedure below for returning results from a CLR procedure.

- Creating .NET CLR routines

### **Procedure**

To return a result set from a CLR procedure:

1. In the CREATE PROCEDURE statement for the CLR routine you must specify along with any other appropriate clauses, the DYNAMIC RESULT SETS clause with a value equal to the number of result sets that are to be returned by the procedure.

2. No parameter marker is required in the procedure declaration for a result set that is to be returned to the caller.
3. In the .NET language implementation of your CLR routine, create a `DB2Connection` object, a `DB2Command` object, and a `DB2Transaction` object. A `DB2Transaction` object is responsible for rolling back and committing database transactions.
4. Initialize the `Transaction` property of the `DB2Command` object to the `DB2Transaction` object.
5. Assign a string query to the `DB2Command` object's `CommandText` property that defines the result set that you want to return.
6. Instantiate a `DB2DataReader`, and assign to it, the result of the invocation of the `DB2Command` object method `ExecuteReader`. The result set of the query will be contained in the `DB2DataReader` object.
7. Do not execute the `Close()` method of the `DB2DataReader` object at any point prior to the procedure's return to the caller. The still open `DB2DataReader` object will be returned as a result set to the caller.  
 When more than one `DB2DataReader` is left open upon the return of a procedure, the `DB2DataReaders` are returned to the caller in the order of their creation. Only the number of result sets specified in the `CREATE PROCEDURE` statement will be returned to the caller.
8. Compile your .NET CLR language procedure and install the assembly in the location specified by the `EXTERNAL` clause in the `CREATE PROCEDURE` statement. Execute the `CREATE PROCEDURE` statement for the CLR procedure, if you have not already done so.
9. Once the CLR procedure assembly has been installed in the appropriate location and the `CREATE PROCEDURE` statement has successfully been executed, you can invoke the procedure with the `CALL` statement to see the result sets return to the caller.

## Security and execution modes for CLR routines

As a database administrator or application developer, you might want to protect the assemblies associated with your DB2 external routines from unwelcome tampering to restrict the actions of routines at run time. DB2 .NET common language runtime (CLR) routines support the specification of an execution control mode that identifies what types of actions a routine will be allowed to perform at run time. At run time, DB2 can detect if the routine attempts to perform actions beyond the scope of its specified execution control mode, which can be helpful when determining whether an assembly has been compromised.

To set the execution control mode of a CLR routine, specify the optional `EXECUTION CONTROL` clause in the `CREATE` statement for the routine. Valid modes are:

- `SAFE`
- `FILEREAD`
- `FILEWRITE`
- `NETWORK`
- `UNSAFE`

To modify the execution control mode in an existing CLR routine, execute the `ALTER PROCEDURE` or `ALTER FUNCTION` statement.



If the EXECUTION CONTROL clause is not specified for a CLR routine, by default the CLR routine is run using the most restrictive execution control mode: SAFE. Routines that are created with this execution control mode can only access resources that are controlled by the database manager. Less restrictive execution control modes allow a routine to access files (FILEREAD or FILEWRITE) or perform network operations such as accessing a web page (NETWORK). The execution control mode UNSAFE specifies that no restrictions are to be placed on the behavior of the routine. Routines defined with UNSAFE execution control mode can execute binary code.

These modes represent a hierarchy of allowable actions, and a higher-level mode includes the actions that are allowed below it in the hierarchy. For example, execution control mode NETWORK allows a routine to access web pages on the internet, read and write to files, and access resources that are controlled by the database manager. It is recommended to use the most restrictive execution control mode possible, and to avoid using the UNSAFE mode.

If DB2 detects at run time that a CLR routine is attempting an action outside of the scope of its execution control mode, DB2 will return error (SQLSTATE 38501).

The EXECUTION CONTROL clause can only be specified for LANGUAGE CLR routines. The scope of applicability of the EXECUTION CONTROL clause is limited to the .NET CLR routine itself, and does not extend to any other routines that it might call.

Refer to the syntax of the CREATE statement for the appropriate routine type for a full description of the supported execution control modes.

## Restrictions on .NET CLR routines

The general implementation restrictions that apply to all external routines or particular routine classes (procedure or UDF) also apply to CLR routines. There are some restrictions that are particular to CLR routines. These restrictions are listed here.

### **The CREATE METHOD statement with LANGUAGE CLR clause is not supported**

You cannot create external methods for DB2 structured types that reference a CLR assembly. The use of a CREATE METHOD statement that specifies the LANGUAGE clause with value CLR is not supported.

### **CLR procedures cannot be implemented as NOT FENCED procedures**

CLR procedures cannot be run as unfenced procedures. The CREATE PROCEDURE statement for a CLR procedure can not specify the NOT FENCED clause.

### **EXECUTION CONTROL clause restricts the logic contained in the routine**

The EXECUTION CONTROL clause and associated value determine what types of logic and operations can be executed in a .NET CLR routine. By default the EXECUTION CONTROL clause value is set to SAFE. For routine logic that reads files, writes to files, or that accesses the internet, a non-default and less restrictive

value for the EXECUTION CONTROL clause must be specified.

### **Maximum decimal precision is 29, maximum decimal scale is 28 in a CLR routine**

The DECIMAL data type in DB2 is represented with a precision of 31 digits and a scale of 28 digits. The .NET CLR System.Decimal data type is limited to a precision of 29 digits and a scale of 28 digits. Therefore, DB2 external CLR routines must not assign a value to a System.Decimal data type that has a value greater than  $(2^{96})-1$ , which is the highest value that can be represented using a 29 digit precision and 28 digit scale. DB2 will raise a runtime error (SQLSTATE 22003, SQLCODE -413) if such an assignment occurs. At the time of execution of the CREATE statement for the routine, if a DECIMAL data type parameter is defined with a scale greater than 28, DB2 will raise an error (SQLSTATE 42613, SQLCODE -628).

If you require your routine to manipulate decimal values with the maximum precision and scale supported by DB2, you can implement your external routine in a different programming language such as Java.

### **Data types not supported in CLR routines**

The following DB2 SQL data types are not supported in CLR routines:

- LONG VARCHAR
- LONG VARCHAR FOR BIT DATA
- LONG GRAPHIC
- ROWID

### **Running a 32-bit CLR routine on a 64-bit instance**

CLR routines cannot be run on 64-bit instances, because the .NET Framework cannot be installed on 64-bit operating systems at this time.

### **.NET CLR not supported for implementing security plug-ins**

The .NET CLR is not supported for compiling and linking source code for security plug-in libraries.

---

## **Creating .NET CLR routines**

### **Before you begin**

Creating .NET CLR routines consists of:

- Executing a CREATE statement that defines the routine in a DB2 database server
- Developing the routine implementation that corresponds to the routine definition

The ways in which you can create .NET CLR routines follow:

- Using the graphical tools provided with the IBM Database Add-Ins for Microsoft Visual Studio
- Using the DB2 Command Window

In general it is easiest to create .NET CLR routines using the IBM Database Add-Ins for Microsoft Visual Studio. If this is not available for use, the DB2 Command Window provides similar support through a command line interface.

- Review the Chapter 4, “.NET common language runtime (CLR) routines,” on page 103.
- Ensure that you have access to a DB2 Version 9 server, including instances and databases.
- Ensure that the operating system is at a version level that is supported by DB2 database products.
- Ensure that the Microsoft .NET development software is at a version level that is supported for .NET CLR routine development.
- Authority to execute the CREATE PROCEDURE or CREATE FUNCTION statement.

For a list of restrictions associated with CLR routines see:

- “Restrictions on .NET CLR routines” on page 111

### **About this task**

Create .NET CLR routines from one of the following interfaces:

#### **Procedure**

- Visual Studio .NET when the IBM Database Add-Ins for Microsoft Visual Studio is also installed. When the Add-In is installed, graphical tools integrated into Visual Studio .NET are available for creating .NET CLR routines that work in DB2 database servers.
- DB2 Command Window

#### **What to do next**

To create .NET CLR routines from DB2 Command Window, see:

- “Creating .NET CLR routines from DB2 Command Window”

## **Creating .NET CLR routines from DB2 Command Window**

### **Before you begin**

- Knowledge of CLR routine implementation. To learn about CLR routines in general and about CLR features, see:
  - Chapter 4, “.NET common language runtime (CLR) routines,” on page 103
- The database server must be running a Windows operating system that supports the Microsoft .NET Framework.
- A supported version of the Microsoft .NET Framework software must be installed on the server. The .NET Framework is independently available or as part of the Microsoft .NET Framework Software Development Kit.
- A supported DB2 database product or IBM Data Server Client must be installed. See the installation requirements for DB2 database products.
- Authority to execute the CREATE statement for the external routine. For the privileges required to execute the CREATE PROCEDURE statement or CREATE FUNCTION statement, see the details of the appropriate statement.

### **Restrictions**

For a list of restrictions associated with CLR routines see:

- “Restrictions on .NET CLR routines” on page 111

## About this task

Procedures and functions that reference an intermediate language assembly are created in the same way as any external routine is created. You would choose to implement an external routine in a .NET language if:

- You want to encapsulate complex logic into a routine that accesses the database or that performs an action outside of the database.
- You require the encapsulated logic to be invoked from any of: multiple applications, the CLP, another routine (procedure, function (UDF), or method), or a trigger.
- You are most comfortable coding this logic in a .NET language.

## Procedure

1. Code the routine logic in any CLR supported language.
  - For general information about .NET CLR routines and .NET CLR routine features see the topics referenced in the Prerequisites section
  - Use or import the IBM.Data.DB2 assembly if your routine will execute SQL.
  - Declare host variables and parameters correctly using data types that map to DB2 SQL data types. For a data type mapping between DB2 and .NET data types:
    - “SQL data type representation in .NET CLR routines” on page 105
  - Parameters and parameter null indicators must be declared using one of DB2’s supported parameter styles and according to the parameter requirements for .NET CLR routines. As well, scratchpads for UDFs, and the DBINFO class are passed into CLR routines as parameters. For more on parameters and prototype declarations see:
    - “Parameters in .NET CLR routines” on page 107
  - If the routine is a procedure and you want to return a result set to the caller of the routine, you do not require any parameters for the result set. For more on returning result sets from CLR routines:
    - “Returning result sets from .NET CLR procedures” on page 109
  - Set a routine return value if required. CLR scalar functions require that a return value is set before returning. CLR table functions require that a return code is specified as an output parameter for each invocation of the table function. CLR procedures do not return with a return value.
2. Build your code into an intermediate language (IL) assembly to be executed by the CLR. For information on how to build CLR .NET routines that access DB2 database products, see the following topic:
  - “Building .NET CLR routine code” on page 115
3. Copy the assembly into the DB2 *function directory* on the database server. It is recommended that you store assemblies or libraries associated with DB2 routines in the function directory. To find out more about the function directory, see the EXTERNAL clause of either of the following statements: CREATE PROCEDURE or CREATE FUNCTION.
 

You can copy the assembly to another directory on the server if you want, but to successfully invoke the routine you must note the fully qualified path name of your assembly as you will require it for the next step.
4. Execute either dynamically or statically the appropriate SQL language CREATE statement for the routine type: CREATE PROCEDURE or CREATE FUNCTION.

- Specify the LANGUAGE clause with value: CLR.
- Specify the PARAMETER STYLE clause with the name of the supported parameter style that was implemented in the routine code.
- Specify the EXTERNAL clause with the name of the assembly to be associated with the routine using one of the following values:
  - the fully qualified path name of the routine assembly.
  - the relative path name of the routine assembly relative to the function directory.

By default the DB2 database manager will look for the assembly by name in the function directory unless a fully qualified or relative path name for the library is specified in the EXTERNAL clause.

When the CREATE statement is executed, if the assembly specified in the EXTERNAL clause is not found by the DB2 database manager, you will receive an error (SQLCODE -20282) with reason code 1.

- Specify the DYNAMIC RESULT SETS clause with an integer value equivalent to the maximum number of result sets that might be returned by the routine.
- You can not specify the NOT FENCED clause for CLR procedures. By default CLR procedures are executed as FENCED procedures.

---

## Building .NET CLR routine code

Once .NET CLR routine implementation code has been written, it must be built before the routine assembly can be deployed and the routine invoked. The steps required to build .NET CLR routines are similar to those required to build any external routine however there are some differences.

### Procedure

There are three ways to build .NET CLR routines:

- Using the graphical tools provided with the IBM Database Add-Ins for Microsoft Visual Studio
- Using DB2 sample batch files
- Entering commands from a DB2 Command Window

The DB2 sample build scripts and batch files for routines are designed for building DB2 sample routines (procedures and user-defined functions) as well as user created routines for a particular operating system using the default supported compilers.

There is a separate set of DB2 sample build scripts and batch files for C# and Visual Basic. In general it is easiest to build .NET CLR routines using the graphical tools or the build scripts which can easily be modified if required, however it is often helpful to know how to build routines from DB2 Command Window as well.

## Building .NET common language runtime (CLR) routine code using sample build scripts

Building .NET common language runtime (CLR) routine source code is a subtask of creating .NET CLR routines. This task can be done quickly and easily using DB2 sample batch files.

The sample build scripts can be used for source code with or without SQL statements. The build scripts take care of the compilation, linking, and deployment of the built assembly to the function directory.

As alternatives, you can simplify the task of building .NET CLR routine code by doing so in Visual Studio .NET or you do the steps in the DB2 sample build scripts manually. Refer to:

- Building .NET common language runtime (CLR) routines in Visual Studio .NET
- Building .NET common language runtime (CLR) routines using DB2 Command Window

The programming language specific sample build scripts for building C# and Visual Basic .NET CLR routines are named **bldrtn**. They are located in DB2 directories along with sample programs that can be built with them as follows:

- For C: sql1ib/samples/cs/
- For C++: sql1ib/samples/vb/

The **bldrtn** scripts can be used to build source code files containing both procedures and user-defined functions. The script does the following:

- Establishes a connection with a user-specified database
- Compiles and links the source code to generate an assembly with a .DLL file suffix
- Copies the assembly to the DB2 function directory on the database server

The **bldrtn** scripts accept two arguments:

- The name of a source code file without any file suffix
- The name of a database to which a connection will be established

The database parameter is optional. If no database name is supplied, the program uses the default sample database. As routines must be built on the same instance where the database resides, no arguments are required for a user ID and password.

#### Prerequisites

- The required .NET CLR routine operating system and development software prerequisites must be satisfied. See: "Support for .NET CLR routine development".
- Source code file containing one or more routine implementations.
- The name of the database within the current DB2 instance in which the routines are to be created.

#### Procedure

To build a source code file that contains one or more routine code implementations, follow the steps below.

1. Open a DB2 Command Window.
2. Copy your source code file into the same directory as the **bldrtn** script file.
3. If the routines will be created in the sample database, enter the build script name followed by the name of the source code file without the .cs or .vb file extension:

```
bldrtn file-name
```

If the routines will be created in another database, enter the build script name, the source code file name without any file extension, and the database name:

```
bldrtn file-name database-name
```

The script compiles and links the source code and produces an assembly. The script then copies the assembly to the function directory on the database server

4. If this is not the first time that the source code file containing the routine implementations was built, stop and restart the database to ensure the new version of the shared library is used by the DB2 database system. You can do this by entering **db2stop** followed by **db2start** on the command line.

Once you have successfully built the routine shared library and deployed it to the function directory on the database server, you should complete the steps associated with the task of creating C and C++ routines.

Creating .NET CLR routines includes a step for executing the CREATE statement for each routine that was implemented in the source code file. After routine creation is completed you can invoke your routines.

## Building .NET common language runtime (CLR) routine code from DB2 Command Window

Building .NET CLR routine source code is a sub-task of creating .NET CLR routines. This task can be done manually from DB2 Command Window. The same procedure can be followed regardless of whether there are SQL statements within the routine code or not. The task steps include compilation of source code written in a .NET CLR supported programming language into an assembly with a .DLL file suffix.

### Before you begin

As alternatives, you can simplify the task of building .NET CLR routine code by doing so in Visual Studio .NET or by using DB2 sample build scripts. Refer to:

- Building .NET common language runtime (CLR) routines in Visual Studio .NET
- Building .NET common language runtime (CLR) routines using sample build scripts
- Required operating system and .NET CLR routine development software prerequisites have been satisfied. See: "Support for .NET CLR routine development".
- Source code written in a supported .NET CLR programming language containing one or more .NET CLR routine implementations.
- The name of the database within the current DB2 instance in which the routines are to be created.
- The operating specific compile and link options required for building .NET CLR routines.

### Procedure

To build a source code file that contains one or more .NET CLR routine code implementations:

1. Open a DB2 Command Window.
2. Navigate to the directory that contains your source code file.
3. Establish a connection with the database in which the routines will be created.
4. Compile the source code file.

5. Link the source code file to generate a shared library. This requires the use of some DB2 specific compile and link options.
6. Copy the assembly file with the .DLL file suffix to the DB2 function directory on the database server.
7. If this is not the first time that the source code file containing the routine implementations was built, stop and restart the database to ensure the new version of the shared library is used by DB2. You can do this by issuing the db2stop command followed by the db2start command.

## Results

Once you have successfully built and deployed the routine library, you should complete the steps associated with the task of creating .NET CLR routines. Creating .NET CLR routines includes a step for executing the CREATE statement for each routine that was implemented in the source code file. This step must also be completed before you will be able to invoke the routines.

## Example

The following example demonstrates the re-building of a .NET CLR source code file. Steps are shown for both a Visual Basic code file named myVBfile.vb containing routine implementations as well as for a C# code file named myCSfile.cs. The routines are being built on a Windows 2000 operating system using Microsoft .NET Framework 1.1 to generate a 64-bit assembly.

1. Open a DB2 Command Window.
2. Navigate to the directory that contains your source code file.
3. Establish a connection with the database in which the routines will be created.  
`db2 connect to database-name`
4. Compile the source code file using the recommended compile and link options (where \$DB2PATH is the install path of the DB2 instance. Replace this value before running the command):

```
C# example
=====
csc /out:myCSfile.dll /target:library
    /reference:$DB2PATH%\bin\netf11\IBM.Data.DB2.dll myCSfile.cs
```

```
Visual Basic example
=====
vbc /target:library /libpath:$DB2PATH\bin\netf11
    /reference:$DB2PATH\bin\netf11\IBM.Data.DB2.dll
    /reference:System.dll
    /reference:System.Data.dll myVBfile.vb
```

The compiler will generate output if there are any errors. This step generates an export file named myfile.exp.

5. Copy the shared library to the DB2 function directory on the database server.

```
C# example
=====
rm -f ~HOME/sql1lib/function/myCSfile.DLL
cp myCSfile $HOME/sql1lib/function/myCSfile.DLL
```

```
Visual Basic example
=====
rm -f ~HOME/sql1lib/function/myVBfile.DLL
cp myVBfile $HOME/sql1lib/function/myVBfile.DLL
```



This step ensures that the routine library is in the default directory where DB2 looks for routine libraries. Refer to the topic on creating .NET CLR routines for more on deploying routine libraries.

6. Stop and restart the database as this is a re-building of a previously built routine source code file.

```
db2stop
db2start
```

Building .NET CLR routines is generally most easily done using the operating specific sample build scripts which also can be used as a reference for how to build routines from the command line.

## CLR .NET routine compile and link options

The following are the compile and link options recommended by DB2 for building Common Language Runtime (CLR) .NET routines on Windows with either the Microsoft Visual Basic .NET compiler or the Microsoft C# compiler, as demonstrated in the `samples\.NET\cs\bldrtn.bat` and `samples\.NET\vb\bldrtn.bat` batch files.

Compile and link options for bldrtn	
<b>Compile and link options using the Microsoft C# compiler:</b>	
<b>csc</b>	The Microsoft C# compiler.
<b>/out:%1.dll /target:library</b>	Output the dynamic link library as a stored procedure assembly dll.
<b>/debug</b>	Use the debugger.
<b>/lib: "%DB2PATH%\bin\netf20\</b>	Use the library path for .NET Framework Version 2.0.
	There are several supported versions of the .NET framework for applications: version 2.0, version 3.0, and version 3.5. There is a dynamic link library for each. For .NET Framework Version 1.1, use the "%DB2PATH%\bin\netf11 sub-directory. For .NET Framework Version 2.0, 3.0, and 3.5, use the "%DB2PATH%\bin\netf20 sub-directory.
<b>/reference:IBM.Data.DB2.dll</b>	Use the DB2 dynamic link library for the IBM Data Server Provider for .NET
Refer to your compiler documentation for additional compiler options.	

#### Compile and link options using the Microsoft Visual Basic .NET compiler:

**vbc** The Microsoft Visual Basic .NET compiler.

**/out:%1.dll /target:library**

Output the dynamic link library as a stored procedure assembly dll.

**/debug** Use the debugger.

**/libpath:"%DB2PATH%\bin\netf20\**

Use the library path for .NET Framework Version 2.0.

There are several supported versions of the .NET framework for applications: version 2.0, version 3.0, and version 3.5. There is a dynamic link library for each. For .NET Framework Version 1.1, use the "%DB2PATH%\bin\netf11 sub-directory. For .NET Framework Version 2.0, 3.0, and 3.5, use the "%DB2PATH%\bin\netf20 sub-directory.

**/reference:IBM.Data.DB2.dll**

Use the DB2 dynamic link library for the IBM Data Server Provider for .NET.

**/reference:System.dll**

Reference the Microsoft Windows System dynamic link library.

**/reference:System.Data.dll**

Reference the Microsoft Windows System Data dynamic link library.

Refer to your compiler documentation for additional compiler options.

---

## Debugging .NET CLR routines

Debugging .NET CLR routines might be required if you fail to be able to create a routine, invoke a routine, or if upon invocation a routine does not behave or perform as expected.

### About this task

Consider the following when debugging .NET CLR routines:

### Procedure

- Verify that a supported operating system for .NET CLR routine development is being used.
- Verify that both a supported DB2 database server and DB2 client for .NET CLR routine development are being used.
- Verify that supported Microsoft .NET Framework development software is being used.
- If routine creation failed:
  - Verify that the user has the required authority and privileges to execute the CREATE PROCEDURE or CREATE FUNCTION statement.
- If routine invocation failed:
  - Verify that the user has authority to execute the routine. If an error (SQLCODE -551, SQLSTATE 42501), this is likely because the invoker does not have the EXECUTE privilege on the routine. This privilege can be granted by any user with SECADM authority, ACCESSCTRL authority, or by any user with EXECUTE WITH GRANT OPTION privilege on the routine.
  - Verify that the routine parameter signature used in the CREATE statement for the routine matches the routine parameter signature in the routine implementation.

- Verify that the data types used in the routine implementation are compatible with the data types specified in the routine parameter signature in the CREATE statement.
- Verify that in the routine implementation that the .NET CLR language specific keywords used to indicate the method by which the parameter must be passed (by value or by reference) are valid.
- Verify that the value specified in the EXTERNAL clause in the CREATE PROCEDURE or CREATE FUNCTION statement matches the location where the .NET CLR assembly that contains the routine implementation is located on the file system of the computer where the DB2 database server is installed.
- If the routine is a function, verify that all of the applicable call types have been programmed correctly in the routine implementation. This is particularly important if the routine was defined with the FINAL CALL clause.
- If the routine is not behaving as expected:
  - Modify your routine such that it outputs diagnostic information to a file located in a globally accessible directory. Output of diagnostic information to the screen is not possible from .NET CLR routines. Do not direct output to files in directories used by DB2 database managers or DB2 databases.
  - Debug your routine locally by writing a simple .NET application that invokes the routine entry point directly. For information on how to use debugging features in Microsoft Visual Studio .NET, consult the Microsoft Visual Studio .NET compiler documentation.

## Results

For more information on common errors related to .NET CLR routine creation and invocation, see:

- “Errors related to .NET CLR routines”

## Errors related to .NET CLR routines

Although external routines share a generally common implementation, there are some DB2 errors that might arise that are specific to CLR routines. This reference lists the most commonly encountered .NET CLR related errors listed by their SQLCODE or behavior along with some debugging suggestions. DB2 errors related to routines can be classified as follows:

### Routine creation time errors

Errors that arise when the CREATE statement for the routine is executed.

### Routine runtime errors

Errors that arise during the routine invocation or execution.

Regardless of when a DB2 routine related error is raised by DB2, the error message text details the cause of the error and the action that the user should take to resolve the problem. Additional routine error scenario information can be found in the db2diag diagnostic log files.

## CLR routine creation time errors

### SQLCODE -451, SQLSTATE 42815

This error is raised upon an attempt to execute a CREATE TYPE statement that includes an external method declaration specifying the LANGUAGE clause with value CLR. You can not create DB2 external methods for structured types that reference a CLR assembly at this time. Change the

LANGUAGE clause so that it specifies a supported language for the method and implement the method in that alternate language.

#### **SQLCODE -449, SQLSTATE 42878**

The CREATE statement for the CLR routine contains an invalidly formatted library or function identification in the EXTERNAL NAME clause. For language CLR, the EXTERNAL clause value must specifically take the form: '<a>:<b>!<c>' as follows:

- <a> is the CLR assembly file in which the class is located.
- <b> is the class in which the method to invoke resides.
- <c> is the method to invoke.

No leading or trailing blank characters are permitted between the single quotation marks, object identifiers, and the separating characters (for example, ' <a> ! <b> ' is invalid). Path and file names, however, can contain blanks if the platform permits. For all file names, the file can be specified using either the short form of the name (example: math.dll) or the fully qualified path name (example: d:\udfs\math.dll). If the short form of the file name is used, if the platform is UNIX or if the routine is a LANGUAGE CLR routine, then the file must reside in the function directory. If the platform is Windows and the routine is not a LANGUAGE CLR routine then the file must reside in the system PATH. File extensions (examples: .a (on UNIX), .dll (on Windows)) should always be included in the file name.

### **CLR routine runtime errors**

#### **SQLCODE -20282, SQLSTATE 42724, reason code 1**

The external assembly specified by the EXTERNAL clause in the CREATE statement for the routine was not found.

- Check that the EXTERNAL clause specifies the correct routine assembly name and that the assembly is located in the specified location. If the EXTERNAL clause does not specify a fully qualified path name to the desired assembly, DB2 presumes that the path name provided is a relative path name to the assembly, relative to the DB2 function directory.

#### **SQLCODE -20282, SQLSTATE 42724, reason code 2**

An assembly was found in the location specified by the EXTERNAL clause in the CREATE statement for the routine, but no class was found within the assembly to match the class specified in the EXTERNAL clause.

- Check that the assembly name specified in the EXTERNAL clause is the correct assembly for the routine and that it exists in the specified location.
- Check that the class name specified in the EXTERNAL clause is the correct class name and that it exists in the specified assembly.

#### **SQLCODE -20282, SQLSTATE 42724, reason code 3**

An assembly was found in the location specified by the EXTERNAL clause in the CREATE statement for the routine, that had a correctly matching class definition, but the routine method signature does not match the routine signature specified in the CREATE statement for the routine.

- Check that the assembly name specified in the EXTERNAL clause is the correct assembly for the routine and that it exists in the specified location.

- Check that the class name specified in the EXTERNAL clause is the correct class name and that it exists in the specified assembly.
- Check that the parameter style implementation matches the parameter style specified in the CREATE statement for the routine.
- Check that the order of the parameter implementation matches the parameter declaration order in the CREATE statement for the routine and that it respects the extra parameter requirements for the parameter style.
- Check that the SQL parameter data types are correctly mapped to CLR .NET supported data types.

**SQLCODE -4301, SQLSTATE 58004, reason code 5 or 6**

An error occurred while attempting to start or communicate with a .NET interpreter. DB2 was unable to load a dependent .NET library [reason code 5] or a call to the .NET interpreter failed [reason code 6].

- Ensure that the DB2 instance is configured correctly to run a .NET procedure or function (mscorlib.dll must be present in the system PATH). Ensure that db2clr.dll is present in the sqllib/bin directory, and that IBM.Data.DB2 is installed in the global assembly cache. If these are not present, ensure that the .NET Framework version 1.1, or a later version, is installed on the database server, and that the database server is running DB2 version 8.2 or a later release.

**SQLCODE -4302, SQLSTATE 38501**

An unhandled exception occurred while executing, preparing to execute, or subsequent to executing the routine. This could be the result of a routine logic programming error that was unhandled or could be the result of an internal processing error. For errors of this type, the .NET stack traceback that indicates where the unhandled exception occurred will be written to the db2diag log files.

This error can also occur if the routine attempted an action that is beyond the scope of allowed actions for the specified execution mode for the routine. In this case, an entry will be made in the db2diag log files specifically indicating that the exception occurred due to an execution control violation. The exception stack traceback that indicates where the violation occurred will also be included.

Determine if the assembly of the routine has been compromised or recently modified. If the routine has been validly modified, this problem can be occurring because the EXECUTION CONTROL mode for the routine is no longer set to a mode that is appropriate for the changed logic. If you are certain that the assembly has not been wrongfully tampered with, you can modify the routine's execution mode with the ALTER PROCEDURE or ALTER FUNCTION statement as appropriate. Refer to the following topic for more information:

- “Security and execution modes for CLR routines” on page 110

---

## Examples of .NET CLR routines

### Procedure

When developing .NET CLR routines, it is helpful to refer to examples to get a sense of what the CREATE statement and the .NET CLR routine code should look like. The following topics contain examples of .NET CLR procedures and functions (including both scalar and table functions):

### **.NET CLR procedures**

- Examples of Visual Basic .NET CLR procedures
- Examples of C# .NET CLR procedures

### **.NET CLR functions**

- Examples of Visual Basic .NET CLR functions
- Examples of C# .NET CLR functions

## **Examples of C# .NET CLR procedures**

Once the basics of procedures, also called stored procedures, and the essentials of .NET common language runtime routines are understood, you can start using CLR procedures in your applications.

### **Before you begin**

This topic contains examples of CLR procedures implemented in C# that illustrate the supported parameter styles, passing parameters, including the dbinfo structure, how to return a result set and more. For examples of CLR UDFs in C#:

- “Examples of C# .NET CLR functions” on page 158

Before working with the CLR procedure examples you might want to read the following concept topics:

- Chapter 4, “.NET common language runtime (CLR) routines,” on page 103
- “Creating .NET CLR routines from DB2 Command Window” on page 113
- “Building .NET CLR routine code” on page 115 *Developing ADO.NET and OLE DB Applications*

The examples below make use of a table named EMPLOYEE that is contained in the SAMPLE database.

### **Procedure**

Use the following examples as references when making your own C# CLR procedures:

- The C# external code file
- Example 1: C# parameter style GENERAL procedure
- Example 2: C# parameter style GENERAL WITH NULLS procedure
- Example 3: C# parameter style SQL procedure
- Example 4: C# procedure returning a result set
- Example 5: C# procedure accessing the dbinfo structure
- Example 6: C# procedure in PROGRAM TYPE MAIN style

### **Example**

#### **The C# external code file**

The examples show a variety of C# procedure implementations. Each example consists of two parts: the CREATE PROCEDURE statement and the external C# code implementation of the procedure from which the associated assembly can be built.

The C# source file that contains the procedure implementations of the following examples is named gwenProc.cs and has the following format:

Table 16. C# external code file format

```
using System;
using System.IO;
using IBM.Data.DB2;

namespace bizLogic
{
    class empOps
    {
        ...
        // C# procedures
        ...
    }
}
```

The file inclusions are indicated at the top of the file. The `IBM.Data.DB2` inclusion is required if any of the procedures in the file contain SQL. There is a namespace declaration in this file and a class `empOps` that contains the procedures. The use of namespaces is optional. If a namespace is used, the namespace must appear in the assembly path name provided in the `EXTERNAL` clause of the `CREATE PROCEDURE` statement.

It is important to note the name of the file, the namespace, and the name of the class, that contains a given procedure implementation. These names are important, because the `EXTERNAL` clause of the `CREATE PROCEDURE` statement for each procedure must specify this information so that DB2 can locate the assembly and class of the CLR procedure.

#### Example 1: C# parameter style GENERAL procedure

This example shows the following:

- `CREATE PROCEDURE` statement for a parameter style GENERAL procedure
- C# code for a parameter style GENERAL procedure

This procedure takes an employee ID and a current bonus amount as input. It retrieves the employee's name and salary. If the current bonus amount is zero, a new bonus is calculated, based on the employee's salary, and returned along with the employee's full name. If the employee is not found, an empty string is returned.

Table 17. Code to create a C# parameter style GENERAL procedure

```
CREATE PROCEDURE setEmpBonusGEN(IN empID CHAR(6), INOUT bonus Decimal(9,2),
                                OUT empName VARCHAR(60))
SPECIFIC SetEmpBonusGEN
LANGUAGE CLR
PARAMETER STYLE GENERAL
MODIFIES SQL DATA
EXECUTION CONTROL SAFE
FENCED
THREADSAFE
DYNAMIC RESULT SETS 0
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!SetEmpBonusGEN' ;
```

Table 17. Code to create a C# parameter style GENERAL procedure (continued)

```

public static void SetEmpBonusGEN(    String empID,
                                     ref Decimal bonus,
                                     out String empName)
{
    // Declare local variables
    Decimal salary = 0;

    DB2Command myCommand = DB2Context.GetCommand();
    myCommand.CommandText =
        "SELECT FIRSTNME, MIDINIT, LASTNAME, SALARY "
        + "FROM EMPLOYEE "
        + "WHERE EMPNO = '" + empID + "'";

    DB2DataReader reader = myCommand.ExecuteReader();

    if (reader.Read()) // If employee record is found
    {
        // Get the employee's full name and salary
        empName = reader.GetString(0) + " " +
            reader.GetString(1) + ". " +
            reader.GetString(2);

        salary = reader.GetDecimal(3);

        if (bonus == 0)
        {
            if (salary > 75000)
            {
                bonus = salary * (Decimal)0.025;
            }
            else
            {
                bonus = salary * (Decimal)0.05;
            }
        }
    }
    else // Employee not found
    {
        empName = ""; // Set output parameter
    }

    reader.Close();
}

```

### Example 2: C# parameter style GENERAL WITH NULLS procedure

This example shows the following:

- CREATE PROCEDURE statement for a parameter style GENERAL WITH NULLS procedure
- C# code for a parameter style GENERAL WITH NULLS procedure

This procedure takes an employee ID and a current bonus amount as input. If the input parameter is not null, it retrieves the employee's name and salary. If the current bonus amount is zero, a new bonus based on salary is calculated and returned along with the employee's full name. If the employee data is not found, a NULL string and integer is returned.



Table 18. Code to create a C# parameter style GENERAL WITH NULLS procedure

```
CREATE PROCEDURE SetEmpbonusGENNULL(IN empID CHAR(6),
                                     INOUT bonus Decimal(9,2),
                                     OUT empName VARCHAR(60))

SPECIFIC SetEmpbonusGENNULL
LANGUAGE CLR
PARAMETER STYLE GENERAL WITH NULLS
DYNAMIC RESULT SETS 0
MODIFIES SQL DATA
EXECUTION CONTROL SAFE
FENCED
THREADSAFE
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!SetEmpBonusGENNULL'
;
```

Table 18. Code to create a C# parameter style GENERAL WITH NULLS procedure (continued)

```

public static void SetEmpBonusGENNULL(   String empID,
                                         ref Decimal bonus,
                                         out String empName,
                                         Int16[] NullInds)
{
    Decimal salary = 0;
    if (NullInds[0] == -1) // Check if the input is null
    {
        NullInds[1] = -1;    // Return a NULL bonus value
        empName = "";      // Set output value
        NullInds[2] = -1;  // Return a NULL empName value
    }
    else
    {
        DB2Command myCommand = DB2Context.GetCommand();
        myCommand.CommandText =
            "SELECT FIRSTNAME, MIDINIT, LASTNAME, SALARY "
            + "FROM EMPLOYEE "
            + "WHERE EMPNO = '" + empID + "'";
        DB2DataReader reader = myCommand.ExecuteReader();

        if (reader.Read()) // If employee record is found
        {
            // Get the employee's full name and salary
            empName = reader.GetString(0) + " "
            +
                reader.GetString(1) + ". " +
                reader.GetString(2);
            salary = reader.GetDecimal(3);

            if (bonus == 0)
            {
                if (salary > 75000)
                {
                    bonus = salary * (Decimal)0.025;
                    NullInds[1] = 0; // Return a non-NULL value
                }
                else
                {
                    bonus = salary * (Decimal)0.05;
                    NullInds[1] = 0; // Return a non-NULL value
                }
            }
        }
        else // Employee not found
        {
            empName = " *sdq;"; // Set output parameter
            NullInds[2] = -1; // Return a NULL value
        }

        reader.Close();
    }
}

```

### Example 3: C# parameter style SQL procedure

This example shows the following:

- CREATE PROCEDURE statement for a parameter style SQL procedure
- C# code for a parameter style SQL procedure

This procedure takes an employee ID and a current bonus amount as input. It retrieves the employee's name and salary. If the current bonus

amount is zero, a new bonus based on salary is calculated and returned along with the employee's full name. If the employee is not found, an empty string is returned.

*Table 19. Code to create a C# procedure in parameter style SQL with parameters*

```
CREATE PROCEDURE SetEmpbonusSQL(IN empID CHAR(6),
                                INOUT bonus Decimal(9,2),
                                OUT empName VARCHAR(60))

SPECIFIC SetEmpbonusSQL
LANGUAGE CLR
PARAMETER STYLE SQL
DYNAMIC RESULT SETS 0
MODIFIES SQL DATA
FENCED
THREADSAFE
EXECUTION CONTROL SAFE
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!SetEmpBonusSQL' ;
```

Table 19. Code to create a C# procedure in parameter style SQL with parameters (continued)

```

public static void SetEmpBonusSQL(    String empID,
                                     ref Decimal bonus,
                                     out String empName,
                                     Int16 empIDNullInd,
                                     ref Int16 bonusNullInd,
                                     out Int16 empNameNullInd,
                                     ref string sqlStateate,
                                     string funcName,
                                     string specName,
                                     ref string sqlMessageText)
{
    // Declare local host variables
    Decimal salary eq; 0;

    if (empIDNullInd == -1) // Check if the input is null
    {
        bonusNullInd = -1; // Return a NULL bonus value
        empName = "";
        empNameNullInd = -1; // Return a NULL empName value
    }
    else
    {
        DB2Command myCommand = DB2Context.GetCommand();
        myCommand.CommandText =
            "SELECT FIRSTNME, MIDINIT, LASTNAME, SALARY
            "
            + "FROM EMPLOYEE "
            + "WHERE EMPNO = '" + empID + "'";

        DB2DataReader reader = myCommand.ExecuteReader();

        if (reader.Read()) // If employee record is found
        {
            // Get the employee's full name and salary
            empName = reader.GetString(0) + " "
            +
            reader.GetString(1) + ". " +
            reader.GetString(2);
            empNameNullInd = 0;
            salary = reader.GetDecimal(3);

            if (bonus == 0)
            {
                if (salary > 75000)
                {
                    bonus = salary * (Decimal)0.025;
                    bonusNullInd = 0; // Return a non-NULL value
                }
                else
                {
                    bonus = salary * (Decimal)0.05;
                    bonusNullInd = 0; // Return a non-NULL value
                }
            }
        }
        else // Employee not found
        {
            empName = ""; // Set output parameter
            empNameNullInd = -1; // Return a NULL value
        }

        reader.Close();
    }
}

```

#### Example 4: C# parameter style GENERAL procedure returning a result set

This example shows the following:

- CREATE PROCEDURE statement for an external C# procedure returning a result set
- C# code for a parameter style GENERAL procedure that returns a result set

This procedure accepts the name of a table as a parameter. It returns a result set containing all the rows of the table specified by the input parameter. This is done by leaving a DB2DataReader for a given query result set open when the procedure returns. Specifically, if reader.Close() is not executed, the result set will be returned.

Table 20. Code to create a C# procedure that returns a result set

<pre>CREATE PROCEDURE ReturnResultSet(IN tableName                                 VARCHAR(20)) SPECIFIC ReturnResultSet DYNAMIC RESULT SETS 1 LANGUAGE CLR PARAMETER STYLE GENERAL FENCED PROGRAM TYPE SUB EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!ReturnResultSet' ;</pre>
<pre>public static void ReturnResultSet(string tableName) {     DB2Command myCommand = DB2Context.GetCommand();      // Set the SQL statement to be executed and execute it.     myCommand.CommandText = "SELECT * FROM " + tableName;     DB2DataReader reader = myCommand.ExecuteReader();      // The DB2DataReader contains the result of the query.     // This result set can be returned with the procedure,     // by simply NOT closing the DB2DataReader.     // Specifically, do NOT execute reader.Close(); }</pre>

#### Example 5: C# parameter style SQL procedure accessing the dbinfo structure

This example shows the following:

- CREATE PROCEDURE statement for a procedure accessing the dbinfo structure
- C# code for a parameter style SQL procedure that accesses the dbinfo structure

To access the dbinfo structure, the DBINFO clause must be specified in the CREATE PROCEDURE statement. No parameter is required for the dbinfo structure in the CREATE PROCEDURE statement however a parameter must be created for it, in the external routine code. This procedure returns only the value of the current database name from the dbname field in the dbinfo structure.

Table 21. Code to create a C# procedure that accesses the dbinfo structure

```

CREATE PROCEDURE ReturnDbName(OUT dbName VARCHAR(20))
SPECIFIC ReturnDbName
DYNAMIC RESULT SETS 0
LANGUAGE CLR
PARAMETER STYLE SQL
FENCED
THREADSAFE
EXECUTION CONTROL SAFE
DBINFO
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!ReturnDbName'
;

public static void ReturnDbName(out string dbName,
                                out Int16 dbNameNullInd,
                                ref string sqlState,
                                string funcName,
                                string specName,
                                ref string sqlMessageText,
                                sqludf_dbinfo dbinfo)
{
    // Retrieve the current database name from the
    // dbinfo structure and return it.
    // ** Note! ** dbinfo field names are case sensitive
    dbName = dbinfo.dbname;
    dbNameNullInd = 0; // Return a non-null value;

    // If you want to return a user-defined error in
    // the SQLCA you can specify a 5 digit user-defined
    // sqlState and an error message string text.
    // For example:
    //
    // sqlState = "ABCDE";
    // sqlMessageText = "A user-defined error has occurred"
    //
    // DB2 returns the above values to the client in the
    // SQLCA structure. The values are used to generate a
    // standard DB2 sqlState error.
}

```

#### Example 6: C# procedure with PROGRAM TYPE MAIN style

This example shows the following:

- CREATE PROCEDURE statement for a procedure using a main program style
- C# parameter style GENERAL WITH NULLS code in using a MAIN program style

To implement a routine in a main program style, the PROGRAM TYPE clause must be specified in the CREATE PROCEDURE statement with the value MAIN. Parameters are specified in the CREATE PROCEDURE statement however in the code implementation, parameters are passed into the routine in an argc integer parameter and an argv array of parameters.

Table 22. Code to create a C# procedure in program type MAIN style

```
CREATE PROCEDURE MainStyle( IN empID CHAR(6),
                           INOUT bonus Decimal(9,2),
                           OUT empName VARCHAR(60))

SPECIFIC MainStyle
DYNAMIC RESULT SETS 0
LANGUAGE CLR
PARAMETER STYLE GENERAL WITH NULLS
MODIFIES SQL DATA
FENCED
THREADSAFE
EXECUTION CONTROL SAFE
PROGRAM TYPE MAIN
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!main' ;
```

Table 22. Code to create a C# procedure in program type MAIN style (continued)

```

public static void main(Int32 argc, Object[]
argv)
{
    String empID = (String)argv[0]; // argv[0] has nullInd:argv[3]
    Decimal bonus = (Decimal)argv[1]; // argv[1] has nullInd:argv[4]
                                        // argv[2] has nullInd:argv[5]

    Decimal salary = 0;
    Int16[] NullInds = (Int16[])argv[3];

    if ((NullInds[0]) == (Int16)(-1)) // Check if empID is null
    {
        NullInds[1] = (Int16)(-1); // Return a NULL bonus value
        argv[1] = (String)""; // Set output parameter empName
        NullInds[2] = (Int16)(-1); // Return a NULL empName value
        Return;
    }
    else
    {
        DB2Command myCommand = DB2Context.GetCommand();
        myCommand.CommandText =
            "SELECT FIRSTNAME, MIDINIT, LASTNAME, salary "
            + "FROM EMPLOYEE "
            + "WHERE EMPNO = '" + empID + "'";

        DB2DataReader reader = myCommand.ExecuteReader();

        if (reader.Read()) // If employee record is found
        {
            // Get the employee's full name and salary
            argv[2] = (String) (reader.GetString(0) + " " +
                reader.GetString(1) + ".
                " +
                reader.GetString(2));
            NullInds[2] = (Int16)0;
            salary = reader.GetDecimal(3);

            if (bonus == 0)
            {
                if (salary > 75000)
                {
                    argv[1] = (Decimal)(salary * (Decimal)0.025);
                    NullInds[1] = (Int16)(0); // Return a non-NULL value
                }
                else
                {
                    argv[1] = (Decimal)(salary * (Decimal)0.05);
                    NullInds[1] = (Int16)(0); // Return a non-NULL value
                }
            }
        }
        else // Employee not found
        {
            argv[2] = (String)(""); // Set output parameter
            NullInds[2] = (Int16)(-1); // Return a NULL value
        }

        reader.Close();
    }
}

```



## Examples of Visual Basic .NET CLR functions

### Before you begin

Once you understand the basics of user-defined functions (UDFs), and the essentials of CLR routines, you can start exploiting CLR UDFs in your applications and database environment. This topic contains some examples of CLR UDFs to get you started. For examples of CLR procedures in Visual Basic:

- “Examples of Visual Basic .NET CLR procedures” on page 140

Before working with the CLR UDF examples you may want to read the following concept topics:

- Chapter 4, “.NET common language runtime (CLR) routines,” on page 103
- “Creating .NET CLR routines from DB2 Command Window” on page 113
- “External scalar functions” on page 60
- “Building .NET CLR routine code” on page 115 *Developing ADO.NET and OLE DB Applications*

The examples below make use of a table named EMPLOYEE that is contained in the SAMPLE database.

### Procedure

Use the following examples as references when making your own Visual Basic CLR UDFs:

- The Visual Basic external code file
- Example 1: Visual Basic parameter style SQL table function
- Example 2: Visual Basic parameter style SQL scalar function

### Example

#### The Visual Basic external code file

The following examples show a variety of Visual Basic UDF implementations. The CREATE FUNCTION statement is provided for each UDF with the corresponding Visual Basic source code from which the associated assembly can be built. The Visual Basic source file that contains the functions declarations used in the following examples is named gwenVbUDF.cs and has the following format:

Table 23. Visual Basic external code file format

```
using System;
using System.IO;
using IBM.Data.DB2;

Namespace bizLogic

    ...
    ' Class definitions that contain UDF declarations
    ' and any supporting class definitions
    ...

End Namespace
```

The function declarations must be contained in a class within a Visual Basic file. The use of namespaces is optional. If a namespace is used, the

namespace must appear in the assembly path name provided in the EXTERNAL clause of the CREATE PROCEDURE statement. The IBM.Data.DB2. inclusion is required if the function contains SQL.

### Example 1: Visual Basic parameter style SQL table function

This example shows the following:

- CREATE FUNCTION statement for a parameter style SQL table function
- Visual Basic code for a parameter style SQL table function

This table function returns a table containing rows of employee data that was created from a data array. There are two classes associated with this example. Class person represents the employees, and the class empOps contains the routine table UDF that uses class person. The employee salary information is updated based on the value of an input parameter. The data array in this example is created within the table function itself on the first call of the table function. Such an array could have also been created by reading in data from a text file on the filesystem. The array data values are written to a scratchpad so that the data can be accessed in subsequent calls of the table function.

On each call of the table function, one record is read from the array and one row is generated in the table that is returned by the function. The row is generated in the table, by setting the output parameters of the table function to the desired row values. After the final call of the table function occurs, the table of generated rows is returned.

Table 24. Code to create a Visual Basic parameter style SQL table function

```
CREATE FUNCTION TableUDF(double)
RETURNS TABLE (name varchar(20),
                job varchar(20),
                salary double)
EXTERNAL NAME 'gwenVbUDF.dll:bizLogic.empOps!TableUDF'
LANGUAGE CLR
PARAMETER STYLE SQL
NOT DETERMINISTIC
FENCED
SCRATCHPAD 10
FINAL CALL
DISALLOW PARALLEL
NO DBINFO
EXECUTION CONTROL SAFE
```

Table 24. Code to create a Visual Basic parameter style SQL table function (continued)

```
Class Person
' The class Person is a supporting class for
' the table function UDF, tableUDF, below.

Private name As String
Private position As String
Private salary As Int32

Public Sub New(ByVal newName As String, _
               ByVal newPosition As String, _
               ByVal newSalary As Int32)

    name = newName
    position = newPosition
    salary = newSalary
End Sub

Public Property GetName() As String
    Get
        Return name
    End Get

    Set (ByVal value As String)
        name = value
    End Set
End Property

Public Property GetPosition() As String
    Get
        Return position
    End Get

    Set (ByVal value As String)
        position = value
    End Set
End Property

Public Property GetSalary() As Int32
    Get
        Return salary
    End Get

    Set (ByVal value As Int32)
        salary = value
    End Set
End Property

End Class
```

Table 24. Code to create a Visual Basic parameter style SQL table function (continued)

```

Class empOps

Public Shared Sub TableUDF(byVal factor As Double, _
                          byRef name As String, _
                          byRef position As String, _
                          byRef salary As Double, _
                          byVal factorNullInd As Int16, _
                          byRef nameNullInd As Int16, _
                          byRef positionNullInd As Int16, _
                          byRef salaryNullInd As Int16, _
                          byRef sqlState As String, _
                          byVal funcName As String, _
                          byVal specName As String, _
                          byRef sqlMessageText As String, _
                          byVal scratchPad As Byte(), _
                          byVal callType As Int32)

    Dim intRow As Int16

    intRow = 0

    ' Create an array of Person type information
    Dim staff(2) As Person
    staff(0) = New Person("Gwen", "Developer", 10000)
    staff(1) = New Person("Andrew", "Developer", 20000)
    staff(2) = New Person("Liu", "Team Leader", 30000)

    ' Initialize output parameter values and NULL indicators
    salary = 0
    name = position = ""
    nameNullInd = positionNullInd = salaryNullInd = -1

    Select callType
    Case -2 ' Case SQLUDF_TF_FIRST:
    Case -1 ' Case SQLUDF_TF_OPEN:
        intRow = 1
        scratchPad(0) = intRow ' Write to scratchpad
    Case 0 ' Case SQLUDF_TF_FETCH:
        intRow = scratchPad(0)
        If intRow > staff.Length
            sqlState = "02000" ' Return an error SQLSTATE
        Else
            ' Generate a row in the output table
            ' based on the staff array data.
            name = staff(intRow).GetName()
            position = staff(intRow).GetPosition()
            salary = (staff(intRow).GetSalary()) * factor
            nameNullInd = 0
            positionNullInd = 0
            salaryNullInd = 0
        End If
        intRow = intRow + 1
        scratchPad(0) = intRow ' Write scratchpad

    Case 1 ' Case SQLUDF_TF_CLOSE:
    Case 2 ' Case SQLUDF_TF_FINAL:
    End Select

End Sub

End Class

```

### Example 2: Visual Basic parameter style SQL scalar function

This example shows the following:

- CREATE FUNCTION statement for a parameter style SQL scalar function
- Visual Basic code for a parameter style SQL scalar function

This scalar function returns a single count value for each input value that it operates on. For an input value in the nth position of the set of input values, the output scalar value is the value n. On each call of the scalar function, where one call is associated with each row or value in the input set of rows or values, the count is increased by one and the current value of the count is returned. The count is then saved in the scratchpad memory buffer to maintain the count value between each call of the scalar function.

This scalar function can be easily invoked if for example we have a table defined as follows:

```
CREATE TABLE T (i1 INTEGER);
INSERT INTO T VALUES 12, 45, 16, 99;
```

A simple query such as the following can be used to invoke the scalar function:

```
SELECT my_count(i1) as count, i1 FROM T;
```

The output of such a query would be:

COUNT	I1
1	12
2	45
3	16
4	99

This scalar UDF is quite simple. Instead of returning just the count of the rows, you could use a scalar function to format data in an existing column. For example you might append a string to each value in an address column or you might build up a complex string from a series of input strings or you might do a complex mathematical evaluation over a set of data where you must store an intermediate result.

*Table 25. Code to create a Visual Basic parameter style SQL scalar function*

```
CREATE FUNCTION mycount(INTEGER)
RETURNS INTEGER
LANGUAGE CLR
PARAMETER STYLE SQL
NO SQL
SCRATCHPAD 10
FINAL CALL
FENCED
EXECUTION CONTROL SAFE
NOT DETERMINISTIC
EXTERNAL NAME 'gwenUDF.dll:bizLogic.empOps!CountUp';
```

Table 25. Code to create a Visual Basic parameter style SQL scalar function (continued)

```

Class empOps
  Public Shared Sub CountUp(byVal input As Int32, _
                           byRef outCounter As Int32, _
                           byVal nullIndInput As Int16, _
                           byRef nullIndOutCounter As Int16, _
                           byRef sqlState As String, _
                           byVal qualName As String, _
                           byVal specName As String, _
                           byRef sqlMessageText As String, _
                           byVal scratchPad As Byte(), _
                           byVal callType As Int32)

    Dim counter As Int32
    counter = 1

    Select callType
      case -1          ' case SQLUDF_TF_OPEN_CALL
        scratchPad(0) = counter
        outCounter = counter
        nullIndOutCounter = 0
      case 0          'case SQLUDF_TF_FETCH_CALL:
        counter = scratchPad(0)
        counter = counter + 1
        outCounter = counter
        nullIndOutCounter = 0
        scratchPad(0) = counter
      case 1          'case SQLUDF_CLOSE_CALL:
        counter = scratchPad(0)
        outCounter = counter
        nullIndOutCounter = 0
      case Else      ' Should never enter here
        ' These cases won't occur for the following reasons:
        ' Case -2 (SQLUDF_TF_FIRST)    ->No FINAL CALL in CREATE stmt
        ' Case 2 (SQLUDF_TF_FINAL)    ->No FINAL CALL in CREATE stmt
        ' Case 255 (SQLUDF_TF_FINAL_CRA) ->No SQL used in the function
        '
        ' * Note!*
        ' -----
        ' The Else is required so that at compile time
        ' out parameter outCounter is always set *
        outCounter = 0
        nullIndOutCounter = -1
    End Select
  End Sub
End Class

```

## Examples of Visual Basic .NET CLR procedures

### Before you begin

Once the basics of procedures, also called stored procedures, and the essentials of .NET common language runtime routines are understood, you can start using CLR procedures in your applications.

This topic contains examples of CLR procedures implemented in Visual Basic; that illustrate the supported parameter styles, passing parameters including the dbinfo structure, how to return a result set and more. For examples of CLR UDFs in Visual Basic:

- “Examples of Visual Basic .NET CLR functions” on page 135

Before working with the CLR procedure examples you might want to read the following concept topics:

- Chapter 4, “.NET common language runtime (CLR) routines,” on page 103
- “Creating .NET CLR routines from DB2 Command Window” on page 113
- “Benefits of using routines” on page 3
- “Building .NET CLR routine code” on page 115 *Developing ADO.NET and OLE DB Applications*

The examples below make use of a table named EMPLOYEE that is contained in the SAMPLE database.

## Procedure

Use the following examples as references when making your own Visual Basic CLR procedures:

- The Visual Basic external code file
- Example 1: Visual Basic parameter style GENERAL procedure
- Example 2: Visual Basic parameter style GENERAL WITH NULLS procedure
- Example 3: Visual Basic parameter style SQL procedure
- Example 4: Visual Basic procedure returning a result set
- Example 5: Visual Basic procedure accessing the dbinfo structure
- Example 6: Visual Basic procedure in PROGRAM TYPE MAIN style

## Example

### The Visual Basic external code file

The examples show a variety of Visual Basic procedure implementations. Each example consists of two parts: the CREATE PROCEDURE statement and the external Visual Basic code implementation of the procedure from which the associated assembly can be built.

The Visual Basic source file that contains the procedure implementations of the following examples is named gwenVbProc.vb and has the following format:

Table 26. Visual Basic external code file format

```
using System;
using System.IO;
using IBM.Data.DB2;

Namespace bizLogic

    Class empOps
        ...
        ' Visual Basic procedures
        ...
    End Class
End Namespace
```

The file inclusions are indicated at the top of the file. The IBM.Data.DB2 inclusion is required if any of the procedures in the file contain SQL. There is a namespace declaration in this file and a class empOps that contains the procedures. The use of namespaces is optional. If a namespace is used, the namespace must appear in the assembly path name provided in the EXTERNAL clause of the CREATE PROCEDURE statement.

It is important to note the name of the file, the namespace, and the name of the class, that contains a given procedure implementation. These names are important, because the EXTERNAL clause of the CREATE PROCEDURE statement for each procedure must specify this information so that DB2 can locate the assembly and class of the CLR procedure.

#### **Example 1: Visual Basic parameter style GENERAL procedure**

This example shows the following:

- CREATE PROCEDURE statement for a parameter style GENERAL procedure
- Visual Basic code for a parameter style GENERAL procedure

This procedure takes an employee ID and a current bonus amount as input. It retrieves the employee's name and salary. If the current bonus amount is zero, a new bonus is calculated, based on the employee salary, and returned along with the employee's full name. If the employee is not found, an empty string is returned.

*Table 27. Code to create a Visual Basic parameter style GENERAL procedure*

```
CREATE PROCEDURE SetEmpBonusGEN(IN empId CHAR(6),
                                INOUT bonus Decimal(9,2),
                                OUT empName VARCHAR(60))
SPECIFIC setEmpBonusGEN
LANGUAGE CLR
PARAMETER STYLE GENERAL
DYNAMIC RESULT SETS 0
FENCED
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!SetEmpBonusGEN'
```



Table 27. Code to create a Visual Basic parameter style GENERAL procedure (continued)

```

Public Shared Sub SetEmpBonusGEN(ByVal empId As String, _
                                ByRef bonus As Decimal, _
                                ByRef empName As String)

    Dim salary As Decimal
    Dim myCommand As DB2Command
    Dim myReader As DB2DataReader

    salary = 0

    myCommand = DB2Context.GetCommand()
    myCommand.CommandText = _
        "SELECT FIRSTNME, MIDINIT, LASTNAME, SALARY " _
        + "FROM EMPLOYEE " _
        + "WHERE EMPNO = '" + empId + "'"
    myReader = myCommand.ExecuteReader()

    If myReader.Read() ' If employee record is found
        ' Get the employee's full name and salary
        empName = myReader.GetString(0) + " " _
            + myReader.GetString(1) + ". " _
            + myReader.GetString(2)

        salary = myReader.GetDecimal(3)

        If bonus = 0
            If salary > 75000
                bonus = salary * 0.025
            Else
                bonus = salary * 0.05
            End If
        End If
    Else ' Employee not found
        empName = "" ' Set output parameter
    End If

    myReader.Close()

End Sub

```

### Example 2: Visual Basic parameter style GENERAL WITH NULLS procedure

This example shows the following:

- CREATE PROCEDURE statement for a parameter style GENERAL WITH NULLS procedure
- Visual Basic code for a parameter style GENERAL WITH NULLS procedure

This procedure takes an employee ID and a current bonus amount as input. If the input parameter is not null, it retrieves the employee's name and salary. If the current bonus amount is zero, a new bonus based on salary is calculated and returned along with the employee's full name. If the employee data is not found, a NULL string and integer is returned.

Table 28. Code to create a Visual Basic parameter style GENERAL WITH NULLS procedure

```

CREATE PROCEDURE SetEmpBonusGENNULL(IN empId CHAR(6),
                                     INOUT bonus Decimal(9,2),
                                     OUT empName VARCHAR(60))

SPECIFIC SetEmpBonusGENNULL
LANGUAGE CLR
PARAMETER STYLE GENERAL WITH NULLS
DYNAMIC RESULT SETS 0
FENCED
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!SetEmpBonusGENNULL'

Public Shared Sub SetEmpBonusGENNULL(ByVal empId As String, _
                                     ByRef bonus As Decimal, _
                                     ByRef empName As String, _
                                     byVal nullInds As Int16())

    Dim salary As Decimal
    Dim myCommand As DB2Command
    Dim myReader As DB2DataReader

    salary = 0

    If nullInds(0) = -1 ' Check if the input is null
        nullInds(1) = -1 ' Return a NULL bonus value
        empName = "" ' Set output parameter
        nullInds(2) = -1 ' Return a NULL empName value
        Return
    Else
        myCommand = DB2Context.GetCommand()
        myCommand.CommandText =
            "SELECT FIRSTNAME, MIDINIT, LASTNAME, SALARY " _
            + "FROM EMPLOYEE " _
            + "WHERE EMPNO = '" + empId + "'"

        myReader = myCommand.ExecuteReader()

        If myReader.Read() ' If employee record is found
            ' Get the employee's full name and salary
            empName = myReader.GetString(0) + " " _
                + myReader.GetString(1) + ". " _
                + myReader.GetString(2)

            salary = myReader.GetDecimal(3)

            If bonus = 0
                If salary > 75000
                    bonus = Salary * 0.025
                    nullInds(1) = 0 'Return a non-NULL value
                Else
                    bonus = salary * 0.05
                    nullInds(1) = 0 ' Return a non-NULL value
                End If
            Else 'Employee not found
                empName = "" ' Set output parameter
                nullInds(2) = -1 ' Return a NULL value
            End If
        End If

        myReader.Close()

    End If

End Sub

```

### Example 3: Visual Basic parameter style SQL procedure

This example shows the following:

- CREATE PROCEDURE statement for a parameter style SQL procedure
- Visual Basic code for a parameter style SQL procedure

This procedure takes an employee ID and a current bonus amount as input. It retrieves the employee's name and salary. If the current bonus amount is zero, a new bonus based on salary is calculated and returned along with the employee's full name. If the employee is not found, an empty string is returned.

*Table 29. Code to create a Visual Basic procedure in parameter style SQL with parameters*

```
CREATE PROCEDURE SetEmpBonusSQL(IN empId CHAR(6),
                                INOUT bonus Decimal(9,2),
                                OUT empName VARCHAR(60))
SPECIFIC SetEmpBonusSQL
LANGUAGE CLR
PARAMETER STYLE SQL
DYNAMIC RESULT SETS 0
FENCED
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!SetEmpBonusSQL'
```

Table 29. Code to create a Visual Basic procedure in parameter style SQL with parameters (continued)

```

Public Shared Sub SetEmpBonusSQL(byVal empId As String, _
                                byRef bonus As Decimal, _
                                byRef empName As String, _
                                byVal empIdNullInd As Int16, _
                                byRef bonusNullInd As Int16, _
                                byRef empNameNullInd As Int16, _
                                byRef sqlState As String, _
                                byVal funcName As String, _
                                byVal specName As String, _
                                byRef sqlMessageText As String)

    ' Declare local host variables
    Dim salary As Decimal
    Dim myCommand As DB2Command
    Dim myReader As DB2DataReader

    salary = 0

    If empIdNullInd = -1 ' Check if the input is null
        bonusNullInd = -1 ' Return a NULL Bonus value
        empName = ""
        empNameNullInd = -1 ' Return a NULL empName value
    Else
        myCommand = DB2Context.GetCommand()
        myCommand.CommandText = _
            "SELECT FIRSTNAME, MIDINIT, LASTNAME, SALARY " _
            + "FROM EMPLOYEE " _
            + " WHERE EMPNO = '" + empId + "'"

        myReader = myCommand.ExecuteReader()

        If myReader.Read() ' If employee record is found
            ' Get the employee's full name and salary
            empName = myReader.GetString(0) + " "
                + myReader.GetString(1) _
                + ". " + myReader.GetString(2)
            empNameNullInd = 0
            salary = myReader.GetDecimal(3)

            If bonus = 0
                If salary > 75000
                    bonus = salary * 0.025
                    bonusNullInd = 0 ' Return a non-NULL value
                Else
                    bonus = salary * 0.05
                    bonusNullInd = 0 ' Return a non-NULL value
                End If
            End If
        Else ' Employee not found
            empName = "" ' Set output parameter
            empNameNullInd = -1 ' Return a NULL value
        End If

        myReader.Close()
    End If

End Sub

```

**Example 4: Visual Basic parameter style GENERAL procedure returning a result set**

This example shows the following:

- CREATE PROCEDURE statement for an external Visual Basic procedure returning a result set
- Visual Basic code for a parameter style GENERAL procedure that returns a result set

This procedure accepts the name of a table as a parameter. It returns a result set containing all the rows of the table specified by the input parameter. This is done by leaving a DB2DataReader for a given query result set open when the procedure returns. Specifically, if reader.Close() is not executed, the result set will be returned.

*Table 30. Code to create a Visual Basic procedure that returns a result set*

```
CREATE PROCEDURE ReturnResultSet(IN tableName VARCHAR(20))
SPECIFIC ReturnResultSet
DYNAMIC RESULT SETS 1
LANGUAGE CLR
PARAMETER STYLE GENERAL
FENCED
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!ReturnResultSet'
```

---

```
Public Shared Sub ReturnResultSet(byVal tableName As String)

    Dim myCommand As DB2Command
    Dim myReader As DB2DataReader

    myCommand = DB2Context.GetCommand()

    ' Set the SQL statement to be executed and execute it.
    myCommand.CommandText = "SELECT * FROM " + tableName
    myReader = myCommand.ExecuteReader()

    ' The DB2DataReader contains the result of the query.
    ' This result set can be returned with the procedure,
    ' by simply NOT closing the DB2DataReader.
    ' Specifically, do NOT execute reader.Close()

End Sub
```

**Example 5: Visual Basic parameter style SQL procedure accessing the dbinfo structure**

This example shows the following:

- CREATE PROCEDURE statement for a procedure accessing the dbinfo structure
- Visual Basic code for a parameter style SQL procedure that accesses the dbinfo structure

To access the dbinfo structure, the DBINFO clause must be specified in the CREATE PROCEDURE statement. No parameter is required for the dbinfo structure in the CREATE PROCEDURE statement however a parameter must be created for it, in the external routine code. This procedure returns only the value of the current database name from the dbname field in the dbinfo structure.

Table 31. Code to create a Visual Basic procedure that accesses the dbinfo structure

<pre> CREATE PROCEDURE ReturnDbName(OUT dbName VARCHAR(20)) SPECIFIC ReturnDbName LANGUAGE CLR PARAMETER STYLE SQL DBINFO FENCED PROGRAM TYPE SUB EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!ReturnDbName' </pre>
<pre> Public Shared Sub ReturnDbName(byRef dbName As String, _                                byRef dbNameNullInd As Int16, _                                byRef sqlState As String, _                                byVal funcName As String, _                                byVal specName As String, _                                byRef sqlMessageText As String, _                                byVal dbinfo As sqludf_dbinfo)      ' Retrieve the current database name from the     ' dbinfo structure and return it.     dbName = dbinfo.dbname     dbNameNullInd = 0 ' Return a non-null value      ' If you want to return a user-defined error in     ' the SQLCA you can specify a 5 digit user-defined     ' SQLSTATE and an error message string text.     ' For example:     '     ' sqlState = "ABCDE"     ' msg_token = "A user-defined error has occurred"     '     ' These will be returned by DB2 in the SQLCA. It     ' will appear in the format of a regular DB2 sqlState     ' error. End Sub </pre>

### Example 6: Visual Basic procedure with PROGRAM TYPE MAIN style

This example shows the following:

- CREATE PROCEDURE statement for a procedure using a main program style
- Visual Basic parameter style GENERAL WITH NULLS code in using a MAIN program style

To implement a routine in a main program style, the PROGRAM TYPE clause must be specified in the CREATE PROCEDURE statement with the value MAIN. Parameters are specified in the CREATE PROCEDURE statement however in the code implementation, parameters are passed into the routine in an argc integer parameter and an argv array of parameters.

Table 32. Code to create a Visual Basic procedure in program type MAIN style

<pre> CREATE PROCEDURE MainStyle(IN empId CHAR(6),                            INOUT bonus Decimal(9,2),                            OUT empName VARCHAR(60))  SPECIFIC mainStyle DYNAMIC RESULT SETS 0 LANGUAGE CLR PARAMETER STYLE GENERAL WITH NULLS FENCED PROGRAM TYPE MAIN EXTERNAL NAME 'gwenVbProc.dll:bizLogic.empOps!Main' </pre>
---

Table 32. Code to create a Visual Basic procedure in program type MAIN style (continued)

```

Public Shared Sub Main( byVal argc As Int32,
                       byVal argv As Object())

    Dim myCommand As DB2Command
    Dim myReader As DB2DataReader
    Dim empId As String
    Dim bonus As Decimal
    Dim salary As Decimal
    Dim nullInds As Int16()

    empId = argv(0) ' argv[0] (IN)    nullInd = argv[3]
    bonus = argv(1) ' argv[1] (INOUT) nullInd = argv[4]
                       ' argv[2] (OUT) nullInd = argv[5]

    salary = 0
    nullInds = argv(3)

    If nullInds(0) = -1 ' Check if the empId input is null
        nullInds(1) = -1 ' Return a NULL Bonus value
        argv(1) = "" ' Set output parameter empName
        nullInds(2) = -1 ' Return a NULL empName value
        Return
    Else
        ' If the employee exists and the current bonus is 0,
        ' calculate a new employee bonus based on the employee's
        ' salary. Return the employee name and the new bonus
        myCommand = DB2Context.GetCommand()
        myCommand.CommandText = _
            "SELECT FIRSTNAME, MIDINIT, LASTNAME, SALARY " _
            + " FROM EMPLOYEE " _
            + " WHERE EMPNO = '" + empId + "'"

        myReader = myCommand.ExecuteReader()

        If myReader.Read() ' If employee record is found
            ' Get the employee's full name and salary
            argv(2) = myReader.GetString(0) + " " _
                + myReader.GetString(1) + ". " _
                + myReader.GetString(2)
            nullInds(2) = 0
            salary = myReader.GetDecimal(3)

            If bonus = 0
                If salary > 75000
                    argv(1) = salary * 0.025
                    nullInds(1) = 0 ' Return a non-NULL value
                Else
                    argv(1) = salary * 0.05
                    nullInds(1) = 0 ' Return a non-NULL value
                End If
            End If
        Else ' Employee not found
            argv(2) = "" ' Set output parameter
            nullInds(2) = -1 ' Return a NULL value
        End If

        myReader.Close()
    End If

End Sub

```

## Example: XML and XQuery support in C# .NET CLR procedure

Once the basics of procedures, the essentials of .NET common language runtime routines, XQuery and XML are understood, you can start creating and using CLR procedures with XML features.

The example below demonstrates a C# .NET CLR procedure with parameters of type XML as well as how to update and query XML data.

### Prerequisites

Before working with the CLR procedure example you might want to read the following concept topics:

- .NET common language runtime (CLR) routines
- Creating .NET CLR routines from DB2 Command Window
- Benefits of using routines
- “Building common language runtime (CLR) .NET routines” in *Developing ADO.NET and OLE DB Applications*

The examples below makes use of a table named `xmlDataTable` that is defined as follows:

```
CREATE TABLE xmlDataTable
(
  num INTEGER,
  xdata XML
)

INSERT INTO xmlDataTable VALUES
(1, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Pontiac</make>
                    <model>Sunfire</model>
                    </doc>' PRESERVE WHITESPACE)),
(2, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Mazda</make>
                    <model>Miata</model>
                    </doc>' PRESERVE WHITESPACE)),
(3, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mary</name>
                    <town>Vancouver</town>
                    <street>Waterside</street>
                    </doc>' PRESERVE WHITESPACE)),
(4, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mark</name>
                    <town>Edmonton</town>
                    <street>Oak</street>
                    </doc>' PRESERVE WHITESPACE)),
(5, XMLPARSE(DOCUMENT '<doc>
                    <type>animal</type>
                    <name>dog</name>
                    </doc>' PRESERVE WHITESPACE)),
(6, NULL),
(7, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Ford</make>
                    <model>Taurus</model>
                    </doc>' PRESERVE WHITESPACE)),
(8, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Kim</name>
                    <town>Toronto</town>
```



```

                                <street>Elm</street>
                                </doc>' PRESERVE WHITESPACE)),
(9, XMLPARSE(DOCUMENT '<doc>
                                <type>person</type>
                                <name>Bob</name>
                                <town>Toronto</town>
                                <street>Oak</street>
                                </doc>' PRESERVE WHITESPACE)),
(10, XMLPARSE(DOCUMENT '<doc>
                                <type>animal</type>
                                <name>bird</name>
                                </doc>' PRESERVE WHITESPACE))@

```

### Procedure

Use the following examples as references when making your own C# CLR procedures:

- The C# external code file
- Example 1: C# parameter style GENERAL procedure with XML features

### The C# external code file

The example consists of two parts: the CREATE PROCEDURE statement and the external C# code implementation of the procedure from which the associated assembly can be built.

The C# source file that contains the procedure implementations of the following examples is named `gwenProc.cs` and has the following format:

*Table 33. C# external code file format*

```

using System;
using System.IO;
using System.Data;
using IBM.Data.DB2;
using IBM.Data.DB2Types;

namespace bizLogic
{
    class empOps
    {
        ...
        // C# procedures
        ...
    }
}

```

The file inclusions are indicated at the top of the file. The `IBM.Data.DB2` inclusion is required if any of the procedures in the file contain SQL. The `IBM.Data.DB2Types` inclusion is required if any of the procedures in the file contains parameters or variables of type XML. There is a namespace declaration in this file and a class `empOps` that contains the procedures. The use of namespaces is optional. If a namespace is used, the namespace must appear in the assembly path name provided in the EXTERNAL clause of the CREATE PROCEDURE statement.

It is important to note the name of the file, the namespace, and the name of the class, that contains a given procedure implementation. These names are important, because the EXTERNAL clause of the CREATE PROCEDURE statement for each procedure must specify this information so that DB2 can locate the assembly and class of the CLR procedure.

## Example 1: C# parameter style GENERAL procedure with XML features

This example shows the following:

- CREATE PROCEDURE statement for a parameter style GENERAL procedure
- C# code for a parameter style GENERAL procedure with XML parameters

This procedure takes two parameters, an integer inNum and inXML. These values are inserted into the table xmlDataTable. Then an XML value is retrieved using XQuery. Another XML value is retrieved using SQL. The retrieved XML values are assigned to two output parameters, outXML1 and outXML2. No result sets are returned.

Table 34. Code to create a C# parameter style GENERAL procedure

```
CREATE PROCEDURE xmlProc1 ( IN inNUM INTEGER,
                           IN inXML XML as CLOB (1K),
                           OUT inXML XML as CLOB (1K),
                           OUT inXML XML as CLOB (1K)
                           )
LANGUAGE CLR
PARAMETER STYLE GENERAL
DYNAMIC RESULT SETS 0
FENCED
THREADSAFE
DETERMINISTIC
NO DBINFO
MODIFIES SQL DATA
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc.dll:bizLogic.empOps!xmlProc1' ;

/*****
// Stored Procedure: xmlProc1
//
// Purpose: insert XML data into XML column
//
// Parameters:
//
// IN:   inNum -- the sequence of XML data to be insert in xmldata table
//       inXML -- XML data to be inserted
// OUT:  outXML1 -- XML data returned - value retrieved using XQuery
//       outXML2 -- XML data returned - value retrieved using SQL
//*****/
```

Table 34. Code to create a C# parameter style GENERAL procedure (continued)

```

public static void xmlProc1 (    int    inNum, DB2Xml  inXML,
                              out DB2Xml outXML1, out DB2Xml  outXML2 )
{
    // Create new command object from connection context
    DB2Parameter parm;
    DB2Command cmd;
    DB2DataReader reader = null;
    outXML1 = DB2Xml.Null;
    outXML2 = DB2Xml.Null;

    // Insert input XML parameter value into a table
    cmd = DB2Context.GetCommand();
    cmd.CommandText = "INSERT INTO "
        + "xmlDataTable( num , xdata ) "
        + "VALUES( ?, ?)";

    parm = cmd.Parameters.Add("@num", DB2Type.Integer );
    parm.Direction = ParameterDirection.Input;
    cmd.Parameters["@num"].Value = inNum;
    parm = cmd.Parameters.Add("@data", DB2Type.Xml);
    parm.Direction = ParameterDirection.Input;
    cmd.Parameters["@data"].Value = inXML ;
    cmd.ExecuteNonQuery();
    cmd.Close();

    // Retrieve XML value using XQuery
    and assign value to an XML output parameter
    cmd = DB2Context.GetCommand();
    cmd.CommandText = "XQUERY for $x " +
        "in db2-fn:xmlcolumn(\"xmlDataTable.xdata\")/doc "+
        "where $x/make = \'Mazda\' " +
        "return <carInfo>{$x/make}{$x/model}</carInfo>";
    reader = cmd.ExecuteReader();
    reader.CacheData= true;

    if (reader.Read())
    { outXML1 = reader.GetDB2Xml(0); }
    else
    { outXML1 = DB2Xml.Null; }

    reader.Close();
    cmd.Close();

    // Retrieve XML value using SQL
    and assign value to an XML output parameter value
    cmd = DB2Context.GetCommand();
    cmd.CommandText = "SELECT xdata "
        + "FROM xmlDataTable "
        + "WHERE num = ?";

    parm = cmd.Parameters.Add("@num", DB2Type.Integer );
    parm.Direction = ParameterDirection.Input;
    cmd.Parameters["@num"].Value = inNum;
    reader = cmd.ExecuteReader();
    reader.CacheData= true;

    if (reader.Read())
    { outXML2 = reader.GetDB2Xml(0); }
    else
    { outXML = DB2Xml.Null; }

    reader.Close() ;
    cmd.Close();

    return;
}

```

## Example: XML and XQuery support in C procedure

Once the basics of procedures, the essentials of C routines, XQuery and XML are understood, you can start creating and using C procedures with XML features.

The example below demonstrates a C procedure with parameters of type XML as well as how to update and query XML data.

### Prerequisites

Before working with the C procedure example you might want to read the following concept topic:

- Benefits of using routines

The examples below makes use of a table named `xmlDataTable` that is defined as follows:

```
CREATE TABLE xmlDataTable
(
  num INTEGER,
  xdata XML
)

INSERT INTO xmlDataTable VALUES
(1, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Pontiac</make>
                    <model>Sunfire</model>
                    </doc>' PRESERVE WHITESPACE)),
(2, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Mazda</make>
                    <model>Miata</model>
                    </doc>' PRESERVE WHITESPACE)),
(3, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mary</name>
                    <town>Vancouver</town>
                    <street>Waterside</street>
                    </doc>' PRESERVE WHITESPACE)),
(4, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mark</name>
                    <town>Edmonton</town>
                    <street>Oak</street>
                    </doc>' PRESERVE WHITESPACE)),
(5, XMLPARSE(DOCUMENT '<doc>
                    <type>animal</type>
                    <name>dog</name>
                    </doc>' PRESERVE WHITESPACE)),
(6, NULL),
(7, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Ford</make>
                    <model>Taurus</model>
                    </doc>' PRESERVE WHITESPACE)),
(8, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Kim</name>
                    <town>Toronto</town>
                    <street>Elm</street>
                    </doc>' PRESERVE WHITESPACE)),
(9, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Bob</name>
                    <town>Toronto</town>
                    <street>Oak</street>
                    </doc>' PRESERVE WHITESPACE)),
(10, XMLPARSE(DOCUMENT '<doc>
                    <type>animal</type>
                    <name>bird</name>
                    </doc>' PRESERVE WHITESPACE))
```

## Procedure

Use the following examples as references when making your own C procedures:

- The C external code file
- Example 1: C parameter style SQL procedure with XML features

## The C external code file

The example consists of two parts: the CREATE PROCEDURE statement and the external C code implementation of the procedure from which the associated assembly can be built.

The C source file that contains the procedure implementations of the following examples is named `gwenProc.SQC` and has the following format:

*Table 35. C external code file format*

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <sqlda.h>
#include <sqlca.h>
#include <sqludf.h>
#include <sql.h>
#include <memory.h>

// C procedures
...
```

The file inclusions are indicated at the top of the file. There are no extra include files required for XML support in embedded SQL routines.

It is important to note the name of the file and the name of the function that corresponds to the procedure implementation. These names are important, because the EXTERNAL clause of the CREATE PROCEDURE statement for each procedure must specify this information so that the DB2 database manager can locate the library and entry point that corresponds to the C procedure.

## Example 1: C parameter style SQL procedure with XML features

This example shows the following:

- CREATE PROCEDURE statement for a parameter style SQL procedure
- C code for a parameter style SQL procedure with XML parameters

This procedure receives two input parameters. The first input parameter is named `inNum` and is of type `INTEGER`. The second input parameter is named `inXML` and is of type `XML`. The values of the input parameters are used to insert a row into the table `xmlDataTable`. Then an XML value is retrieved using an SQL statement. Another XML value is retrieved using an XQuery expression. The retrieved XML values are respectively assigned to two output parameters, `out1XML` and `out2XML`. No result sets are returned.

Table 36. Code to create a C parameter style SQL procedure

```

CREATE PROCEDURE xmlProc1 ( IN inNUM INTEGER,
                           IN inXML XML as CLOB (1K),
                           OUT inXML XML as CLOB (1K),
                           OUT inXML XML as CLOB (1K)
                           )

LANGUAGE C
PARAMETER STYLE SQL
DYNAMIC RESULT SETS 0
FENCED
THREADSAFE
DETERMINISTIC
NO DBINFO
MODIFIES SQL DATA
PROGRAM TYPE SUB
EXTERNAL NAME 'gwenProc!xmlProc1' ;

/*****
// Stored Procedure: xmlProc1
//
// Purpose:  insert XML data into XML column
//
// Parameters:
//
// IN:    inNum -- the sequence of XML data to be insert in xmldata table
//        inXML -- XML data to be inserted
// OUT:   out1XML -- XML data returned - value retrieved using XQuery
//        out2XML -- XML data returned - value retrieved using SQL
//*****/

```

Table 36. Code to create a C parameter style SQL procedure (continued)

```

#ifdef __cplusplus
extern "C"
#endif
SQL_API_RC SQL_API_FN testSecA1(sqlint32* inNum,
                                SQLUDF_CLOB* inXML,
                                SQLUDF_CLOB* out1XML,
                                SQLUDF_CLOB* out2XML,
                                SQLUDF_NULLIND *inNum_ind,
                                SQLUDF_NULLIND *inXML_ind,
                                SQLUDF_NULLIND *out1XML_ind,
                                SQLUDF_NULLIND *out2XML_ind,
                                SQLUDF_TRAIL_ARGS)
{
    char *str;
    FILE *file;

    EXEC SQL INCLUDE SQLCA;

    EXEC SQL BEGIN DECLARE SECTION;
        sqlint32 hvNum1;
        SQL TYPE IS XML AS CLOB(200) hvXML1;
        SQL TYPE IS XML AS CLOB(200) hvXML2;
        SQL TYPE IS XML AS CLOB(200) hvXML3;
    EXEC SQL END DECLARE SECTION;

    /* Check null indicators for input parameters */
    if ((*inNum_ind < 0) || (*inXML_ind < 0)) {
        strcpy(sqludf_sqlstate, "38100");
        strcpy(sqludf_msgtext, "Received null input");
        return 0;
    }

    /* Copy input parameters to host variables */
    hvNum1 = *inNum;
    hvXML1.length = inXML->length;
    strncpy(hvXML1.data, inXML->data, inXML->length);

    /* Execute SQL statement */
    EXEC SQL
        INSERT INTO xmlDataTable (num, xdata) VALUES (:hvNum1, :hvXML1);

    /* Execute SQL statement */
    EXEC SQL
        SELECT xdata INTO :hvXML2
        FROM xmlDataTable
        WHERE num = :hvNum1;

    sprintf(stmt5, "SELECT XMLQUERY('for $x in $xmldata/doc
                                return <carInfo>{$x/model}</carInfo>'
                                passing by ref xmlDataTable.xdata
                                as \"xmldata\" returning sequence)
                                FROM xmlDataTable WHERE num = ?");

    EXEC SQL PREPARE selstmt5 FROM :stmt5 ;
    EXEC SQL DECLARE c5 CURSOR FOR selstmt5;
    EXEC SQL OPEN c5 using :hvNum1;
    EXEC SQL FETCH c5 INTO :hvXML3;

    exit:

    /* Set output return code */
    *outReturnCode = sqlca.sqlcode;
    *outReturnCode_ind = 0;

    return 0;
}

```

## Examples of C# .NET CLR functions

### Before you begin

Once you understand the basics of user-defined functions (UDFs), and the essentials of CLR routines, you can start exploiting CLR UDFs in your applications and database environment. This topic contains some examples of CLR UDFs to get you started. For examples of CLR procedures in C#:

- “Examples of C# .NET CLR procedures” on page 124

Before working with the CLR UDF examples you might want to read the following concept topics:

- Chapter 4, “.NET common language runtime (CLR) routines,” on page 103
- “Creating .NET CLR routines from DB2 Command Window” on page 113
- “External scalar functions” on page 60
- “Building .NET CLR routine code” on page 115 there *Developing ADO.NET and OLE DB Applications*

The examples below make use of a table named EMPLOYEE that is contained in the SAMPLE database.

### Procedure

Use the following examples as references when making your own C# CLR UDFs:

- The C# external code file
- Example 1: C# parameter style SQL table function
- Example 2: C# parameter style SQL scalar function

### Example

#### The C# external code file

The following examples show a variety of C# UDF implementations. The CREATE FUNCTION statement is provided for each UDF with the corresponding C# source code from which the associated assembly can be built. The C# source file that contains the functions declarations used in the following examples is named gwenUDF.cs and has the following format:

Table 37. C# external code file format

```
using System;
using System.IO;
using IBM.Data.DB2;

namespace bizLogic
{
    ...
    // Class definitions that contain UDF declarations
    // and any supporting class definitions
    ...
}
```

The function declarations must be contained in a class within a C# file. The use of namespaces is optional. If a namespace is used, the namespace must appear in the assembly path name provided in the EXTERNAL clause of the CREATE PROCEDURE statement. The IBM.Data.DB2. inclusion is required if the function contains SQL.

#### Example 1: C# parameter style SQL table function



This example shows the following:

- CREATE FUNCTION statement for a parameter style SQL table function
- C# code for a parameter style SQL table function

This table function returns a table containing rows of employee data that was created from a data array. There are two classes associated with this example. Class `person` represents the employees, and the class `empOps` contains the routine table UDF that uses class `person`. The employee salary information is updated based on the value of an input parameter. The data array in this example is created within the table function itself on the first call of the table function. Such an array could have also been created by reading in data from a text file on the file system. The array data values are written to a scratchpad so that the data can be accessed in subsequent calls of the table function.

On each call of the table function, one record is read from the array and one row is generated in the table that is returned by the function. The row is generated in the table, by setting the output parameters of the table function to the desired row values. After the final call of the table function occurs, the table of generated rows is returned.

*Table 38. Code to create a C# parameter style SQL table function*

```
CREATE FUNCTION tableUDF(double)
RETURNS TABLE (name varchar(20),
                job varchar(20),
                salary double)
EXTERNAL NAME 'gwenUDF.dll:bizLogic.empOps!tableUDF'
LANGUAGE CLR
PARAMETER STYLE SQL
NOT DETERMINISTIC
FENCED
THREADSAFE
SCRATCHPAD 10
FINAL CALL
EXECUTION CONTROL SAFE
DISALLOW PARALLEL
NO DBINFO
```

Table 38. Code to create a C# parameter style SQL table function (continued)

```
// The class Person is a supporting class for
// the table function UDF, tableUDF, below.
class Person
{
    private String name;
    private String position;
    private Int32 salary;

    public Person(String newName, String newPosition, Int32
newSalary)
    {
        this.name = newName;
        this.position = newPosition;
        this.salary = newSalary;
    }

    public String getName()
    {
        return this.name;
    }

    public String getPosition()
    {
        return this.position;
    }

    public Int32 getSalary()
    {
        return this.salary;
    }
}
```

Table 38. Code to create a C# parameter style SQL table function (continued)

```

class empOps
{
    public static void TableUDF( Double factor, out String name,
                                out String position, out Double salary,
                                Int16 factorNullInd, out Int16 nameNullInd,
                                out Int16 positionNullInd, out Int16 salaryNullInd,
                                ref String sqlState, String funcName,
                                String specName, ref String sqlMessageText,
                                Byte[] scratchPad, Int32 callType)
    {
        Int16 intRow = 0;

        // Create an array of Person type information
        Person[] Staff = new
        Person[3];
        Staff[0] = new Person("Gwen", "Developer", 10000);
        Staff[1] = new Person("Andrew", "Developer", 20000);
        Staff[2] = new Person("Liu", "Team Leader", 30000);

        salary = 0;
        name = position = "";
        nameNullInd = positionNullInd = salaryNullInd = -1;

        switch(callType)
        {
            case (-2): // Case SQLUDF_TF_FIRST:
                break;

            case (-1): // Case SQLUDF_TF_OPEN:
                intRow = 1;
                scratchPad[0] = (Byte)intRow; // Write to scratchpad
                break;

            case (0): // Case SQLUDF_TF_FETCH:
                intRow = (Int16)scratchPad[0];
                if (intRow > Staff.Length)
                {
                    sqlState = "02000"; // Return an error SQLSTATE
                }
                else
                {
                    // Generate a row in the output table
                    // based on the Staff array data.
                    name =
                    Staff[intRow-1].getName();
                    position = Staff[intRow-1].getPosition();
                    salary = (Staff[intRow-1].getSalary()) * factor;
                    nameNullInd = 0;
                    positionNullInd = 0;
                    salaryNullInd = 0;
                }
                intRow++;
                scratchPad[0] = (Byte)intRow; // Write scratchpad
                break;

            case (1): // Case SQLUDF_TF_CLOSE:
                break;

            case (2): // Case SQLUDF_TF_FINAL:
                break;
        }
    }
}

```

## Example 2: C# parameter style SQL scalar function

This example shows the following:

- CREATE FUNCTION statement for a parameter style SQL scalar function
- C# code for a parameter style SQL scalar function

This scalar function returns a single count value for each input value that it operates on. For an input value in the nth position of the set of input values, the output scalar value is the value n. On each call of the scalar function, where one call is associated with each row or value in the input set of rows or values, the count is increased by one and the current value of the count is returned. The count is then saved in the scratchpad memory buffer to maintain the count value between each call of the scalar function.

This scalar function can be easily invoked if for example we have a table defined as follows:

```
CREATE TABLE T (i1 INTEGER);
INSERT INTO T VALUES 12, 45, 16, 99;
```

A simple query such as the following can be used to invoke the scalar function:

```
SELECT countUp(i1) as count, i1 FROM T;
```

The output of such a query would be:

COUNT	I1
1	12
2	45
3	16
4	99

This scalar UDF is quite simple. Instead of returning just the count of the rows, you could use a scalar function to format data in an existing column. For example you might append a string to each value in an address column or you might build up a complex string from a series of input strings or you might do a complex mathematical evaluation over a set of data where you must store an intermediate result.

*Table 39. Code to create a C# parameter style SQL scalar function*

```
CREATE FUNCTION countUp(INTEGER)
RETURNS INTEGER
LANGUAGE CLR
PARAMETER STYLE SQL
SCRATCHPAD 10
FINAL CALL
NO SQL
FENCED
THREADSAFE
NOT DETERMINISTIC
EXECUTION CONTROL SAFE
EXTERNAL NAME 'gwenUDF.dll:bizLogic.empOps!CountUp' ;
```

Table 39. Code to create a C# parameter style SQL scalar function (continued)

```

class empOps
{
    public static void CountUp(    Int32 input,
                                  out Int32 outCounter,
                                  Int16 inputNullInd,
                                  out Int16 outCounterNullInd,
                                  ref String sqlState,
                                  String funcName,
                                  String specName,
                                  ref String sqlMessageText,
                                  Byte[] scratchPad,
                                  Int32 callType)

    {
        Int32 counter = 1;

        switch(callType)
        {
            case -1: // case SQLUDF_FIRST_CALL
                scratchPad[0] = (Byte)counter;
                outCounter = counter;
                outCounterNullInd = 0;
                break;
            case 0: // case SQLUDF_NORMAL_CALL:
                counter = (Int32)scratchPad[0];
                counter = counter + 1;
                outCounter = counter;
                outCounterNullInd = 0;
                scratchPad[0] =
                    (Byte)counter;
                break;
            case 1: // case SQLUDF_FINAL_CALL:
                counter =
                    (Int32)scratchPad[0];
                outCounter = counter;
                outCounterNullInd = 0;
                break;
            default: // Should never enter here
                // * Required so that at compile time
                //   out parameter outCounter is always set *
                outCounter = (Int32)0;
                outCounterNullInd = -1;
                sqlState="ABCDE";
                sqlMessageText = "Should not get here: Default
                case!";
                break;
        }
    }
}

```



---

## Chapter 5. C and C++ routines

C and C++ routines are external routines that are created by executing a CREATE PROCEDURE, CREATE FUNCTION, or CREATE METHOD statement that references a library built from C or C++ source code as its external code body.

C and C++ routines can optionally execute SQL statements by including embedded SQL statements.

The following terms are important in the context of C and C++ routines:

### **CREATE statement**

The SQL language CREATE statement used to create the routine in the database.

### **Routine-body source code**

The source code file containing the C or C++ routine implementation that corresponds to the CREATE statement EXTERNAL clause specification.

### **Precompiler**

The DB2 utility that pre-parses the routine source code implementation to validate SQL statements contained in the code and generates a package.

### **Compiler**

The programming language specific software required to compile and link the source code implementation.

### **Package**

The file containing the runtime access path information that DB2 will use at routine runtime to execute the SQL statements contained in the routine code implementation.

### **Routine library**

A file that contains the compiled form of the routine source code. In Windows this is sometimes called a DLL, because these files have .dll file extensions.

Before developing a C or C++ routine, it is important to both understand the basics of routines and the unique features and characteristics specific to C and C++ routines. An understanding of the Embedded SQL API and the basics of embedded SQL application development is also important. To learn more about these subjects, refer to the following topics:

- External routines
- Embedded SQL
- Include files for C and C++ routines
- Parameters in C and C++ routines
- Restrictions on C and C++ routines

Developing a C or C++ routines involves following a series of step by step instructions and looking at C or C++ routine examples. Refer to:

- Creating C and C++ routines
- Examples of C procedures
- Examples of C user-defined functions

---

## Support for external routine development in C

To develop external routines in C you must use supported compilers and development software.

The supported compilers and development software for DB2 database application development in C can all be used for external routine development in C.

---

## Support for external routine development in C++

To develop external routines in C++ you must use supported compilers and development software.

The supported compilers and development software for DB2 database application development in C can all be used for external routine development in C++.

---

## Tools for developing C and C++ routines

The tools supported for C and C++ routines are the same as those supported for embedded SQL C and C++ applications.

There are no DB2 development environments or graphical user interface tools for developing, debugging, or deploying embedded SQL applications or routines.

The following command line interfaces are commonly used for developing, debugging, and deploying embedded SQL applications and routines:

- DB2 Command Line Processor
- DB2 Command Window

These interfaces support the execution of the SQL statements required to create routines in a database. The PREPARE statement and the **BIND** command required to build C and C++ routines that contain embedded SQL can also be issued from these interfaces.

---

## Designing C and C++ routines

Designing C and C++ routines is a task that should precede creating C and C++ routines. Designing C and C++ routines is generally related to both designing external routines implemented in other programming languages and designing embedded SQL applications.

### Before you begin

- General knowledge of external routines
- C or C++ programming experience
- Optional: Knowledge of and experience with embedded SQL or CLI application development (if the routine will execute SQL statements)

The following topics can provide you with some of the required prerequisite information.

For more information on the features and uses of external routines:

- Refer to the topic, “External routine implementation” on page 21

For more information on the characteristics of the embedded SQL API:



- Refer to the topic, “Introduction to embedded SQL” in *Developing Embedded SQL Applications*

## About this task

With the prerequisite knowledge, designing embedded SQL routines consists mainly of learning about the unique features and characteristics of C and C++ routines:

### Procedure

- “Include file required for C and C++ routine development (sqludf.h)”
- “Parameters in C and C++ routines” on page 169
- “Parameter style SQL C and C++ procedures” on page 170
- “Parameter style SQL C and C++ functions” on page 173
- “SQL data type handling in C and C++ routines” on page 183
- “Graphic host variables in C and C++ routines” on page 203
- “Returning result sets from C and C++ procedures” on page 205
- “C++ type decoration” on page 203
- “Restrictions on external routines” on page 91

### Results

After having learned about the C and C++ characteristics, you might want to refer to:

- “Creating C and C++ routines” on page 206

## Include file required for C and C++ routine development (sqludf.h)

The `sqludf.h` include file contains structures, definitions, and values that are required when coding routine implementations. Although the file has 'udf' in its name, (for historical reasons) it is also useful for stored procedures and methods. When compiling your routine, you need to reference the DB2 installation include directory that contains this file.

Use of objects in this file is recommended to ensure that the correct C data type for your specific operating system and operating system bit-width are used.

The `sqludf.h` file contains structure definitions and descriptions of the structure definitions. The following is a brief summary of its content:

- Macro definitions for SQL data types that are supported as parameters to external routines that do not require representation as a C or C++ structure. In the file, the definitions have name formats like: `SQLUDF_x` and `SQLUDF_x_FBD` where `x` is an SQL data type name and `FBD` represents FOR BIT DATA for those data types that are stored in binary form.  
Also included is a C language type for an argument or result that is defined with the `AS LOCATOR` clause. This is applicable only to UDFs and methods.
- C structure definitions required to represent the following SQL data types and special parameters:
  - `VARCHAR FOR BIT DATA` data type
  - `LONG VARCHAR` data type
  - `LONG VARCHAR FOR BIT DATA` data type

- LONG VARCHAR data type
- BLOB data type
- CLOB data type
- DBCLOB data type
- scratchpad structure
- dbinfo structure

Each of these is represented by a structure with more than one field value rather than by a simple C data type.

The scratchpad structure defines a buffer, that is passed to a user-defined function for use during the function invocation. Unlike a variable, however the data stored in a scratchpad is persistent between multiple user-defined function calls within a single invocation. This can be useful both for functions that return aggregated values and for functions that require initial setup logic.

The dbinfo structure is a structure that contains database and routine information that can be passed to and from a routine implementation as an extra argument if and only if the DBINFO clause is included in the CREATE statement for the routine.

- Definition of C language types for the scratchpad and call-type arguments. An enum type definition is specified for the call-type argument.  
External user-defined functions are invoked multiple times for a set of values. Call-types are used to identify individual external function invocations. Each invocation is identified with a call-type value that can be referenced within the function logic. For example there are special call-types for the first invocation of a function, for data fetching calls, and for the final invocation. Call-types are useful, because specific logic can be associated with a particular call-type. Examples of call-types include: FIRST call, FETCH call FINAL call.
- Macros for defining the standard trailing arguments required in user-defined function (UDF) prototypes. The trailing arguments include the SQL-state, function-name, specific-name, diagnostic-message, scratchpad, and call-type UDF invocation arguments. Also included are definitions for referencing these constructs, and the various valid SQLSTATE values. There are various macro definitions provided that differ in their inclusion or exclusion of the scratchpad and call-type arguments. These corresponds to the presence or absence of the use of the SCRATCHPAD clause and FINAL CALL clause in the function definition.

In general when defining a user-defined function, it is recommended to use the macro SQLUDF\_TRAIL\_ARGS to simplify the function prototype. An example is shown below:

```
void SQL_API_FN ScalarUDF(SQLUDF_CHAR *inJob,
                        SQLUDF_DOUBLE *inSalary,
                        SQLUDF_DOUBLE *outNewSalary,
                        SQLUDF_SMALLINT *jobNullInd,
                        SQLUDF_SMALLINT *salaryNullInd,
                        SQLUDF_SMALLINT *newSalaryNullInd,
                        SQLUDF_TRAIL_ARGS)
```

- Macro definitions that can be used to test whether or not SQL arguments have null values.

To see how the various definitions, macros, and structures that are defined in the file sqludf.h are used, see the C and C++ sample applications and routines.

## Parameters in C and C++ routines

Parameter declaration in C and C++ routines must conform to the requirements of one of the supported parameter styles and the program type.

If the routine is to use a scratchpad, the dbinfo structure, or to have a PROGRAM TYPE MAIN parameter interface, there are additional details to consider including:

- “Parameter styles supported for C and C++ routines”
- “Parameter null indicators in C and C++ routines”
- “Parameter style SQL C and C++ procedures” on page 170
- “Parameter style SQL C and C++ functions” on page 173
- “Passing parameters by value or by reference in C and C++ routines” on page 175
- “Parameters are not required for C and C++ procedure result sets” on page 175
- “Dbinfo structure as C or C++ routine parameter” on page 175
- “Scratchpad as C or C++ function parameter” on page 178
- “Program type MAIN support for C and C++ procedures” on page 179

It is very important that you implement the parameter interface to C and C++ routines correctly. This can be easily done with just a bit of care taken to ensure that the correct parameter style and data types are chosen and implemented according to the specification.

### Parameter styles supported for C and C++ routines

The following parameter styles are supported for C and C++ routines:

- SQL (Supported for procedures and functions; recommended)
- GENERAL (Supported for procedures)
- GENERAL WITH NULLS (Supported for procedures)

It is strongly recommended that the parameter style SQL be used for all C and C++ routines. This parameter style supports NULL values, provides a standard interface for reporting errors, as well as supporting scratchpads and call types.

To specify the parameter style to be used for a routine, you must specify the PARAMETER STYLE clause in the CREATE statement for the routine at routine creation time.

The parameter style must be accurately reflected in the implementation of the C or C++ routine code.

For more information about these parameter styles refer to: “Syntax for passing parameters to C and C++ routines”.

### Parameter null indicators in C and C++ routines

If the parameter style chosen for a C or C++ routine (procedure or function) requires that a null indicator parameter be specified for each of the SQL parameters, as is required by parameter style SQL and GENERAL, the null indicators are to be passed as parameters of data type SQLUDF\_NULLIND\*. For parameter style GENERAL WITH NULLS, they must be passed as an array of type SQLUDF\_NULLIND. This data type is defined in embedded SQL application and routine include file: `sqludf.h`.

Null-indicator parameters indicate whether the corresponding parameter value is equivalent to NULL in SQL or if it has a literal value. If the null indicator value for

a parameter is 0, this indicates that the parameter value is not null. If the null-indicator value for a parameter is -1, the parameter is to be considered to have a value equivalent to the SQL value NULL.

When null indicators are used it is important to include code within your routine that:

- Checks null-indicator values for input parameters before using them.
- Sets null indicator values for output parameters before the routine returns.

For more information about parameter SQL refer to:

- “External routine parameter styles” on page 71
- “Parameter style SQL C and C++ procedures”
- “Parameter style SQL C and C++ functions” on page 173

### Parameter style SQL C and C++ procedures

C and C++ procedures should be created using the PARAMETER STYLE SQL clause in the CREATE PROCEDURE statement. The parameter passing conventions of this parameter style should be implemented in the corresponding procedure code implementation.

The C and C++ PARAMETER STYLE SQL signature implementation required for procedures follows this format:

```
SQL_API_RC SQL_API_FN function-name (  
    SQL-arguments,  
    SQL-argument-inds,  
    sqlstate,  
    routine-name,  
    specific-name,  
    diagnostic-message )
```

#### SQL\_API\_RC SQL\_API\_FN

SQL\_API\_RC and SQL\_API\_FN are macros that specify the return type and calling convention for a C or C++ procedure, which can vary across supported operating systems. The use of these macros is required for C and C++ routines. The macros are declared in embedded SQL application and routine include file `sqlsystem.h`.

#### *function-name*

Name of the C or C++ function within the code file. This value does not have to be the same as the name of the procedure specified within the corresponding CREATE PROCEDURE statement. This value in combination with the library name however must be specified in the EXTERNAL NAME clause to identify the correct function entry point within the library to be used. For C++ routines, the C++ compiler applies type decoration to the entry point name. Either the type decorated name needs to be specified in the EXTERNAL NAME clause, or the entry point should be defined as extern "C" in the user code. The function name must be explicitly exported.

#### *SQL-arguments*

C or C++ arguments that correspond to the set of SQL parameters specified in the CREATE PROCEDURE statement. IN, OUT, and INOUT mode parameters are passed using individual pointer values.

#### *SQL-argument-inds*

C or C++ null indicators that correspond to the set of SQL parameters specified in the CREATE PROCEDURE statement. For each IN, OUT, and INOUT mode parameter, there must be an associated null-indicator

parameter. Null indicators can be passed as individual arguments of type `SQLUDF_NULLIND` or as part of a single array of null indicators defined as `SQLUDF_NULLIND*`.

*sqlstate* Input-output parameter value used by the routine to signal warning or error conditions. Typically this argument is used to assign a user-defined `SQLSTATE` value that corresponds to an error or a warning that can be passed back to the caller. `SQLSTATE` values of the form `38xxx`, where `xxx` is any numeric value are available for user-defined `SQLSTATE` error values. `SQLSTATE` values of the form `01Hxx` where `xx` is any numeric value are available for user-defined `SQLSTATE` warning values.

*routine-name*

Input parameter value that contains the qualified routine name. This value is generated by DB2 and passed to the routine in the form `<schema-name>.<routine-name>` where `<schema-name>` and `<routine-name>` correspond respectively to the `ROUTINESHEMA` column value and `ROUTINENAME` column value for the routine within the `SYSCAT.ROUTINES` catalog view. This value can be useful if a single routine implementation is used by multiple different routine definitions. When the routine definition name is passed into the routine, logic can be conditionally executed based on which definition was used. The routine name can also be useful when formulating diagnostic information including error messages, or when writing to a log file.

*specific-name*

Input parameter value that contains the unique routine specific name. This value is generated by DB2 and passed to the routine. This value corresponds to the `SPECIFICNAME` column value for the routine in the `SYSCAT.ROUTINES` view. It can be useful in the same way as the `routine-name`.

*diagnostic-message*

Output parameter value optionally used by the routine to return message text to the invoking application or routine. This parameter is intended to be used as a complement to the `SQLSTATE` argument. It can be used to assign a user-defined error-message to accompany a user-defined `SQLSTATE` value which can provide more detailed diagnostic error or warning information to the caller of the routine.

**Note:** To simplify the writing of C and C++ procedure signatures the macro definition `SQLUDF_TRAIL_ARGS` defined in `sqludf.h` can be used in the procedure signature in place of using individual arguments to implement the non-SQL data type arguments.

The following is an example of a C or C++ procedure implementation that accepts a single input parameter, and returns a single output parameter and a result set:

```
/******
```

```
Routine:  cstp
```

```
Purpose:   Returns an output parameter value based on an input  
         parameter value
```

```
Shows how to:
```

- define a procedure using `PARAMETER STYLE SQL`
- define `NULL` indicators for the parameter
- execute an SQL statement
- how to set a `NULL` indicator when parameter is not null

Parameters:

IN: inParm  
OUT: outParm

When PARAMETER STYLE SQL is defined for the routine (see routine registration script spcreate.db2), in addition to the parameters passed during invocation, the following arguments are passed to the routine in the following order:

- one null indicator for each IN/INOUT/OUT parameter ordered to match order of parameter declarations
- SQLSTATE to be returned to DB2 (output)
- qualified name of the routine (input)
- specific name of the routine (input)
- SQL diagnostic string to return an optional error message text to DB2 (output)

See the actual parameter declarations below to see the recommended datatypes and sizes for them.

CODE TIP:

-----

Instead of coding the 'extra' parameters:  
sqlstate, qualified name of the routine,  
specific name of the routine, diagnostic message,  
a macro SQLUDF\_TRAIL\_ARGS can be used instead.  
This macro is defined in DB2 include file sqludf.h

TIP EXAMPLE:

-----

The following is equivalent to the actual prototype used that makes use of macro definitions included in sqludf.h. The form actually implemented is simpler and removes datatype concerns.

```
extern "C" SQL_API_RC SQL_API_FN OutLanguage(  
    sqlint16 *inParm,  
    double *outParm,  
    sqlint16 *inParmNullInd,  
    sqlint16 *outParmNullInd,  
    char sqlst[6],  
    char qualName[28],  
    char specName[19],  
    char diagMsg[71])  
)  
  
*****/  
  
extern "C" SQL_API_RC SQL_API_FN cstp ( sqlint16 *inParm,  
    double *outParm,  
    SQLUDF_NULLIND *inParmNullInd,  
    SQLUDF_NULLIND *outParmNullInd,  
    SQLUDF_TRAIL_ARGS )  
{  
    EXEC SQL INCLUDE SQLCA;  
  
    EXEC SQL BEGIN DECLARE SECTION;  
        sqlint16 sql_inParm;  
    EXEC SQL END DECLARE SECTION;  
  
    sql_inParm = *inParm;  
  
    EXEC SQL DECLARE cur1 CURSOR FOR  
        SELECT value  
        FROM table01
```

```

        WHERE index = :sql_inParm;

        *outParm = (*inParm) + 1;
        *outParmNullInd = 0;

EXEC SQL OPEN cur1;

return (0);
}

```

The corresponding CREATE PROCEDURE statement for this procedure follows:

```

CREATE PROCEDURE cproc( IN inParm INT, OUT outParm INT )
LANGUAGE c
PARAMETER STYLE sql
DYNAMIC RESULT SETS 1
FENCED
THREADSAFE
RETURNS NULL ON NULL INPUT
EXTERNAL NAME 'c_rtms!cstp'

```

The preceding statement assumes that the C or C++ procedure implementation is in a library file named `c_rtms` and a function named `cstp`.

## Parameter style SQL C and C++ functions

C and C++ user-defined functions should be created using the PARAMETER STYLE SQL clause in the CREATE FUNCTION statement. The parameter passing conventions of this parameter style should be implemented in the corresponding source code implementation. The C and C++ PARAMETER STYLE SQL signature implementation required for user-defined functions follows this format:

```

SQL_API_RC SQL_API_FN function-name ( SQL-arguments,
    SQL-argument-inds,
    SQLUDF_TRAIL_ARGS )

```

### SQL\_API\_RC SQL\_API\_FN

SQL\_API\_RC and SQL\_API\_FN are macros that specify the return type and calling convention for a C or C++ user-defined function, which can vary across supported operating systems. The use of these macros is required for C and C++ routines. The macros are declared in embedded SQL application and routine include file `sqlsystem.h`.

### *function-name*

Name of the C or C++ function within the code file. This value does not have to be the same as the name of the function specified within the corresponding CREATE FUNCTION statement. This value in combination with the library name however must be specified in the EXTERNAL NAME clause to identify the correct function entry point within the library to be used. For C++ routines, the C++ compiler applies type decoration to the entry point name. Either the type decorated name needs to be specified in the EXTERNAL NAME clause, or the function declaration within the source code file should be prefixed with `extern "C"` as shown in the following example: `extern "C" SQL_API_RC SQL_API_FN OutLanguage(char *, sqlint16 *, char *, char *, char *, char *);`

### *SQL-arguments*

C or C++ arguments that correspond to the set of SQL parameters specified in the CREATE FUNCTION statement.

### *SQL-argument-inds*

For each SQL-argument a null indicator parameter is required to specify whether the parameter value is intended to be interpreted within the routine implementation as a NULL value in SQL. Null indicators must be

specified with data type SQLUDF\_NULLIND. This data type is defined in embedded SQL routine include file sqludf.h.

#### SQLUDF\_TRAIL\_ARGS

A macro defined in embedded SQL routine include file sqludf.h that once expanded defines the additional trailing arguments required for a complete parameter style SQL signature. There are two macros that can be used: SQLUDF\_TRAIL\_ARGS and SQLUDF\_TRAIL\_ARGS\_ALL.

SQLUDF\_TRAIL\_ARGS when expanded, as defined in sqludf.h, is equivalent to the addition of the following routine arguments:

```
SQLUDF_CHAR *sqlState,  
SQLUDF_CHAR qualName,  
SQLUDF_CHAR specName,  
SQLUDF_CHAR *sqlMessageText,
```

In general these arguments are not required or generally used as part of user-defined function logic. They represent the output SQLSTATE value to be passed back to the function invoker, the input fully qualified function name, input function specific name, and output message text to be returned with the SQLSTATE. SQLUDF\_TRAIL\_ARGS\_ALL when expanded, as defined in sqludf.h, is equivalent to the addition of the following routine arguments:

```
SQLUDF_CHAR  qualName,  
SQLUDF_CHAR  specName,  
SQLUDF_CHAR  sqlMessageText,  
SQLUDF_SCRAT *scratchpad  
SQLUDF_CALLT *callType
```

If the UDF CREATE statement includes the SCRATCHPAD clause or the FINAL CALL clause, then the macro SQLUDF\_TRAIL\_ARGS\_ALL must be used. In addition to arguments provided with SQLUDF\_TRAIL\_ARGS, this macro also contains pointers to a scratchpad structure, and a call type value.

The following is an example of a simple C or C++ UDF that returns in an output parameter the value of the product of its two input parameter values:

```
SQL_API_RC SQL_API_FN product ( SQLUDF_DOUBLE *in1,  
                                SQLUDF_DOUBLE *in2,  
                                SQLUDF_DOUBLE *outProduct,  
                                SQLUDF_NULLIND *in1NullInd,  
                                SQLUDF_NULLIND *in2NullInd,  
                                SQLUDF_NULLIND *productNullInd,  
                                SQLUDF_TRAIL_ARGS )  
{  
  
    /* Check that input parameter values are not null  
       by checking the corresponding null indicator values  
       0 : indicates parameter value is not NULL  
       -1 : indicates parameter value is NULL  
  
       If values are not NULL, calculate the product.  
       If values are NULL, return a NULL output value. */  
  
    if ((*in1NullInd != -1) &&  
        *in2NullInd != -1)  
    {  
        *outProduct = (*in1) * (*in2);  
        *productNullInd = 0;  
    }  
    else  
    {
```



```

    *productNullInd = -1;
}
return (0);
}

```

The corresponding CREATE FUNCTION statement that can be used to create this UDF could be:

```

CREATE FUNCTION product( in1 DOUBLE, in2 DOUBLE )
  RETURNS DOUBLE
  LANGUAGE C
  PARAMETER STYLE SQL
  NO SQL
  FENCED THREADSAFE
  DETERMINISTIC
  RETURNS NULL ON NULL INPUT
  NO EXTERNAL ACTION
  EXTERNAL NAME 'c_rtms!product'

```

The preceding SQL statement assumes that the C or C++ function is in a library file in the function directory named c\_rtms.

### Passing parameters by value or by reference in C and C++ routines

For C and C++ routines, parameter values must always be passed by reference to routines using pointers. This is required for input-only, input-output, and output parameters. by reference.

Null-indicator parameters must also be passed by reference to routines using pointers.

**Note:** DB2 controls the allocation of memory for all parameters and maintains C or C++ references to all parameters passed into or out of a routine. There is no need to allocate or free memory associated with routine parameters and null indicators.

### Parameters are not required for C and C++ procedure result sets

No parameter is required in the CREATE PROCEDURE statement signature for a procedure or in the associated procedure implementation in order to return a result set to the caller.

Result sets returned from C procedures, are returned using cursors.

For more on returning result sets from LANGUAGE C procedures, see:

- “Returning result sets from C and C++ procedures” on page 205

### Dbinfo structure as C or C++ routine parameter

The dbinfo structure is a structure that contains database and routine information that can be passed to and from a routine implementation as an extra argument if and only if the DBINFO clause is included in the CREATE statement for the routine.

The dbinfo structure is supported LANGUAGE C routines through the use of the sqludf\_dbinfo structure. This C structure is defined in the DB2 include file sqludf.h located in the sqllib\include directory.

The sqludf\_dbinfo structure is defined as follows:

```

SQL_STRUCTURE sqludf_dbinfo
{
    unsigned short  dbnamelen;                /* Database name length */

```

```

unsigned char  dbname[SQLUDF_MAX_IDENT_LEN]; /* Database name */
unsigned short authidlen; /* Authorization ID length */
unsigned char  authid[SQLUDF_MAX_IDENT_LEN]; /* Authorization ID */
union db_cdpq codepq; /* Database code page */
unsigned short tbschemalen; /* Table schema name length */
unsigned char  tbschema[SQLUDF_MAX_IDENT_LEN]; /* Table schema name */
unsigned short tbnamelen; /* Table name length */
unsigned char  tbname[SQLUDF_MAX_IDENT_LEN]; /* Table name */
unsigned short colnamelen; /* Column name length */
unsigned char  colname[SQLUDF_MAX_IDENT_LEN]; /* Column name */
unsigned char  ver_rel[SQLUDF_SH_IDENT_LEN]; /* Database version/release */
unsigned char  resd0[2]; /* Alignment */
sqluint32 platform; /* Platform */
unsigned short numtfcoll; /* # of entries in TF column */
/* List array */
/* Reserved */
unsigned char  resd1[2]; /* Reserved */
sqluint32 procid; /* Current procedure ID */
unsigned char  resd2[32]; /* Reserved */
unsigned short *tfcoll; /* Tfcoll to be allocated */
/* dynamically if a table */
/* function is defined; */
/* else a NULL pointer */
char *appl_id; /* Application identifier */
sqluint32 dbpartitionnum; /* Database partition number */
/* where routine executed */
unsigned char  resd3[16]; /* Reserved */
};

```

Although, not all of the fields in the `dbinfo` structure might be useful within a routine, several of the values in this structure's fields might be useful when formulating diagnostic error message information. For example, if an error occurs within a routine, it might be useful to return the database name, database name length, the database code page, the current authorization ID, and the length of the current authorization ID.

To reference the `sqludf_dbinfo` structure in a LANGUAGE C routine implementation:

- Add the `DBINFO` clause to the `CREATE` statement that defines the routine.
- Include the `sqludf.h` header file at the top of the file containing the routine implementation.
- Add a parameter of type `sqludf_dbinfo` to the routine signature in the position specified by the parameter style used.

Here is an example of a C procedure with `PARAMETER STYLE GENERAL` that demonstrates the use of the `dbinfo` structure. Here is the `CREATE PROCEDURE` statement for the procedure. Note that as specified by the `EXTERNAL NAME` clause, the procedure implementation is located in a library file named `spserver` that contains a C function named `DbinfoExample`

```

CREATE PROCEDURE DBINFO_EXAMPLE (IN job CHAR(8),
                                OUT salary DOUBLE,
                                OUT dbname CHAR(128),
                                OUT dbversion CHAR(8),
                                OUT errorcode INTEGER)

DYNAMIC RESULT SETS 0
LANGUAGE C
PARAMETER STYLE GENERAL
DBINFO
FENCED NOT THREADSAFE
READS SQL DATA
PROGRAM TYPE SUB
EXTERNAL NAME 'spserver!DbinfoExample'@

```

Here is the C procedure implementation that corresponds to the procedure definition:

```

/*****
Routine:   DbinfoExample

IN:       inJob       - a job type, used in a SELECT predicate
OUT:      salary      - average salary of employees with job injob
          dbname      - database name retrieved from DBINFO
          dbversion   - database version retrieved from DBINFO
          outSqlError - sqlcode of error raised (if any)
          sqludf_dbinfo - pointer to DBINFO structure

Purpose:  This routine takes in a job type and returns the
          average salary of all employees with that job, as
          well as information about the database (name,
          version of database). The database information
          is retrieved from the dbinfo object.

Shows how to:
          - define IN/OUT parameters in PARAMETER STYLE GENERAL
          - declare a parameter pointer to the dbinfo structure
          - retrieve values from the dbinfo structure
*****/
SQL_API_RC SQL_API_FN DbinfoExample(char inJob[9],
                                   double *salary,
                                   char dbname[129],
                                   char dbversion[9],
                                   sqlint32 *outSqlError,
                                   struct sqludf_dbinfo * dbinfo
                                   )
{
    /* Declare a local SQLCA */
    struct sqlca sqlca;

    EXEC SQL WHENEVER SQLERROR GOTO return_error;

    /* SQL host variable declaration section */
    /* Each host variable names must be unique within a code
       file, or the the precompiler raises SQL0307 error */
    EXEC SQL BEGIN DECLARE SECTION;
    char dbinfo_injob[9];
    double dbinfo_outsalary;
    sqlint16 dbinfo_outsalaryind;
    EXEC SQL END DECLARE SECTION;

    /* Initialize output parameters - se strings to NULL */
    memset(dbname, '\0', 129);
    memset(dbversion, '\0', 9);
    *outSqlError = 0;

    /* Copy input parameter into local host variable */
    strcpy(dbinfo_injob, inJob);

    EXEC SQL SELECT AVG(salary) INTO:dbinfo_outsalary
               FROM employee
               WHERE job =:dbinfo_injob;

    *salary = dbinfo_outsalary;

    /* Copy values from the DBINFO structure into the output parameters
       You must explicitly null-terminate the strings.
       Information such as the database name, and the version of the
       database product can be found in the DBINFO structure as well as
       other information fields. */

    strncpy(dbname, (char *) (dbinfo->dbname), dbinfo->dbnamelen);

```

```

dbname[dbinfo->dbnameLen] = '\0';
strncpy(dbversion, (char *) (dbinfo->ver_rel), 8);
dbversion[8] = '\0';

return 0;

/* Copy SQLCODE to OUT parameter if SQL error occurs */

return_error:
{
    *outSqlError = SQLCODE;
    EXEC SQL WHENEVER SQLERROR CONTINUE;
    return 0;
}
} /* DbinfoExample function */

```

## Scratchpad as C or C++ function parameter

The scratchpad structure, used for storing UDF values between invocations for each UDF input value, is supported in C and C++ routines through the use of the `sqludf_scrat` structure.

This C structure is defined in the DB2 include file `sqludf.h`.

To reference the `sqludf_scrat` structure, include the `sqludf.h` header file at the top of the file containing the C or C++ function implementation, and use the `SQLUDF_TRAIL_ARGS_ALL` macro within the signature of the routine implementation.

The following example demonstrates a C scalar function implementation that includes a parameter of type `SQLUDF_TRAIL_ARGS_ALL`:

```

#ifdef __cplusplus
extern "C"
#endif
void SQL_API_FN ScratchpadScUDF(SQLUDF_INTEGER *outCounter,
                               SQLUDF_SMALLINT *counterNullInd,
                               SQLUDF_TRAIL_ARGS_ALL)
{
    struct scalar_scratchpad_data *pScratData;

    /* SQLUDF_CALLT and SQLUDF_SCRAT are */
    /* parts of SQLUDF_TRAIL_ARGS_ALL */

    pScratData = (struct scalar_scratchpad_data *)SQLUDF_SCRAT->data;
    switch (SQLUDF_CALLT)
    {
        case SQLUDF_FIRST_CALL:
            pScratData->counter = 1;
            break;
        case SQLUDF_NORMAL_CALL:
            pScratData->counter = pScratData->counter + 1;
            break;
        case SQLUDF_FINAL_CALL:
            break;
    }

    *outCounter = pScratData->counter;
    *counterNullInd = 0;
} /* ScratchpadScUDF */

```

The `SQLUDF_TRAIL_ARGS_ALL` macro expands to define other parameter values including one called `SQLUDF_SCRAT` that defines a buffer parameter to be used as a scratchpad. When the scalar function is invoked for a set of values, for each

time the scalar function is invoked, the buffer is passed as a parameter to the function. The buffer can be used to be accessed

The `SQLUDF_TRAIL_ARGS_ALL` macro value also defines another parameter `SQLUDF_CALLT`. This parameter is used to indicate a call type value. Call type values can be used to identify if a function is being invoked for the first time for a set of values, the last time, or at a time in the middle of the processing.

### **Program type MAIN support for C and C++ procedures**

Although the default `PROGRAM TYPE` clause value `SUB` is generally recommended for C procedures, the `PROGRAM TYPE` clause value `MAIN` is supported in `CREATE PROCEDURE` statements where the `LANGUAGE` clause value is `C`.

The `PROGRAM TYPE` clause value `MAIN` is required for routines with greater than ninety parameters.

When a `PROGRAM TYPE MAIN` clause is specified, procedures must be implemented using a signature that is consistent with the default style for a main routine in a C source code file. This does not mean that the routine must be implemented by a function named `main`, but rather that the parameters be passed in the format generally associated with a default type main routine application implementation that uses typical C programming `argc` and `argv` arguments.

Here is an example of a C or C++ routine signature that adheres to the `PGRAM TYPE MAIN` specification:

```
SQL_API_RC SQL_API_FN functionName(int argc, char **argv)
{
    ...
}
```

The total number of arguments to the function is specified by the value of `argc`. The argument values are passed as array elements within the `argv` array. The number and order of the arguments depends on the `PARAMETER STYLE` clause value specified in the `CREATE PROCEDURE` statement.

As an example, consider the following `CREATE PROCEDURE` statement for a C procedure specified to have a `PROGRAM TYPE MAIN` style and the recommended `PARAMETER STYLE SQL`:

```
CREATE PROCEDURE MAIN_EXAMPLE (
    IN job CHAR(8),
    OUT salary DOUBLE)
SPECIFIC CPP_MAIN_EXAMPLE
DYNAMIC RESULT SETS 0
NOT DETERMINISTIC
LANGUAGE C
PARAMETER STYLE SQL
NO DBINFO
FENCED NOT THREADSAFE
READS SQL DATA
PROGRAM TYPE MAIN
EXTERNAL NAME 'spserver!MainExample'@
```

The routine signature implementation that corresponds to this `CREATE PROCEDURE` statement follows:

```
//*****
// Stored Procedure: MainExample
//
// SQL parameters:
```

```

//      IN:      argv[1] - job   (char[8])
//      OUT:     argv[2] - salary (double)
//*****
SQL_API_RC SQL_API_FN MainExample(int argc, char **argv)
{
    ...
}

```

Because PARAMETER STYLE SQL is used, in addition to the SQL parameter values passed at procedure invocation time, the additional parameters required for that style are also passed to the routine.

Parameter values can be accessed by referencing the argv array element of interest within the source code. For the example given above, the argc and the argv array elements contain the following values:

```

argc      : Number of argv array elements
argv[0]   : The function name
argv[1]   : Value of parameter job (char[8], input)
argv[2]   : Value of parameter salary (double, output)
argv[3]   : null indicator for parameter job
argv[4]   : null indicator for parameter salary
argv[5]   : sqlstate (char[6], output)
argv[6]   : qualName (char[28], output)
argv[7]   : specName (char[19], output)
argv[8]   : diagMsg (char[71], output)

```

## Supported SQL data types in C and C++ routines

The following table lists the supported mappings between SQL data types and C data types for routines. Accompanying each C/C++ data type is the corresponding defined type from sqludf.h.

Table 40. SQL Data Types Mapped to C/C++ Declarations

SQL Column Type	C/C++ Data Type	SQL Column Type Description
SMALLINT	sqlint16 SQLUDF_SMALLINT	16-bit signed integer
INTEGER	sqlint32 SQLUDF_INTEGER	32-bit signed integer
BIGINT	sqlint64 SQLUDF_BIGINT	64-bit signed integer
REAL FLOAT( <i>n</i> ) where 1<= <i>n</i> <=24	float SQLUDF_REAL	Single-precision floating point
DOUBLE FLOAT FLOAT( <i>n</i> ) where 25<= <i>n</i> <=53	double SQLUDF_DOUBLE	Double-precision floating point
DECIMAL( <i>p</i> , <i>s</i> )	Not supported.	To pass a decimal value, define the parameter to be of a data type castable from DECIMAL (for example CHAR or DOUBLE) and explicitly cast the argument to this type.
CHAR( <i>n</i> )	char[ <i>n</i> +1] where <i>n</i> is large enough to hold the data  1<= <i>n</i> <=254  SQLUDF_CHAR	Fixed-length, null-terminated character string

Table 40. SQL Data Types Mapped to C/C++ Declarations (continued)

SQL Column Type	C/C++ Data Type	SQL Column Type Description
CHAR( <i>n</i> ) FOR BIT DATA	char[ <i>n</i> ] where <i>n</i> is large enough to hold the data  1<= <i>n</i> <=254  SQLUDF_CHAR	Fixed-length, not null-terminated character string
VARCHAR( <i>n</i> )	char[ <i>n</i> +1] where <i>n</i> is large enough to hold the data  1<= <i>n</i> <=32 672  SQLUDF_VARCHAR	Null-terminated varying length string
VARCHAR( <i>n</i> ) FOR BIT DATA	struct { sqluint16 length; char[ <i>n</i> ] }  1<= <i>n</i> <=32 672  SQLUDF_VARCHAR_FBD	Not null-terminated varying length character string
LONG VARCHAR	struct { sqluint16 length; char[ <i>n</i> ] }  1<= <i>n</i> <=32 700  SQLUDF_LONG	Not null-terminated varying length character string
CLOB( <i>n</i> )	struct { sqluint32 length; char    data[ <i>n</i> ]; }  1<= <i>n</i> <=2 147 483 647  SQLUDF_CLOB	Not null-terminated varying length character string with 4-byte string length indicator
BLOB( <i>n</i> )	struct { sqluint32 length; char    data[ <i>n</i> ]; }  1<= <i>n</i> <=2 147 483 647  SQLUDF_BLOB	Not null-terminated varying binary string with 4-byte string length indicator
DATE	char[11] SQLUDF_DATE	Null-terminated character string of the following format: yyyy-mm-dd
TIME	char[9] SQLUDF_TIME	Null-terminated character string of the following format: hh.mm.ss

Table 40. SQL Data Types Mapped to C/C++ Declarations (continued)

SQL Column Type	C/C++ Data Type	SQL Column Type Description
TIMESTAMP	char[20] - char[33] SQLUDF_STAMP	<p>Null-terminated character string of the following format: yyyy-mm-dd-hh.mm.ss.nnnnnnnnnnn</p> <p>The character string can be from 19 - 32 bytes in length depending on the number of fractional seconds specified. The fractional seconds of the TIMESTAMP data type can be optionally specified with 0-12 digits of timestamp precision.</p> <p>For example: (VALUES(CURRENT_TIMESTAMP(0))) 1 ----- 2008-07-09-14.48.36  1 record(s) selected.</p> <p>LENGTH (VALUES(CURRENT_TIMESTAMP(0))) 1 ----- 19  1 record(s) selected. (VALUES(CURRENT_TIMESTAMP(12))) 1 ----- 2008-07-09-14.48.36.123456789012  1 record(s) selected.</p> <p>LENGTH (VALUES(CURRENT_TIMESTAMP(0))) 1 ----- 32</p> <p>When a timestamp value is assigned to a timestamp variable with a different number of fractional seconds, the value is either truncated or padded with 0's to match the format of the timestamp variable.</p>
LOB LOCATOR	sqluint32 SQLUDF_LOCATOR	32-bit signed integer
GRAPHIC( <i>n</i> )	sqlbchar[ <i>n</i> +1] where <i>n</i> is large enough to hold the data  1<= <i>n</i> <=127  SQLUDF_GRAPH	Fixed-length, null-terminated double-byte character string
VARGRAPHIC( <i>n</i> )	sqlbchar[ <i>n</i> +1] where <i>n</i> is large enough to hold the data  1<= <i>n</i> <=16 336  SQLUDF_GRAPH	Null-terminated, variable-length double-byte character string



Table 40. SQL Data Types Mapped to C/C++ Declarations (continued)

SQL Column Type	C/C++ Data Type	SQL Column Type Description
LONG VARCHAR	<pre>struct {     sqluint16 length;     sqldbchar[n] }</pre> <p>1&lt;=n&lt;=16 350</p> <p>SQLUDF_LONGVARG</p>	Not null-terminated, variable-length double-byte character string
DBCLOB(n)	<pre>struct {     sqluint32 length;     sqldbchar data[n]; }</pre> <p>1&lt;=n&lt;=1 073 741 823</p> <p>SQLUDF_DBCLOB</p>	Not null-terminated varying length character string with 4-byte string length indicator
XML AS CLOB	<pre>struct {     sqluint32 length;     char data[n]; }</pre> <p>1&lt;=n&lt;=2 147 483 647</p> <p>SQLUDF_CLOB</p>	Not null-terminated varying length serialized character string with 4-byte string length indicator.

**Note:** XML data types can only be implemented as CLOB data types in external routines implemented in C or C++.

**Note:** The following data types are only available in the DBCS or EUC environment when precompiled with the WCHARTYPE NOCONVERT option:

- GRAPHIC(n)
- VARCHAR(n)
- LONG VARCHAR
- DBCLOB(n)

## SQL data type handling in C and C++ routines

This section identifies the valid types for routine parameters and results, and it specifies how the corresponding argument should be defined in your C or C++ language routine. All arguments in the routine must be passed as pointers to the appropriate data type. Note that if you use the `sqludf.h` include file and the types defined there, you can automatically generate language variables and structures that are correct for the different data types and compilers. For example, for `BIGINT` you can use the `SQLUDF_BIGINT` data type to hide differences in the type required for `BIGINT` representation between different compilers.

It is the data type for each parameter defined in the routine's `CREATE` statement that governs the format for argument values. Promotions from the argument's data type might be needed to get the value in the appropriate format. Such promotions are performed automatically by DB2 on argument values. However, if incorrect data types are specified in the routine code, then unpredictable behavior, such as loss of data or abends, will occur.

For the result of a scalar function or method, it is the data type specified in the CAST FROM clause of the CREATE FUNCTION statement that defines the format. If no CAST FROM clause is present, then the data type specified in the RETURNS clause defines the format.

In the following example, the presence of the CAST FROM clause means that the routine body returns a SMALLINT and that DB2 casts the value to INTEGER before passing it along to the statement where the function reference occurs:

```
... RETURNS INTEGER CAST FROM SMALLINT ...
```

In this case, the routine must be written to generate a SMALLINT, as defined later in this section. Note that the CAST FROM data type must be *castable* to the RETURNS data type, therefore, it is not possible to arbitrarily choose another data type.

The following is a list of the SQL types and their C/C++ language representations. It includes information on whether each type is valid as a parameter or a result. Also included are examples of how the types could appear as an argument definition in your C or C++ language routine:

- SMALLINT

**Valid.** Represent in C as SQLUDF\_SMALLINT or sqlint16.

Example:

```
sqlint16 *arg1;          /* example for SMALLINT */
```

When defining integer routine parameters, consider using INTEGER rather than SMALLINT because DB2 does not promote INTEGER arguments to SMALLINT. For example, suppose you define a UDF as follows:

```
CREATE FUNCTION SIMPLE(SMALLINT)...
```

If you invoke the SIMPLE function using INTEGER data, (... SIMPLE(1)...), you will receive an SQLCODE -440 (SQLSTATE 42884) error indicating that the function was not found, and end-users of this function might not perceive the reason for the message. In the preceding example, 1 is an INTEGER, so you can either cast it to SMALLINT or define the parameter as INTEGER.

- INTEGER or INT

**Valid.** Represent in C as SQLUDF\_INTEGER or sqlint32. You must #include sqludf.h or #include sqlsystem.h to pick up this definition.

Example:

```
sqlint32 *arg2;          /* example for INTEGER */
```

- BIGINT

**Valid.** Represent in C as SQLUDF\_BIGINT or sqlint64.

Example:

```
sqlint64 *arg3;          /* example for INTEGER */
```

DB2 defines the sqlint64 C language type to overcome differences between definitions of the 64-bit signed integer in compilers and operating systems. You must #include sqludf.h or #include sqlsystem.h to pick up the definition.

- REAL or FLOAT(*n*) where 1 <= *n* <= 24

**Valid.** Represent in C as SQLUDF\_REAL or float.

Example:

```
float *result;           /* example for REAL */
```

- DOUBLE or DOUBLE PRECISION or FLOAT or FLOAT(*n*) where 25 <= *n* <= 53

**Valid.** Represent in C as SQLUDF\_DOUBLE or double.

Example:

```
double *result;      /* example for DOUBLE */
```

- DECIMAL(p,s) or NUMERIC(p,s)

**Not valid** because there is no C language representation. If you want to pass a decimal value, you must define the parameter to be of a data type castable from DECIMAL (for example CHAR or DOUBLE) and explicitly cast the argument to this type. In the case of DOUBLE, you do not need to explicitly cast a decimal argument to a DOUBLE parameter, because DB2 promotes it automatically.

Example:

Suppose you have two columns, WAGE as DECIMAL(5,2) and HOURS as DECIMAL(4,1), and you wish to write a UDF to calculate weekly pay based on wage, number of hours worked and some other factors. The UDF could be as follows:

```
CREATE FUNCTION WEEKLY_PAY (DOUBLE, DOUBLE, ...)
  RETURNS DECIMAL(7,2) CAST FROM DOUBLE
  ...;
```

For the preceding UDF, the first two parameters correspond to the wage and number of hours. You invoke the UDF WEEKLY\_PAY in your SQL select statement as follows:

```
SELECT WEEKLY_PAY (WAGE, HOURS, ...) ...;
```

Note that no explicit casting is required because the DECIMAL arguments are castable to DOUBLE.

Alternatively, you could define WEEKLY\_PAY with CHAR arguments as follows:

```
CREATE FUNCTION WEEKLY_PAY (VARCHAR(6), VARCHAR(5), ...)
  RETURNS DECIMAL (7,2) CAST FROM VARCHAR(10)
  ...;
```

You would invoke it as follows:

```
SELECT WEEKLY_PAY (CHAR(WAGE), CHAR(HOURS), ...) ...;
```

Observe that explicit casting is required because DECIMAL arguments are not promotable to VARCHAR.

An advantage of using floating point parameters is that it is easy to perform arithmetic on the values in the routine; an advantage of using character parameters is that it is always possible to exactly represent the decimal value. This is not always possible with floating point.

- CHAR(n) or CHARACTER(n) with or without the FOR BIT DATA modifier.

**Valid.** Represent in C as SQLUDF\_CHAR or char...[n+1] (this is a C null-terminated string).

Example:

```
char   arg1[14];      /* example for CHAR(13) */
char   *arg1;         /* also acceptable */
```

Input routine parameters of data type CHAR are always automatically null terminated. For a CHAR(n) input parameter, where *n* is the length of the CHAR data type, *n* bytes of data are moved to the buffer in the routine implementation and the character in the *n* + 1 position is set to the ASCII null terminator character (X'00').

Output parameters of procedures and return values of functions of data type CHAR must be explicitly null terminated by the routine. For a return value of a UDF specified by the RETURNS clause, such as RETURNS CHAR(n), or a procedure output parameter specified as CHAR(n), where *n* is the length of the CHAR value, a null terminator character must exist within the first *n*+1 bytes of the buffer. If a null terminator is found within the first *n*+1 bytes of the buffer,

the remaining bytes, up to byte *n*, are set to ASCII blank characters X'20'). If no null terminator is found, an SQL error (SQLSTATE 39501) results.

For input and output parameters of procedures or function return values of data type CHAR that also specify the FOR BIT DATA clause, which indicates that the data is to be manipulated in its binary form, null terminators are not used to indicate the end of the parameter value. For either a RETURNS CHAR(*n*) FOR BIT DATA function return value or a CHAR(*n*) FOR BIT DATA output parameter, the first *n* bytes of the buffer are copied over regardless of any occurrences of string null terminators within the first *n* bytes. Null terminator characters identified within the buffer are ignored as null terminators and instead are simply treated as normal data.

Exercise caution when using the normal C string handling functions in a routine that manipulates a FOR BIT DATA value, because many of these functions look for a null terminator to delimit a string argument and null terminators (X'00') can legitimately appear in the middle of a FOR BIT DATA value. Using the C functions on FOR BIT DATA values might cause the undesired truncation of the data value.

When defining character routine parameters, consider using VARCHAR rather than CHAR as DB2 does not promote VARCHAR arguments to CHAR and string literals are automatically considered as VARCHARs. For example, suppose you define a UDF as follows:

```
CREATE FUNCTION SIMPLE(INT,CHAR(1))...
```

If you invoke the SIMPLE function using VARCHAR data, (... SIMPLE(1, 'A') ...), you will receive an SQLCODE -440 (SQLSTATE 42884) error indicating that the function was not found, and end-users of this function might not perceive the reason for the message. In the preceding example, 'A' is VARCHAR, so you can either cast it to CHAR or define the parameter as VARCHAR.

- VARCHAR(*n*) FOR BIT DATA or LONG VARCHAR with or without the FOR BIT DATA modifier.

**Valid.** Represent VARCHAR(*n*) FOR BIT DATA in C as SQLUDF\_VARCHAR\_FBD. Represent LONG VARCHAR in C as SQLUDF\_LONG. Otherwise represent these two SQL types in C as a structure similar to the following from the sqludf.h include file:

```
struct sqludf_vc_fbd
{
    unsigned short length;      /* length of data */
    char          data[1];     /* first char of data */
};
```

The [1] indicates an array to the compiler. It does not mean that only one character is passed; because the address of the structure is passed, and not the actual structure, it provides a way to use array logic.

These values are not represented as C null-terminated strings because the null-character could legitimately be part of the data value. The length is explicitly passed to the routine for parameters using the structure variable length. For the RETURNS clause, the length that is passed to the routine is the length of the buffer. What the routine body must pass back, using the structure variable length, is the actual length of the data value.

Example:

```
struct sqludf_vc_fbd *arg1; /* example for VARCHAR(n) FOR BIT DATA */
struct sqludf_vc_fbd *result; /* also for LONG VARCHAR FOR BIT DATA */
```

- VARCHAR(*n*) without FOR BIT DATA.

**Valid.** Represent in C as SQLUDF\_VARCHAR or char...[*n*+1]. (This is a C null-terminated string.)

For a VARCHAR(n) parameter, DB2 will put a null in the (k+1) position, where k is the length of the particular string. The C string-handling functions are well suited for manipulation of these values. For a RETURNS VARCHAR(n) value or an output parameter of a stored procedure, the routine body must delimit the actual value with a null because DB2 will determine the result length from this null character.

Example:

```
char    arg2[51];    /* example for VARCHAR(50) */
char    *result;    /* also acceptable */
```

- DATE

**Valid.** Represent in C same as SQLUDF\_DATE or CHAR(10), that is as char...[11]. The date value is always passed to the routine in ISO format:

yyyy-mm-dd

Example:

```
char    arg1[11];    /* example for DATE      */
char    *result;    /* also acceptable */
```

**Note:** For DATE, TIME and TIMESTAMP return values, DB2 demands the characters be in the defined form, and if this is not the case the value could be misinterpreted by DB2 (For example, 2001-04-03 will be interpreted as April 3 even if March 4 is intended) or will cause an error (SQLCODE -493, SQLSTATE 22007).

- TIME

**Valid.** Represent in C same as SQLUDF\_TIME or CHAR(8), that is, as char...[9]. The time value is always passed to the routine in ISO format:

hh.mm.ss

Example:

```
char    *arg;        /* example for TIME      */
char    result[9];   /* also acceptable */
```

- TIMESTAMP

**Valid.** Represent in C as SQLUDF\_STAMP or as CHAR(19) - CHAR(32), that is, as char[20] to char[33]. The timestamp value has the following format:

yyyy-mm-dd-hh.mm.ss.nnnnnnnnnnn

where:

**yyyy** Represents the year.

**mm** Represents the month.

**dd** Represents the day.

**hh** Represents the hour.

**mm** Represents the minutes.

**ss** Represents the seconds.

**nnnnnnnnnnnn**

Represents the fractional seconds. The fractional seconds of the TIMESTAMP data type can be optionally specified with 0-12 digits of timestamp precision.

When a timestamp value is assigned to a timestamp variable with a different number of fractional seconds, the value is either truncated or padded with 0's to match the format of the timestamp variable.

The character string can be from 19 - 32 bytes in length depending on the number of fractional seconds specified. The fractional seconds of the `TIMESTAMP` data type can be optionally specified with 0-12 digits of timestamp precision.

For example:

```
(VALUES(CURRENT TIMESTAMP(0))
1
-----
2008-07-09-14.48.36
```

1 record(s) selected.

```
LENGTH (VALUES(CURRENT TIMESTAMP(0))
1
-----
19
```

1 record(s) selected.

```
(VALUES(CURRENT TIMESTAMP(12))
1
-----
2008-07-09-14.48.36.123456789012
```

1 record(s) selected.

```
LENGTH (VALUES(CURRENT TIMESTAMP(0))
1
-----
32
```

The following are variable declarations that can hold a `TIMESTAMP(12)` value:

```
char    arg1[33];      /* example for TIMESTAMP */
char    *result;      /* also acceptable */
```

- `GRAPHIC(n)`

**Valid.** Represent in C as `SQLUDF_GRAPH` or `sqldbchar[n+1]`. (This is a null-terminated graphic string). Note that you can use `wchar_t[n+1]` on operating systems where `wchar_t` is defined to be 2 bytes in length; however, `sqldbchar` is recommended.

For a `GRAPHIC(n)` parameter, DB2 moves *n* double-byte characters to the buffer and sets the following two bytes to null. Data passed from DB2 to a routine is in DBCS format, and the result passed back is expected to be in DBCS format. This behavior is the same as using the `WCHARTYPE NOCONVERT` precompiler option. For a `RETURNS GRAPHIC(n)` value or an output parameter of a stored procedure, DB2 looks for an embedded `GRAPHIC` null `CHAR`, and if it finds it, pads the value out to *n* with `GRAPHIC` blank characters.

When defining graphic routine parameters, consider using `VARGRAPHIC` rather than `GRAPHIC` as DB2 does not promote `VARGRAPHIC` arguments to `GRAPHIC`. For example, suppose you define a routine as follows:

```
CREATE FUNCTION SIMPLE(GRAPHIC)...
```

If you invoke the `SIMPLE` function using `VARGRAPHIC` data, (`... SIMPLE('graphic_literal')...`), you will receive an `SQLCODE -440 (SQLSTATE 42884)` error indicating that the function was not found, and end-users of this function might not understand the reason for this message. In the preceding example, `graphic_literal` is a literal DBCS string that is interpreted as `VARGRAPHIC` data, so you can either cast it to `GRAPHIC` or define the parameter as `VARGRAPHIC`.

Example:

```

    sqldbchar  arg1[14];      /* example for GRAPHIC(13) */
    sqldbchar  *arg1;        /* also acceptable */

```

- **VARGRAPHIC(n)**

**Valid.** Represent in C as `SQLUDF_GRAPH` or `sqldbchar[n+1]`. (This is a null-terminated graphic string). Note that you can use `wchar_t[n+1]` on operating systems where `wchar_t` is defined to be 2 bytes in length; however, `sqldbchar` is recommended.

For a `VARGRAPHIC(n)` parameter, DB2 will put a graphic null in the  $(k+1)$  position, where  $k$  is the length of the particular occurrence. A graphic null refers to the situation where all the bytes of the last character of the graphic string contain binary zeros (`'\0's`). Data passed from DB2 to a routine is in DBCS format, and the result passed back is expected to be in DBCS format. This behavior is the same as using the `WCHARTYPE NOCONVERT` precompiler option. For a `RETURNS VARGRAPHIC(n)` value or an output parameter of a stored procedure, the routine body must delimit the actual value with a graphic null, because DB2 will determine the result length from this graphic null character.

Example:

```

    sqldbchar  args[51],      /* example for VARGRAPHIC(50) */
    sqldbchar  *result,      /* also acceptable */

```

- **LONG VARGRAPHIC**

**Valid.** Represent in C as `SQLUDF_LONGVARG` or a structure:

```

struct sqludf_vg
{
    unsigned short length;      /* length of data */
    sqldbchar      data[1];    /* first char of data */
};

```

Note that in the preceding structure, you can use `wchar_t` in place of `sqldbchar` on operating systems where `wchar_t` is defined to be 2 bytes in length, however, the use of `sqldbchar` is recommended.

The `[1]` merely indicates an array to the compiler. It does not mean that only one graphic character is passed. Because the address of the structure is passed, and not the actual structure, it provides a way to use array logic.

These are not represented as null-terminated graphic strings. The length, in double-byte characters, is explicitly passed to the routine for parameters using the structure variable `length`. Data passed from DB2 to a routine is in DBCS format, and the result passed back is expected to be in DBCS format. This behavior is the same as using the `WCHARTYPE NOCONVERT` precompiler option. For the `RETURNS` clause or an output parameter of a stored procedure, the length that is passed to the routine is the length of the buffer. What the routine body must pass back, using the structure variable `length`, is the actual length of the data value, in double byte characters.

Example:

```

struct sqludf_vg *arg1; /* example for VARGRAPHIC(n) */
struct sqludf_vg *result; /* also for LONG VARGRAPHIC */

```

- **BLOB(n) and CLOB(n)**

**Valid.** Represent in C as `SQLUDF_BLOB`, `SQLUDF_CLOB`, or a structure:

```

struct sqludf_lob
{
    sqluint32  length;      /* length in bytes */
    char       data[1];    /* first byte of lob */
};

```

The [1] merely indicates an array to the compiler. It does not mean that only one character is passed; because the address of the structure is passed, and not the actual structure, it provides a way to use array logic.

These are not represented as C null-terminated strings. The length is explicitly passed to the routine for parameters using the structure variable length. For the RETURNS clause or an output parameter of a stored procedure, the length that is passed back to the routine, is the length of the buffer. What the routine body must pass back, using the structure variable length, is the actual length of the data value.

Example:

```
struct sqludf_lob *arg1; /* example for BLOB(n), CLOB(n) */
struct sqludf_lob *result;
```

- DBCLOB(n)

**Valid.** Represent in C as SQLUDF\_DBCLOB or a structure:

```
struct sqludf_lob
{
    sqluint32 length;      /* length in graphic characters */
    sqldbchar data[1];    /* first byte of lob */
};
```

Note that in the preceding structure, you can use wchar\_t in place of sqldbchar on operating systems where wchar\_t is defined to be 2 bytes in length, however, the use of sqldbchar is recommended.

The [1] merely indicates an array to the compiler. It does not mean that only one graphic character is passed; because the address of the structure is passed, and not the actual structure, it provides a way to use array logic.

These are not represented as null-terminated graphic strings. The length is explicitly passed to the routine for parameters using the structure variable length. Data passed from DB2 to a routine is in DBCS format, and the result passed back is expected to be in DBCS format. This behavior is the same as using the WCHARTYPE NOCONVERT precompiler option. For the RETURNS clause or an output parameter of a stored procedure, the length that is passed to the routine is the length of the buffer. What the routine body must pass back, using the structure variable length, is the actual length of the data value, with all of these lengths expressed in double byte characters.

Example:

```
struct sqludf_lob *arg1; /* example for DBCLOB(n) */
struct sqludf_lob *result;
```

- Distinct Types

**Valid or invalid depending on the base type.** Distinct types will be passed to the UDF in the format of the base type of the UDT, so can be specified if and only if the base type is valid.

Example:

```
struct sqludf_lob *arg1; /* for distinct type based on BLOB(n) */
double          *arg2; /* for distinct type based on DOUBLE */
char            res[5]; /* for distinct type based on CHAR(4) */
```

- XML

**Valid.** Represent in C as SQLUDF\_XML or in the way as a CLOB data type is represented; that is with a structure:

```
struct sqludf_lob
{
    sqluint32 length;      /* length in bytes */
    char      data[1];    /* first byte of lob */
};
```



The [1] merely indicates an array to the compiler. It does not mean that only one character is passed; because the address of the structure is passed, and not the actual structure, it provides a way to use array logic.

These are not represented as C null-terminated strings. The length is explicitly passed to the routine for parameters using the structure variable length. For the RETURNS clause or an output parameter of a stored procedure, the length that is passed back to the routine, is the length of the buffer. What the routine body must pass back, using the structure variable length, is the actual length of the data value.

Example:

```
struct sqludf_lob *arg1; /* example for XML(n) */
struct sqludf_lob *result;
```

The assignment and access of XML parameter and variable values in C and C++ external routine code is done in the same way as for CLOB values.

- Distinct Types AS LOCATOR, or any LOB type AS LOCATOR

**Valid for parameters and results of UDFs and methods.** It can only be used to modify LOB types or any distinct type that is based on a LOB type. Represent in C as SQLUDF\_LOCATOR or a four byte integer.

The locator value can be assigned to any locator host variable with a compatible type and then be used in an SQL statement. This means that locator variables are only useful in UDFs and methods defined with an SQL access indicator of CONTAINS SQL or higher. For compatibility with existing UDFs and methods, the locator APIs are still supported for NOT FENCED NO SQL UDFs. Use of these APIs is not encouraged for new functions.

Example:

```
sqludf_locator      *arg1; /* locator argument */
sqludf_locator      *result; /* locator result */
```

```
EXEC SQL BEGIN DECLARE SECTION;
SQL TYPE IS CLOB LOCATOR arg_loc;
SQL TYPE IS CLOB LOCATOR res_loc;
EXEC SQL END DECLARE SECTION;
```

```
/* Extract some characters from the middle */
/* of the argument and return them          */
*arg_loc = arg1;
EXEC SQL VALUES SUBSTR(arg_loc, 10, 20) INTO :res_loc;
*result = res_loc;
```

- Structured Types

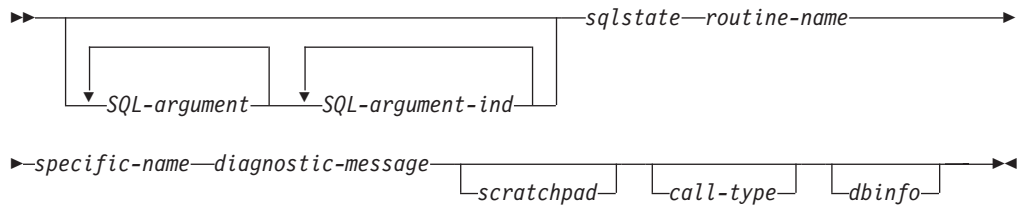
Valid for parameters and results of UDFs and methods where an appropriate transform function exists. Structured type parameters will be passed to the function or method in the result type of the FROM SQL transform function. Structured type results will be passed in the parameter type of the TO SQL transform function.

## Passing arguments to C, C++, OLE, or COBOL routines

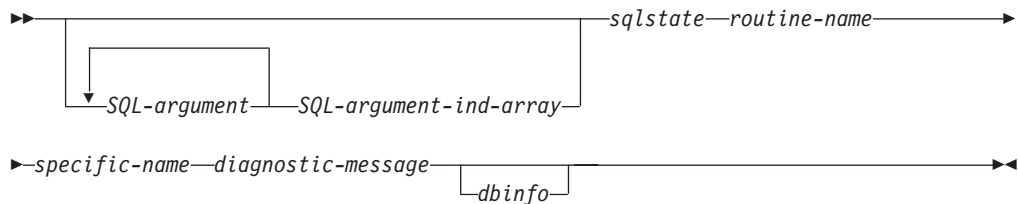
In addition to the SQL arguments that are specified in the DML reference for a routine, DB2 passes additional arguments to the external routine body. The nature and order of these arguments is determined by the parameter style with which you registered your routine. To ensure that information is exchanged correctly between invokers and the routine body, you must ensure that your routine accepts arguments in the order they are passed, according to the parameter style being used. The sqludf include file can aid you in handling and using these arguments.

The following parameter styles are applicable only to LANGUAGE C, LANGUAGE OLE, and LANGUAGE COBOL routines.

### PARAMETER STYLE SQL routines



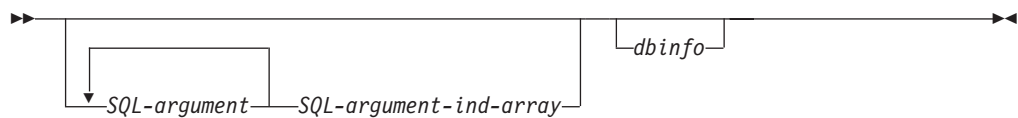
### PARAMETER STYLE DB2SQL procedures



### PARAMETER STYLE GENERAL procedures



### PARAMETER STYLE GENERAL WITH NULLS procedures



**Note:** For UDFs and methods, PARAMETER STYLE SQL is equivalent to PARAMETER STYLE DB2SQL.

The arguments for the above parameter styles are described as follows:

#### SQL-argument...

Each *SQL-argument* represents one input or output value defined when the routine was created. The list of arguments is determined as follows:

- For a scalar function, one argument for each input parameter to the function followed by one *SQL-argument* for the result of the function.
- For a table function, one argument for each input parameter to the function followed by one *SQL-argument* for each column in the result table of the function.
- For a method, one *SQL-argument* for the subject type of the method, then one argument for each input parameter to the method followed by one *SQL-argument* for the result of the method.

- For a stored procedure, one *SQL-argument* for each parameter to the stored procedure.

Each *SQL-argument* is used as follows:

- Input parameter of a function or method, subject type of a method, or an IN parameter of a stored procedure

This argument is set by DB2 before calling the routine. The value of each of these arguments is taken from the expression specified in the routine invocation. It is expressed in the data type of the corresponding parameter definition in the CREATE statement.

- Result of a function or method or an OUT parameter of a stored procedure

This argument is set by the routine before returning to DB2. DB2 allocates the buffer and passes its address to the routine. The routine puts the result value into the buffer. Enough buffer space is allocated by DB2 to contain the value expressed in the data type. For character types and LOBs, this means the maximum size, as defined in the create statement, is allocated.

For scalar functions and methods, the result data type is defined in the CAST FROM clause, if it is present, or in the RETURNS clause, if no CAST FROM clause is present.

For table functions, DB2 defines a performance optimization where every defined column does not have to be returned to DB2. If you write your UDF to take advantage of this feature, it returns only the columns required by the statement referencing the table function. For example, consider a CREATE FUNCTION statement for a table function defined with 100 result columns. If a given statement referencing the function is only interested in two of them, this optimization enables the UDF to return only those two columns for each row and not spend time on the other 98 columns. See the dbinfo argument below for more information on this optimization.

For each value returned, the routine should not return more bytes than is required for the data type and length of the result. Maximums are defined during the creation of the routine's catalog entry. An overwrite by the routine can cause unpredictable results or an abnormal termination.

- INOUT parameter of a stored procedure

This argument behaves as both an IN and an OUT parameter and therefore follows both sets of rules shown above. DB2 will set the argument before calling the stored procedure. The buffer allocated by DB2 for the argument is large enough to contain the maximum size of the data type of the parameter defined in the CREATE PROCEDURE statement. For example, an INOUT parameter of a CHAR type could have a 10 byte varchar going in to the stored procedure, and a 100 byte varchar coming out of the stored procedure. The buffer is set by the stored procedure before returning to DB2.

DB2 aligns the data for *SQL-argument* according to the data type and the server operating system, also known as platform.

*SQL-argument-ind...*

There is an *SQL-argument-ind* for each *SQL-argument* passed to the routine. The *n*th *SQL-argument-ind* corresponds to the *n*th *SQL-argument* and indicates whether the *SQL-argument* has a value or is NULL.

Each *SQL-argument-ind* is used as follows:

- Input parameter of a function or method, subject type of a method, or an IN parameter of a stored procedure

This argument is set by DB2 before calling the routine. It contains one of the following values:

- 0 The argument is present and not NULL.
- 1 The argument is present and its value is NULL.

If the routine is defined with RETURNS NULL ON NULL INPUT, the routine body does not need to check for a NULL value. However, if it is defined with CALLED ON NULL INPUT, any argument can be NULL and the routine should check *SQL-argument-ind* before using the corresponding *SQL-argument*.

- Result of a function or method or an OUT parameter of a stored procedure

This argument is set by the routine before returning to DB2. This argument is used by the routine to signal if the particular result value is NULL:

- 0 The result is not NULL.
- 1 The result is the NULL value.

Even if the routine is defined with RETURNS NULL ON NULL INPUT, the routine body must set the *SQL-argument-ind* of the result. For example, a divide function could set the result to null when the denominator is zero.

For scalar functions and methods, DB2 treats a NULL result as an arithmetic error if the following is true:

- The database configuration parameter **dft\_sqlmathwarn** is YES
- One of the input arguments is a null because of an arithmetic error

This is also true if you define the function with the RETURNS NULL ON NULL INPUT option

For table functions, if the UDF takes advantage of the optimization using the result column list, then only the indicators corresponding to the required columns need be set.

- INOUT parameter of a stored procedure

This argument behaves as both an IN and an OUT parameter and therefore follows both sets of rules shown above. DB2 will set the argument before calling the stored procedure. The *SQL-argument-ind* is set by the stored procedure before returning to DB2.

Each *SQL-argument-ind* takes the form of a SMALLINT value. DB2 aligns the data for *SQL-argument-ind* according to the data type and the server operating system.

#### *SQL-argument-ind-array*

There is an element in *SQL-argument-ind-array* for each SQL-argument passed to the stored procedure. The *n*th element in *SQL-argument-ind-array* corresponds to the *n*th SQL-argument and indicates whether the *SQL-argument* has a value or is NULL

Each element in *SQL-argument-ind-array* is used as follows:

- IN parameter of a stored procedure

This element is set by DB2 before calling the routine. It contains one of the following values:

- 0 The argument is present and not NULL.
- 1 The argument is present and its value is NULL.

If the stored procedure is defined with RETURNS NULL ON NULL INPUT, the stored procedure body does not need to check for a NULL value. However, if it is defined with CALLED ON NULL INPUT, any argument can be NULL and the stored procedure should check *SQL-argument-ind* before using the corresponding *SQL-argument*.

- OUT parameter of a stored procedure

This element is set by the routine before returning to DB2. This argument is used by the routine to signal if the particular result value is NULL:

**0 or positive**

The result is not NULL.

**negative**

The result is the NULL value.

- INOUT parameter of a stored procedure

This element behaves as both an IN and an OUT parameter and therefore follows both sets of rules shown above. DB2 will set the argument before calling the stored procedure. The element of *SQL-argument-ind-array* is set by the stored procedure before returning to DB2.

Each element of *SQL-argument-ind-array* takes the form of a SMALLINT value. DB2 aligns the data for *SQL-argument-ind-array* according to the data type and the server operating system.

*sqlstate* This argument is set by the routine before returning to DB2. It can be used by the routine to signal warning or error conditions. The routine can set this argument to any value. The value '00000' means that no warning or error situations were detected. Values that start with '01' are warning conditions. Values that start with anything other than '00' or '01' are error conditions. When the routine is called, the argument contains the value '00000'.

For error conditions, the routine returns an SQLCODE of -443. For warning conditions, the routine returns an SQLCODE of +462. If the SQLSTATE is 38001 or 38502, then the SQLCODE is -487.

The *sqlstate* takes the form of a CHAR(5) value. DB2 aligns the data for *sqlstate* according to the data type and the server operating system.

*routine-name*

This argument is set by DB2 before calling the routine. It is the qualified function name, passed from DB2 to the routine

The form of the *routine-name* that is passed is:

*schema.routine*

The parts are separated by a period. Two examples are:

PABLO.BLOOP WILLIE.FINDSTRING

This form enables you to use the same routine body for multiple external routines, and still differentiate between the routines when it is invoked.

**Note:** Although it is possible to include the period in object names and schema names, it is not recommended. For example, if a function, ROTATE is in a schema, OBJ.OP, the routine name that is passed to the function is OBJ.OP.ROTATE, and it is not obvious if the schema name is OBJ or OBJ.OP.

The *routine-name* takes the form of a VARCHAR(257) value. DB2 aligns the data for *routine-name* according to the data type and the server operating system.

#### *specific-name*

This argument is set by DB2 before calling the routine. It is the specific name of the routine passed from DB2 to the routine.

Two examples are:

```
WILLIE_FIND_FEB99    SQL9904281052440430
```

This first value is provided by the user in his CREATE statement. The second value is generated by DB2 from the current timestamp when the user does not specify a value.

As with the *routine-name* argument, the reason for passing this value is to give the routine the means of distinguishing exactly which specific routine is invoking it.

The *specific-name* takes the form of a VARCHAR(18) value. DB2 aligns the data for *specific-name* according to the data type and the server operating system.

#### *diagnostic-message*

This argument is set by the routine before returning to DB2. The routine can use this argument to insert message text in a DB2 message.

When the routine returns either an error or a warning, using the *sqlstate* argument described previously, it can include descriptive information here. DB2 includes this information as a token in its message.

DB2 sets the first character to null before calling the routine. Upon return, it treats the string as a C null-terminated string. This string will be included in the SQLCA as a token for the error condition. At least the first part of this string will appear in the SQLCA or DB2 CLP message. However, the actual number of characters that will appear depends on the lengths of the other tokens, because DB2 truncates the tokens to conform to the limit on total token length imposed by the SQLCA. Avoid using X'FF' in the text because this character is used to delimit tokens in the SQLCA.

The routine should not return more text than will fit in the VARCHAR(70) buffer that is passed to it. An overwrite by the routine can cause unpredictable results or an abend.

DB2 assumes that any message tokens returned from the routine to DB2 are in the same code page as the routine. Your routine should ensure that this is the case. If you use the 7-bit invariant ASCII subset, your routine can return the message tokens in any code page.

The *diagnostic-message* takes the form of a VARCHAR(70) value. DB2 aligns the data for *diagnostic-message* according to the data type and the server operating system.

#### *scratchpad*

This argument is set by DB2 before invoking the UDF or method. It is only present for functions and methods that specified the SCRATCHPAD keyword during registration. This argument is a structure, exactly like the structure used to pass a value of any of the LOB data types, with the following elements:

- An INTEGER containing the length of the scratchpad. Changing the length of the scratchpad will result in SQLCODE -450 (SQLSTATE 39501)

- The actual scratchpad initialized to all binary 0s as follows:
  - For scalar functions and methods, it is initialized before the first call, and not generally looked at or modified by DB2 thereafter.
  - For table functions, the scratchpad is initialized prior to the FIRST call to the UDF if FINAL CALL is specified on the CREATE FUNCTION. After this call, the scratchpad content is totally under control of the table function. If NO FINAL CALL was specified or defaulted for a table function, then the scratchpad is initialized for each OPEN call, and the scratchpad content is completely under control of the table function between OPEN calls. (This can be very important for a table function used in a join or subquery. If it is necessary to maintain the content of the scratchpad across OPEN calls, then FINAL CALL must be specified in your CREATE FUNCTION statement. With FINAL CALL specified, in addition to the normal OPEN, FETCH and CLOSE calls, the table function will also receive FIRST and FINAL calls, for the purpose of scratchpad maintenance and resource release.)

The scratchpad can be mapped in your routine using the same type as either a CLOB or a BLOB, as the argument passed has the same structure.

Ensure your routine code does not make changes outside of the scratchpad buffer. An overwrite by the routine can cause unpredictable results, an abend, and might not result in a graceful failure by DB2.

If a scalar UDF or method that uses a scratchpad is referenced in a subquery, DB2 might decide to refresh the scratchpad between invocations of the subquery. This refresh occurs after a final-call is made, if FINAL CALL is specified for the UDF.

DB2 initializes the scratchpad so that the data field is aligned for the storage of any data type. This can result in the entire scratchpad structure, including the length field, being improperly aligned.

#### *call-type*

This argument, if present, is set by DB2 before invoking the UDF or method. This argument is present for all table functions and for scalar functions and methods that specified FINAL CALL during registration

All the current possible values for *call-type* follow. Your UDF or method should contain a switch or case statement that explicitly tests for all the expected values, rather than containing “if A do AA, else if B do BB, else it must be C so do CC” type logic. This is because it is possible that additional call types will be added in the future, and if you do not explicitly test for condition C you will have trouble when new possibilities are added.

#### **Note:**

1. For all values of *call-type*, it might be appropriate for the routine to set a *sqlstate* and *diagnostic-message* return value. This information will not be repeated in the following descriptions of each *call-type*. For all calls DB2 will take the indicated action as described previously for these arguments.
2. The include file `sqludf.h` is intended for use with routines. The file contains symbolic defines for the following *call-type* values, which are spelled out as constants.

For scalar functions and methods *call-type* contains:

### **SQLUDF\_FIRST\_CALL (-1)**

This is the FIRST call to the routine for this statement. The *scratchpad* (if any) is set to binary zeros when the routine is called. All argument values are passed, and the routine should do whatever one-time initialization actions are required. In addition, a FIRST call to a scalar UDF or method is like a NORMAL call, in that it is expected to develop and return an answer.

**Note:** If SCRATCHPAD is specified but FINAL CALL is not, then the routine will not have this *call-type* argument to identify the very first call. Instead, it will have to rely on the all-zero state of the scratchpad.

### **SQLUDF\_NORMAL\_CALL (0)**

This is a NORMAL call. All the SQL input values are passed, and the routine is expected to develop and return the result. The routine can also return *sqlstate* and *diagnostic-message* information.

### **SQLUDF\_FINAL\_CALL (1)**

This is a FINAL call, that is no *SQL-argument* or *SQL-argument-ind* values are passed, and attempts to examine these values can cause unpredictable results. If a *scratchpad* is also passed, it is untouched from the previous call. The routine is expected to release resources at this point.

### **SQLUDF\_FINAL\_CRA (255)**

This is a FINAL call, identical to the FINAL call described previously, with one additional characteristic, namely that it is made to routines that are defined as being able to issue SQL, and it is made at such a time that the routine must not issue any SQL except CLOSE cursor. (SQLCODE -396, SQLSTATE 38505) For example, when DB2 is in the middle of COMMIT processing, it can not tolerate new SQL, and any FINAL call issued to a routine at that time would be a 255 FINAL call. Routines that are not defined as containing any level of SQL access will never receive a 255 FINAL call, whereas routines that do use SQL might be given either type of FINAL call.

#### *Releasing resources*

A scalar UDF or method is expected to release resources it has required, for example, memory. If FINAL CALL is specified for the routine, then that FINAL call is a natural place to release resources, provided that SCRATCHPAD is also specified and is used to track the resource. If FINAL CALL is not specified, then any resource acquired should be released on the same call.

For table functions *call-type* contains:

### **SQLUDF\_TF\_FIRST (-2)**

This is the FIRST call, which only occurs if the FINAL CALL keyword was specified for the UDF. The *scratchpad* is set to binary zeros before this call. Argument values are passed to the table function. The table function can acquire memory or perform other one-time only resource initialization. This is not an OPEN call. An OPEN call follows this call. On a FIRST call the table function should not return any data to DB2 as DB2 ignores the data.

### **SQLUDF\_TF\_OPEN (-1)**

This is the OPEN call. The *scratchpad* will be initialized if NO



FINAL CALL is specified, but not necessarily otherwise. All SQL argument values are passed to the table function on OPEN. The table function should not return any data to DB2 on the OPEN call.

#### **SQLUDF\_TF\_FETCH (0)**

This is a FETCH call, and DB2 expects the table function to return either a row comprising the set of return values, or an end-of-table condition indicated by SQLSTATE value '02000'. If *scratchpad* is passed to the UDF, then on entry it is untouched from the previous call.

#### **SQLUDF\_TF\_CLOSE (1)**

This is a CLOSE call to the table function. It balances the OPEN call, and can be used to perform any external CLOSE processing (for example, closing a source file), and resource release (particularly for the NO FINAL CALL case).

In cases involving a join or a subquery, the OPEN/FETCH.../CLOSE call sequences can repeat within the execution of a statement, but there is only one FIRST call and only one FINAL call. The FIRST and FINAL call only occur if FINAL CALL is specified for the table function.

#### **SQLUDF\_TF\_FINAL (2)**

This is a FINAL call, which only occurs if FINAL CALL was specified for the table function. It balances the FIRST call, and occurs only once per execution of the statement. It is intended for the purpose of releasing resources.

#### **SQLUDF\_TF\_FINAL\_CRA (255)**

This is a FINAL call, identical to the FINAL call described above, with one additional characteristic, namely that it is made to UDFs which are defined as being able to issue SQL, and it is made at such a time that the UDF must not issue any SQL except CLOSE cursor. (SQLCODE -396, SQLSTATE 38505) For example, when DB2 is in the middle of COMMIT processing, it can not tolerate new SQL, and any FINAL call issued to a UDF at that time would be a 255 FINAL call. Note that UDFs which are not defined as containing any level of SQL access will never receive a 255 FINAL call, whereas UDFs which do use SQL can be given either type of FINAL call.

#### *Releasing resources*

Write routines to release any resources that they acquire. For table functions, there are two natural places for this release: the CLOSE call and the FINAL call. The CLOSE call balances each OPEN call and can occur multiple times in the execution of a statement. The FINAL call only occurs if FINAL CALL is specified for the UDF, and occurs only once per statement.

If you can apply a resource across all OPEN/FETCH/CLOSE sequences of the UDF, write the UDF to acquire the resource on the FIRST call and free it on the FINAL call. The *scratchpad* is a natural place to track this resource. For table functions, if FINAL CALL is specified, the *scratchpad* is initialized only before the FIRST call. If FINAL CALL is not specified, then it is reinitialized before each OPEN call.

If a resource is specific to each OPEN/FETCH/CLOSE sequence, write the UDF to free the resource on the CLOSE call.

**Note:** When a table function is in a subquery or join, it is very possible that there will be multiple occurrences of the OPEN/FETCH/CLOSE sequence, depending on how the DB2 Optimizer chooses to organize the execution of the statement.

The *call-type* takes the form of an INTEGER value. DB2 aligns the data for *call-type* according to the data type and the server operating system.

### **dbinfo**

This argument is set by DB2 before calling the routine. It is only present if the CREATE statement for the routine specifies the DBINFO keyword. The argument is the `sqludf_dbinfo` structure defined in the header file `sqludf.h`. The variables in this structure that contain names and identifiers might be longer than the longest value possible in this release of DB2, but they are defined this way for compatibility with future releases. You can use the length variable that complements each name and identifier variable to read or extract the portion of the variable that is actually used. The *dbinfo* structure contains the following elements:

1. Database name length (`dbnamelen`)

The length of *database name* below. This field is an unsigned short integer.

2. Database name (`dbname`)

The name of the currently connected database. This field is a long identifier of 128 characters. The *database name length* field described previously identifies the actual length of this field. It does not contain a null terminator or any padding.

3. Application Authorization ID Length (`authidlen`)

The length of *application authorization ID* below. This field is an unsigned short integer.

4. Application authorization ID (`authid`)

The application run-time authorization ID. This field is a long identifier of 128 characters. It does not contain a null terminator or any padding. The *application authorization ID length* field described above identifies the actual length of this field.

5. Environment code pages (`codepg`)

This is a union of three 48-byte structures; one is common to all DB2 database products (`cdpg_db2`), one is used by routines written for older versions of DB2 database (`cdpg_cs`), and the last is for use by older versions of DB2 Universal Database™ for z/OS and OS/390® (`cdpg_mvs`). For portability, it is recommended that the common structure, `cdpg_db2`, be used in all routines.

The `cdpg_db2` structure is made up of an array (`db2_ccsids_triplet`) of three sets of code page information representing the possible encoding schemes in the database as follows:

- a. ASCII encoding scheme. Note that for compatibility with previous version of DB2 database, if the database is a Unicode database then the information for the Unicode encoding scheme will be placed here as well as appearing in the third element.
- b. EBCDIC encoding scheme
- c. Unicode encoding scheme

Following the encoding scheme information is the array index of the encoding scheme for the routine (`db2_encoding_scheme`). Each element of the array is composed of three fields:

- db2\_sbcs. Single byte code page, an unsigned long integer.
  - db2\_dbcs. Double byte code page, an unsigned long integer.
  - db2\_mixed. Composite code page (also called mixed code page), an unsigned long integer.
6. Schema name length (tbschemalen)
 

The length of *schema name* below. Contains 0 (zero) if a table name is not passed. This field is an unsigned short integer.
  7. Schema name (tbschema)
 

Schema for the *table name* below. This field is a long identifier of 128 characters. It does not contain a null terminator or any padding. The *schema name length* field described previously identifies the actual length of this field.
  8. Table name length (tbnamelen)
 

The length of the *table name* below. Contains 0 (zero) if a table name is not passed. This field is an unsigned short integer.
  9. Table name (tbyname)
 

This is the name of the table being updated or inserted. This field is set only if the routine reference is the right-side of a SET clause in an UPDATE statement, or an item in the VALUES list of an INSERT statement. This field is a long identifier of 128 characters. It does not contain a null terminator or any padding. The *table name length* field described previously, identifies the actual length of this field. The *schema name* field described previously, together with this field form the fully qualified table name.
  10. Column name length (colnamelen)
 

Length of *column name* below. It contains a 0 (zero) if a column name is not passed. This field is an unsigned short integer.
  11. Column name (colname)
 

Under the exact same conditions as for table name, this field contains the name of the column being updated or inserted; otherwise, it is not predictable. This field is a long identifier of 128 characters. It does not contain a null terminator or any padding. The *column name length* field described above, identifies the actual length of this field.
  12. Version/Release number (ver\_rel) An 8 character field that identifies the product and its version, release, and modification level with the format *pppvrrm* where:
    - *ppp* identifies the product as follows:
      - DSN** DB2 for z/OS or OS/390
      - ARI** SQL/DS or DB2 for VM or VSE
      - QSQ** DB2 Database for System i
      - SQL** DB2 Database for Linux, UNIX, and Windows
    - *vv* is a two digit version identifier.
    - *rr* is a two digit release identifier.
    - *m* is a one digit modification level identifier.
  13. Reserved field (resd0)
 

This field is for future use.
  14. Platform (platform)
 

The operating system (platform) for the application server, as follows:

**SQLUDF\_PLATFORM\_AIX**

AIX®

**SQLUDF\_PLATFORM\_HP**

HP-UX

**SQLUDF\_PLATFORM\_LINUX**

Linux

**SQLUDF\_PLATFORM\_MVS**

OS/390

**SQLUDF\_PLATFORM\_NT**

Windows 2000, Windows XP

**SQLUDF\_PLATFORM\_SUN**

Solaris operating system

**SQLUDF\_PLATFORM\_WINDOWS95**

Windows 95, Windows 98, Windows Me

**SQLUDF\_PLATFORM\_UNKNOWN**

Unknown operating system or platform

For additional operating systems that are not contained in the above list, see the contents of the `sqludf.h` file.

15. Number of table function column list entries (`numtfcol`)

The number of non-zero entries in the table function column list specified in the *table function column list* field below.

16. Reserved field (`resd1`)

This field is for future use.

17. Routine id of the stored procedure that invoked the current routine (`procid`)

The stored procedure's routine id matches the `ROUTINEID` column in `SYSCAT.ROUTINES`, which can be used to retrieve the name of the invoking stored procedure. This field is a 32-bit signed integer.

18. Reserved field (`resd2`)

This field is for future use.

19. Table function column list (`tfcolumn`)

If this is a table function, this field is a pointer to an array of short integers that is dynamically allocated by DB2. If this is any other type of routine, this pointer is null.

This field is used only for table functions. Only the first *n* entries, where *n* is specified in the *number of table function column list entries* field, `numtfcol`, are of interest. *n* can be equal to 0, and *n* is less than or equal to the number of result columns defined for the function in the `RETURNS TABLE(...)` clause of the `CREATE FUNCTION` statement. The values correspond to the ordinal numbers of the columns that this statement needs from the table function. A value of '1' means the first defined result column, '2' means the second defined result column, and so on, and the values can be in any order. Note that *n* could be equal to zero, that is, the variable `numtfcol` might be zero, for a statement similar to `SELECT COUNT(*) FROM TABLE(TF(...)) AS QQ`, where no actual column values are needed by the query.

This array represents an opportunity for optimization. The UDF need not return all values for all the result columns of the table function, only those needed in the particular context, and these are the columns

identified (by number) in the array. As this optimization can complicate the UDF logic in order to gain the performance benefit, the UDF can choose to return every defined column.

20. Unique application identifier (appl\_id)

This field is a pointer to a C null-terminated string that uniquely identifies the application's connection to DB2. It is generated by DB2 at connect time.

The string has a maximum length of 32 characters, and its exact format depends on the type of connection established between the client and DB2. Generally it takes the form:

`x.y.ts`

where the *x* and *y* vary by connection type, but the *ts* is a 12 character time stamp of the form YYMMDDHHMMSS, which is potentially adjusted by DB2 to ensure uniqueness.

Example: `*LOCAL.db2inst.980707130144`

21. Reserved field (resd3)

This field is for future use.

## Graphic host variables in C and C++ routines

Any routine written in C or C++ that receives or returns graphic data through its parameter input or output should generally be precompiled with the `WCHARTYPE NOCONVERT` option. This is because graphic data passed through these parameters is considered to be in DBCS format, rather than the `wchar_t` process code format. Using `NOCONVERT` means that graphic data manipulated in SQL statements in the routine will also be in DBCS format, matching the format of the parameter data.

With `WCHARTYPE NOCONVERT`, no character code conversion occurs between the graphic host variable and the database manager. The data in a graphic host variable is sent to, and received from, the database manager as unaltered DBCS characters. If you do not use `WCHARTYPE NOCONVERT`, it is still possible for you to manipulate graphic data in `wchar_t` format in a routine; however, you must perform the input and output conversions manually.

`CONVERT` can be used in `FENCED` routines, and it will affect the graphic data in SQL statements within the routine, but not data passed through the routine's parameters. `NOT FENCED` routines must be built using the `NOCONVERT` option.

In summary, graphic data passed to or returned from a routine through its input or output parameters is in DBCS format, regardless of how it was precompiled with the `WCHARTYPE` option.

## C++ type decoration

The names of C++ functions can be overloaded. Two C++ functions with the same name can coexist if they have different arguments, for example:

```
int func( int i )
```

and

```
int func( char c )
```

C++ compilers type-decorate or 'mangle' function names by default. This means that argument type names are appended to their function names to resolve them,

as in `func__Fi` and `func__Fc` for the two earlier examples. The mangled names will be different on each operating system, so code that explicitly uses a mangled name is not portable.

On Windows operating systems, the type-decorated function name can be determined from the `.obj` (object) file.

With the Microsoft Visual C++ compiler on Windows, you can use the `dumpbin` command to determine the type-decorated function name from the `.obj` (object) file, as follows:

```
dumpbin /symbols myprog.obj
```

where `myprog.obj` is your program object file.

On UNIX operating systems, the type-decorated function name can be determined from the `.o` (object) file, or from the shared library, using the `nm` command. This command can produce considerable output, so it is suggested that you pipe the output through `grep` to look for the right line, as follows:

```
nm myprog.o | grep myfunc
```

where `myprog.o` is your program object file, and `myfunc` is the function in the program source file.

The output produced by all of these commands includes a line with the mangled function name. On UNIX, for example, this line is similar to the following:

```
myfunc__FP1T1PsT3PcN35| 3792|unamex| | ...
```

Once you have obtained the mangled function name from one of the preceding commands, you can use it in the appropriate command. This is demonstrated later in this section using the mangled function name obtained from the preceding UNIX example. A mangled function name obtained on Windows would be used in the same way.

When registering a routine with the `CREATE` statement, the `EXTERNAL NAME` clause must specify the mangled function name. For example:

```
CREATE FUNCTION myfunco(...) RETURNS...
...
EXTERNAL NAME '/whatever/path/myprog!myfunc__FP1T1PsT3PcN35'
...
```

If your routine library does not contain overloaded C++ function names, you have the option of using `extern "C"` to force the compiler to not type-decorate function names. (Note that you can always overload the SQL function names given to UDFs, because DB2 resolves what library function to invoke based on the name and the parameters it takes.)

```
#include <string.h>
#include <stdlib.h>
#include "sqludf.h"
```

```
/*-----*/
/* function fold: output = input string is folded at point indicated */
/*                                     by the second argument.          */
/*      inputs: CLOB,                input string                      */
/*              LONG,                 position to fold on              */
/*      output: CLOB                  folded string                    */
/*-----*/
extern "C" void fold(
    SQLUDF_CLOB *in1, /* input CLOB to fold */
```

```

...
...
}
/* end of UDF: fold */

/*-----*/
/* function find_vowel:                               */
/*     returns the position of the first vowel.       */
/*     returns error if no vowel.                    */
/*     defined as NOT NULL CALL                       */
/*     inputs: VARCHAR(500)                           */
/*     output: INTEGER                                */
/*-----*/
extern "C" void findvwl(
    SQLUDF_VARCHAR *in,                               /* input smallint */
    ...
    ...
}
/* end of UDF: findvwl */

```

In this example, the UDFs `fold` and `findvwl` are not type-decorated by the compiler, and should be registered in the `CREATE FUNCTION` statement using their plain names. Similarly, if a C++ stored procedure or method is coded with `extern "C"`, its undecorated function name would be used in the `CREATE` statement.

## Returning result sets from C and C++ procedures

You can develop C and C++ procedures that return result sets to a calling routine or application that is implemented using an API that supports the retrieval of procedure result sets.

Most APIs support the retrieval of procedure result sets, however embedded SQL does not.

The C and C++ representation of a result set is an SQL cursor. Any SQL cursor that has been declared, opened, and not explicitly closed within a procedure, prior to the return of the procedure can be returned to the caller. The order in which result sets are returned to the caller is the same as the order in which cursor objects are opened within the routine. No additional parameters are required in the `CREATE PROCEDURE` statement or in the procedure implementation in order to return a result set.

### Prerequisites

A general understanding of how to create C and C++ routines will help you to follow the steps in the procedure below for returning results from a C or C++ procedure.

Creating C and C++ routines

Cursors declared in C or C++ embedded SQL procedures are not scrollable cursors.

### Procedure

To return a result set from a C or C++ procedure:

1. In the `CREATE PROCEDURE` statement for the C or C++ procedure you must specify along with any other appropriate clauses, the `DYNAMIC RESULT SETS` clause with a value equal to the maximum number of result sets that are to be returned by the procedure.

2. No parameter marker is required in the procedure declaration for a result set that is to be returned to the caller.
3. In the C or C++ procedure implementation of your routine, declare a cursor using the DECLARE CURSOR statement within the declaration section in which host variables are declared. The cursor declaration associates an SQL with the cursor.
4. Within the C or C++ routine code, open the cursor by executing the OPEN statement. This executes the query specified in the DECLARE CURSOR statement and associates the result of the query with the cursor.
5. Optional: Fetch rows in the result set associated with the cursor using the FETCH statement.

6.

Do not execute the CLOSE statement used for closing the cursor at any point prior to the procedure's return to the caller. The open cursor will be returned as a result set to the caller when the procedure returns.

When more than one cursor is left open upon the return of a procedure, the result sets associated with the cursors are returned to the caller in the order in which they were opened. No more than the maximum number of result sets specified by the DYNAMIC RESULT SETS clause value can be returned with the procedure. If the number of cursors left open in the procedure implementation is greater than the value specified by the DYNAMIC RESULT SETS clause, the excess result sets are simply not returned. No error or warning will be raised by DB2 in this situation.

Once the creation of the C or C++ procedure is completed successfully, you can invoke the procedure with the CALL statement from the DB2 Command Line Processor or a DB2 Command Window to verify that the result sets are successfully being returned to the caller.

For information on calling procedures and other types of routines:

- Routine invocation

---

## Creating C and C++ routines

Procedures and functions that reference a C or C++ library are created in a similar way to external routines with other implementations. This task comprises a few steps including the formulation of the CREATE statement for the routine, the coding of the routine implementation, pre-compilation, compilation and linking of code, and the deployment of source code.

### Before you begin

- Knowledge of C and C++ routine implementation. To learn about C and C++ routines in general see:
  - Chapter 5, “C and C++ routines,” on page 165
- The IBM data server client which includes application development support must be installed on the client computer.
- The database server must be running an operating system that supports a DB2 supported C or C++ compiler for routine development.
- The required compilers must be installed on the database server.



- Authority to execute the CREATE statement for the external routine. For the privileges required to execute the CREATE PROCEDURE statement or the CREATE FUNCTION statement, see the documentation for the statement.

## About this task

You would choose to implement a C or C++ routine if:

- You want to encapsulate complex logic into a routine that accesses the database or that performs an action outside of the database.
- You require the encapsulated logic to be invoked from any of: multiple applications, the CLP, another routine (procedure, function (UDF), or method), or a trigger.
- You are most comfortable coding this logic using an embedded SQL programming language such as C or C++.

## Procedure

1. Code the routine logic in the chosen programming language: C or C++.
  - For general information about C and C++ routines and C and C++ routine features, see the topics referenced in the Prerequisites section.
  - Include any C or C++ header files required for additional C functionality as well as the DB2 C or C++ header files required for SQL data type and SQL execution support. Include the following header files: `sqludf.h`, `sql.h`, `sqlda.h`, `sqlca.h`, and `memory.h`.
  - A routine parameter signature must be implemented using one of the supported parameter styles. It is strongly recommended that parameter style SQL be used for all C and C++ routines. Scratchpads and dbinfo structures are passed into C and C++ routines as parameters. For more on parameter signatures and parameter implementations see:
    - “Parameters in C and C++ routines” on page 169
    - “Parameter style SQL C and C++ procedures” on page 170
    - “Parameter style SQL C and C++ functions” on page 173
  - Declare host variables and parameter markers in the same manner as is done for embedded SQL C and C++ applications. Be careful to correctly use data types that map to DB2 SQL data types. For more on data type mapping between DB2 and C or C++ data types refer to:
    - “Supported SQL data types in C and C++ routines” on page 180
  - Include routine logic. Routine logic can consist of any code supported in the C or C++ programming language. It can also include the execution of embedded SQL statements which is implemented in the same way as for embedded SQL applications. For more on executing SQL statements in embedded SQL see:
    - “Executing SQL statements in embedded SQL applications” in *Developing Embedded SQL Applications*
  - If the routine is a procedure and you want to return a result set to the caller of the routine, you do not require any parameters for the result set. For more on returning result sets from routines:
    - “Returning result sets from C and C++ procedures” on page 205
  - Set a routine return value at the end of the routine.
2. Build your code to produce a library file. For information on how to build embedded SQL C and C++ routines, see:
  - “Building C and C++ routine code” on page 208

3. Copy the library into the DB2 *function directory* on the database server. It is recommended that you store libraries associated with DB2 routines in the function directory. To find out more about the function directory, see the EXTERNAL clause of either of the following statements: CREATE PROCEDURE or CREATE FUNCTION.

You can copy the library to another directory on the server, but to successfully invoke the routine you must note the fully qualified path name of your library as you will require it for the next step.

4. Execute either dynamically or statically the appropriate SQL language CREATE statement for the routine type: CREATE PROCEDURE or CREATE FUNCTION.
  - Specify the LANGUAGE clause with value: C
  - Specify the PARAMETER STYLE clause with the name of the supported parameter style that was implemented in the routine code. It is strongly recommended that PARAMETER STYLE SQL be used.
  - Specify the EXTERNAL clause with the name of the library to be associated with the routine using one of the following values:
    - the fully qualified path name of the routine library
    - the relative path name of the routine library relative to the function directory.

By default DB2 will look for the library in the function directory unless a fully qualified or relative path name for it is specified in the EXTERNAL clause.

- Specify DYNAMIC RESULT SETS with a numeric value if your routine is a procedure and it will return one or more result sets to the caller.
- Specify any other non-default clause values in the CREATE statement to be used to characterize the routine.

## Results

To invoke your C or C++ routine, see Chapter 10, “Invoking routines,” on page 295.

---

## Building C and C++ routine code

Once embedded SQL C or C++ routine implementation code has been written, it must be built into a library and deployed before the routine can be invoked. Although the steps required to build embedded SQL C and C++ routines are similar to those required to build embedded SQL C and C++ applications, there are some differences. The same steps can be followed if there are no embedded SQL statements within the routines - the procedure will be faster and simpler.

### Procedure

There are two ways to build C and C++ routines:

- Using DB2 sample build scripts (UNIX) or build batch files (Windows)
- Entering DB2 and C or C++ compiler commands from a DB2 Command Window

The DB2 sample build scripts and batch files for routines are designed for building DB2 sample routines (procedures and user-defined functions) as well as user created routines for a particular operating system using the default supported compilers.

There is a separate set of DB2 sample build scripts and batch files for C and C++.

In general it is easiest to build embedded SQL routines using the build scripts or batch files, which can easily be modified if required, however it is often helpful to know how to build routines from DB2 Command Window as well.

## Building C and C++ routine code using sample `bldrtn` scripts

Building C and C++ routine source code is a sub-task of creating C and C++ routines. This task can be done quickly and easily using DB2 sample build scripts (UNIX) and batch files (Windows). The sample build scripts can be used for source code with or without embedded SQL statements. The build scripts take care of the pre-compilation, compilation, and linking of C and C++ source code that would otherwise have to be done in individual steps from the command line. They also take care of binding any packages to the specified database.

### Before you begin

The sample build scripts for building C and C++ routines are named `bldrtn`. They are located in DB2 directories along with sample programs that can be built with them as follows:

- For C: `sqllib/samples/c/`
- For C++: `sqllib/samples/cpp/`

The `bldrtn` script can be used to build a source code file containing both procedures and function implementations. The script does the following:

- Establishes a connection with a user-specified database
- Precompiles the user-specified source code file
- Binds the package to the current database
- Compiles and links the source code to generate a shared library
- Copies the shared library to the DB2 function directory on the database server

The `bldrtn` scripts accept two arguments:

- The name of a source code file without any file extension
- The name of a database to which a connection will be established

The database parameter is optional. If no database name is supplied, the program uses the default sample database. As routines must be built on the same instance where the database resides, no arguments are required for a user ID and password.

- Source code file containing one or more routine implementations.
- The name of the database within the current DB2 instance in which the routines are to be created.

### Procedure

To build a source code file that contains one or more routine code implementations:

1. Open a DB2 Command Window.
2. Copy your source code file into the same directory as the `bldrtn` script file.
3. If the routines will be created in the sample database, enter the build script name followed by the name of the source code file without the `.sqc` or `.sqC` file extension:

```
bldrtn file-name
```

If the routines will be created in another database, enter the build script name, the source code file name without any file extension, and the database name:

```
bldrtn file-name database-name
```

The script precompiles, compiles and links the source code and produces a shared library. The script then copies the shared library to the function directory on the database server.

4. If this is not the first time that the source code file containing the routine implementations was built, stop and restart the database to ensure the new version of the shared library is used by DB2. You can do this by entering **db2stop** followed by **db2start** on the command line.

## What to do next

Once you have successfully built the routine shared library and deployed it to the function directory on the database server, you should complete the steps associated with the task of creating C and C++ routines. After routine creation is completed you will be able to invoke your routines.

## Building routines in C or C++ using the sample build script (UNIX)

### About this task

DB2 provides build scripts for compiling and linking C and C++ programs. These are located in the `sql11ib/samples/c` directory for routines in C and `sql11ib/samples/cpp` directory for routines in C++, along with sample programs that can be built with these files.

The script, `bldrtn`, contains the commands to build routines (stored procedures and user-defined functions). The script compiles the routines into a shared library that can be loaded by the database manager and called by a client application.

The first parameter, `$1`, specifies the name of your source file. The second parameter, `$2`, specifies the name of the database to which you want to connect.

The database parameter is optional. If no database name is supplied, the program uses the default `sample` database. There are no parameters for user ID and password, because the stored procedure must be built on the same instance where the database resides.

The following examples show you how to build routine shared libraries with:

- stored procedures
- non-embedded SQL user-defined functions (UDFs)
- embedded SQL user-defined functions (UDFs)

### Stored procedure shared library

To build the sample program `spserver` from the source file `spserver.sqc` for C and `spserver.sqC` for C++:

### Procedure

1. If connecting to the `sample` database, enter the build script name and program name:

```
bldrtn spserver
```

If connecting to another database, also enter the database name:

```
bldrtn spserver database
```

The script copies the shared library to the server in the path `sqllib/function`.

2. Next, catalog the routines by running the `spcat` script on the server:

```
spcat
```

This script connects to the sample database, uncatalogs the routines if they were previously cataloged by calling `spdrop.db2`, then catalogs them by calling `spscreate.db2`, and finally disconnects from the database. You can also call the `spdrop.db2` and `spscreate.db2` scripts individually.

3. Then, if this is not the first time the stored procedure is built, stop and restart the database to ensure the new version of the shared library is recognized. You can do this by entering `db2stop` followed by `db2start` on the command line.

## What to do next

Once you build the shared library, `spserver`, you can build the client application, `spclient`, that accesses the shared library.

You can build `spclient` by using the script, `bldapp`.

To call the stored procedures in the shared library, run the sample client application by entering: `spclient database userid password`

where

### **database**

Is the name of the database to which you want to connect. The name could be `sample`, or its alias, or another database name.

**userid** Is a valid user ID.

### **password**

Is a valid password for the user ID.

The client application accesses the shared library, `spserver`, and executes a number of stored procedure functions on the server database. The output is returned to the client application.

## Embedded SQL UDF shared library

To build the embedded SQL user-defined function program, `udfemsrv`, from the source file `udfemsrv.sqc` for C and `udfemsrv.sqc` for C++, if connecting to the `sample` database, enter the build script name and program name:

```
bldrtn udfemsrv
```

If connecting to another database, also enter the database name:

```
bldrtn udfemsrv database
```

The script copies the UDF to the `sqllib/function` directory.

Once you build `udfemsrv`, you can build the client application, `udfemcli`, that calls it. You can build the `udfemcli` client program from the source file `udfemcli.sqc`, in `sqllib/samples/c`, using the script, `bldapp`.

To call the UDFs in the shared library, run the client application by entering:  
`udfemcli database userid password`

where

**database**

Is the name of the database to which you want to connect. The name could be `sample`, or its alias, or another database name.

**userid** Is a valid user ID.

**password**

Is a valid password for the user ID.

The client application accesses the shared library, `udfemsrv`, and executes the user-defined functions on the server database. The output is returned to the client application.

**Note:** The `LD_LIBRARY_PATH` operating system environment variable is ignored when embedded SQL procedures are built.

## Building C/C++ routines on Windows

### About this task

DB2 provides build scripts for compiling and linking DB2 API and embedded SQL programs in C and C++. These are located in the `sqllib\samples\c` and `sqllib\samples\cpp` directories, along with sample programs that can be built with these files.

The batch file `bldrtn.bat` contains the commands to build embedded SQL routines (stored procedures and user-defined functions). The batch file builds a DLL on the server. It takes two parameters, represented inside the batch file by the variables `%1` and `%2`.

The first parameter, `%1`, specifies the name of your source file. The batch file uses the source file name for the DLL name. The second parameter, `%2`, specifies the name of the database to which you want to connect. Since the DLL must be built on the same instance where the database resides, there are no parameters for user ID and password.

Only the first parameter, the source file name, is required. Database name is optional. If no database name is supplied, the program uses the default `sample` database.

The following examples show you how to build routine DLLs with:

- stored procedures
- non-embedded SQL user-defined functions (UDFs)
- embedded SQL user-defined functions (UDFs)

### Stored procedure DLL

To build the `spserver` DLL from either the C source file, `spserver.sqc`, or the C++ source file, `spserver.sqx`:

## Procedure

1. Enter the batch file name and program name:

```
bldrtn spserver
```

If connecting to another database, also enter the database name:

```
bldrtn spserver database
```

The batch file uses the module definition file `spserver.def`, contained in the same directory as the sample programs, to build the DLL. The batch file copies the DLL, `spserver.dll`, to the server in the path `sqllib\function`.

2. Next, catalog the routines by running the `spcat` script on the server:

```
spcat
```

This script connects to the sample database, uncatalogs the routines if they were previously cataloged by calling `spdop.db2`, then catalogs them by calling `spcreate.db2`, and finally disconnects from the database. You can also call the `spdop.db2` and `spcreate.db2` scripts individually.

3. Then, stop and restart the database to allow the new DLL to be recognized. If necessary, set the file mode for the DLL, so that the DB2 instance can access it.

## What to do next

Once you build the DLL, `spserver`, you can build the client application `spclient` that calls it.

You can build `spclient` by using the batch file, `bdapp.bat`.

To call the DLL, run the sample client application by entering:

```
spclient database userid password
```

where

### **database**

Is the name of the database to which you want to connect. The name could be `sample`, or its alias, or another database name.

**userid** Is a valid user ID.

### **password**

Is a valid password for the user ID.

The client application accesses the DLL, `spserver`, and executes a number of routines on the server database. The output is returned to the client application.

## Non-embedded SQL UDF DLL

To build the user-defined function `udfsrv` from the source file `udfsrv.c`, enter:

```
bldrtn udfsrv
```

The batch file uses the module definition file, `udfsrv.def`, contained in the same directory as the sample program files, to build the user-defined function DLL. The batch file copies the user-defined function DLL, `udfsrv.dll`, to the server in the path `sqllib\function`.

Once you build `udfsrv`, you can build the client application, `udfcli`, that calls it. CLI, as well as embedded SQL C and C++ versions of this program are provided.

You can build the CLI `udfcli` program from the `udfcli.c` source file in `sqllib\samples\cli` using the batch file `bldapp`.

You can build the embedded SQL C `udfcli` program from the `udfcli.sqc` source file in `sqllib\samples\c` using the batch file `bldapp`.

You can build the embedded SQL C++ `udfcli` program from the `udfcli.sqx` source file in `sqllib\samples\cpp` using the batch file `bldapp`.

To run the UDF, enter:

```
udfcli
```

The calling application calls the `ScalarUDF` function from the `udfsrv` DLL.

### Embedded SQL UDF DLL

To build the embedded SQL user-defined function library `udfemsrv` from the C source file `udfemsrv.sqc` in `sqllib\samples\c`, or from the C++ source file `udfemsrv.sqx` in `sqllib\samples\cpp`, enter:

```
bldrtn udfemsrv
```

If connecting to another database, also enter the database name:

```
bldrtn udfemsrv database
```

The batch file uses the module definition file, `udfemsrv.def`, contained in the same directory as the sample programs, to build the user-defined function DLL. The batch file copies the user-defined function DLL, `udfemsrv.dll`, to the server in the path `sqllib\function`.

Once you build `udfemsrv`, you can build the client application, `udfemcli`, that calls it. You can build `udfemcli` from the C source file `udfemcli.sqc` in `sqllib\samples\c`, or from the C++ source file `udfemcli.sqx` in `sqllib\samples\cpp` using the batch file `bldapp`.

To run the UDF, enter:

```
udfemcli
```

The calling application calls the UDFs in the `udfemsrv` DLL.

## Building C and C++ routine code from DB2 Command Window

Building C and C++ routine source code is a sub-task of creating C and C++ routines. This task can be done manually from the command line. The same procedure can be followed regardless of whether there are embedded SQL statements within the C or C++ routine code or not. The task steps include pre-compilation, compilation, and linking of C and C++ source code containing routine implementations, binding the generated package (if there were embedded SQL statements), and deploying the routine library. You might choose to do this task from a DB2 Command Window as part of testing the use of a precompiler, compiler, or `bind` option, if you want to defer binding the routine packages until a later time, or if you are developing customized build scripts.

### Before you begin

As an alternative, you can use DB2 sample build scripts to simplify this task. Refer to: Building embedded SQL C and C++ routine code using sample build scripts.



- Source code file containing one or more embedded SQL C or C++ routine implementations.
- The name of the database within the current DB2 instance in which the routines are to be created.
- The operating specific compile and link options required for building C and C++ routines. Refer to the topics referenced in the related links at the bottom of this topic.

## Procedure

To build a source code file that contains one or more routine code implementations:

1. Open a DB2 Command Window.
2. Navigate to the directory that contains your source code file.
3. Establish a connection with the database in which the routines will be created.
4. Precompile the source code file.
5. Bind the package that was generated to the database.
6. Compile the source code file.
7. Link the source code file to generate a shared library. This requires the use of some DB2 specific compile and link options for the compiler being used.
8. Copy the shared library to the DB2 function directory on the database server.
9. If this is not the first time that the source code file containing the routine implementations was built, stop and restart the database to ensure the new version of the shared library is used by DB2. You can do this by issuing the `db2stop` command followed by the `db2start` command.

## Results

Once you have successfully built and deployed the routine library, you should complete the steps associated with the task of creating C and C++ routines. Creating C and C++ routines includes a step for executing the CREATE statement for each routine that was implemented in the source code file. This step must also be completed before you will be able to invoke the routines.

## Example

The following example demonstrates the re-building of an embedded SQL C++ source code file named `myfile.sqC` containing routine implementations. The routines are being built on an AIX operating system using the default supported IBM VisualAge® C++ compiler to generate a 32-bit routine library.

1. Open a DB2 Command Window.
2. Navigate to the directory that contains your source code file.
3. Establish a connection with the database in which the routines will be created.

```
db2 connect to database-name
```

4. Precompile the source code file using the PREPARE command.

```
db2 prep myfile.sqC bindfile
```

The precompiler will generate output indicating if the precompilation proceeded successfully or if there were any errors. This step generates bind file named `myfile.bnd` that can be used to generate a package in the next step.

5. Bind the package that was generated to the database using the **BIND** command.

```
db2 bind myfile.bnd
```

The `bind` utility will generate output indicating if the `bind` proceeded successfully or if there were any errors.

6. Compile the source code file using the recommended compile and link options:

```
x1C_r -qstaticinline -I$HOME/sql1lib/include -c $myfile.C
```

The compiler will generate output if there are any errors. This step generates an export file named `myfile.exp`.

7. Link the source code file to generate a shared library.

```
x1C_r -qmksprobj -o $1 $1.o -L$ HOME/sql1lib/include/lib32 -lDB2
```

The linker will generate output if there are any errors. This step generates a shared library file name `myfile`.

8. Copy the shared library to the DB2 function directory on the database server.

```
rm -f ~HOME/sql1lib/function/myfile
cp myfile $HOME/sql1lib/function/myfile
```

This step ensures that the routine library is in the default directory where DB2 looks for routine libraries. Refer to the topic on creating C and C++ routines for more on deploying routine libraries.

9. Stop and restart the database as this is a re-building of a previously built routine source code file.

```
db2stop
db2start
```

Building C and C++ routines is generally most easily done using the operating specific sample build scripts which also can be used as a reference for how to build routines from the command line.

**Note:** The `LD_LIBRARY_PATH` operating system environment variable is ignored when embedded SQL procedures are built.

## Compile and link options for C and C++ routines

### AIX C routine compile and link options

The following are the compile and link options recommended by DB2 for building C routines (stored procedures and user-defined functions) with the AIX IBM C compiler, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

**x1c\_r** Use the multi-threaded version of the IBM C compiler, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

**\$EXTRA\_CFLAG**

Contains "-q64" for an instance where 64-bit support is enabled; otherwise, it contains no value.

**-I\$DB2PATH/include**

Specify the location of the DB2 include files. For example: `$HOME/sql1lib/include`.

**-c**

Perform compile only; no link. Compile and link are separate steps.

Link options:

**x1c\_r** Use the multi-threaded version of the compiler as a front end for the linker.

**\$EXTRA\_CFLAG**

Contains "-q64" for an instance where 64-bit support is enabled; otherwise, it contains no value.

**-qmksbobj**

Create the shared library.

**-o \$1** Specify the output file name.

**\$1.o** Specify the object file.

**-ldb2** Link with the DB2 library.

**-L\$DB2PATH/\$LIB**

Specify the location of the DB2 runtime shared libraries. For example: \$HOME/sqllib/\$LIB. If you do not specify the -L option, the compiler assumes the following path: /usr/lib:/lib.

**-bE:\$1.exp**

Specify an export file. The export file contains a list of the routines.

Refer to your compiler documentation for additional compiler options.

## AIX C++ routine compile and link options

The following are the compile and link options recommended by DB2 for building C++ routines (stored procedures and user-defined functions) with the AIX IBM XL C/C++ compiler, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

**x1c\_r** The multi-threaded version of the IBM XL C/C++ compiler, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

**\$EXTRA\_CFLAG**

Contains "-q64" for an instance where 64-bit support is enabled; otherwise, it contains no value.

**-I\$DB2PATH/include**

Specify the location of the DB2 include files. For example: \$HOME/sqllib/include.

**-c**

Perform compile only; no link. Compile and link are separate steps.

Link options:

**x1C\_r** Use the multi-threaded version of the compiler as a front-end for the linker.

**\$EXTRA\_CFLAG**

Contains "-q64" for an instance where 64-bit support is enabled; otherwise, it contains no value.

**-qmksbobj**

Create a shared library.

**-o \$1** Specify the output as a shared library file.

**\$1.o** Specify the program object file.

**-L\$DB2PATH/\$LIB**

Specify the location of the DB2 runtime shared libraries. For example: \$HOME/sqllib/\$LIB. If you do not specify the -L option, the compiler assumes the following path: /usr/lib:/lib.

**-ldb2** Link with the DB2 library.

**-bE:\$1.exp**

Specify an export file. The export file contains a list of the routines.

Refer to your compiler documentation for additional compiler options.

## HP-UX C routine compile and link options

The following are the compile and link options recommended by DB2 for building C routines (stored procedures and user-defined functions) with the HP-UX C compiler, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

**cc** The C compiler.

**\$EXTRA\_CFLAG**

If the HP-UX platform is IA64 and 64-bit support is enabled, this flag contains the value **+DD64**; if 32-bit support is enabled, it contains the value **+DD32**.

**+DD64** Must be used to generate 64-bit code for HP-UX on IA64.

**+DD32** Must be used to generate 32-bit code for HP-UX on IA64.

**+u1** Allow unaligned data access. Use only if your application uses unaligned data.

**+z** Generate position-independent code.

**-Ae** Enables HP ANSI extended mode.

**-I\$DB2PATH/include**

Specify the location of the DB2 include files. For example: `-I$DB2PATH/include`.

**-D\_POSIX\_C\_SOURCE=199506L**

POSIX thread library option that ensures `_REENTRANT` is defined, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

**-c** Perform compile only; no link. Compile and link are separate steps.

Link options:

- ld** Use the linker to link.
- b** Create a shared library rather than a normal executable.
- o \$1** Specify the output as a shared library file.
- \$1.o** Specify the program object file.
- \$EXTRA\_LFLAG**  
Specify the runtime path. If set, for 32-bit it contains the value "+b\$HOME/sqllib/lib32", and for 64-bit: "+b\$HOME/sqllib/lib64". If not set, it contains no value.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries. For 32-bit: \$HOME/sqllib/lib32; for 64-bit: \$HOME/sqllib/lib64.
- ldb2** Link with the DB2 library.
- lpthread**  
Link with the POSIX thread library.

Refer to your compiler documentation for additional compiler options.

## HP-UX C++ routine compile and link options

The following are the compile and link options recommended by DB2 for building C++ routines (stored procedures and user-defined functions) with the HP-UX C++ compiler, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

- aCC** The HP aC++ compiler.
- \$EXTRA\_CFLAG**  
If the HP-UX platform is IA64 and 64-bit support is enabled, this flag contains the value **+DD64**; if 32-bit support is enabled, it contains the value **+DD32**.
  - +DD64** Must be used to generate 64-bit code for HP-UX on IA64.
  - +DD32** Must be used to generate 32-bit code for HP-UX on IA64.
- +u1** Allows unaligned data access.
- +z** Generate position-independent code.
- ext** Allow various C++ extensions including "long long" support.
- mt** Allows threads support for the HP aC++ compiler, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).
- I\$DB2PATH/include**  
Specify the location of the DB2 include files. For example: \$DB2PATH/include
- c** Perform compile only; no link. Compile and link are separate steps.

Link options:

**aCC** Use the HP aC++ compiler as a front end for the linker.

**\$EXTRA\_CFLAG**  
If the HP-UX platform is IA64 and 64-bit support is enabled, this flag contains the value **+DD64**; if 32-bit support is enabled, it contains the value **+DD32**.

**+DD64** Must be used to generate 64-bit code for HP-UX on IA64.

**+DD32** Must be used to generate 32-bit code for HP-UX on IA64.

**-mt** Allows threads support for the HP aC++ compiler, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

**-b** Create a shared library rather than a normal executable.

**-o \$1** Specify the executable.

**\$1.o** Specify the program object file.

**\$EXTRA\_LFLAG**  
Specify the runtime path. If set, for 32-bit it contains the value **-Wl,+b\$HOME/sqllib/lib32**, and for 64-bit: **-Wl,+b\$HOME/sqllib/lib64**. If not set, it contains no value.

**-L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries. For 32-bit: **"\$HOME/sqllib/lib32"**; for 64-bit: **"\$HOME/sqllib/lib64"**.

**-ldb2** Link with the DB2 library.

Refer to your compiler documentation for additional compiler options.

## Linux C routine compile and link options

The following are the compile and link options recommended by DB2 for building C routines (stored procedures and user-defined functions) with the Linux C compiler, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

**\$CC** The gcc or xlc\_r compiler

**\$EXTRA\_C\_FLAGS**  
Contains one of the following:

- **-m31** on Linux for zSeries® only, to build a 32-bit library;
- **-m32** on Linux for x86, x64 and POWER®, to build a 32-bit library;
- **-m64** on Linux for zSeries, POWER, x64, to build a 64-bit library; or
- No value on Linux for IA64, to build a 64-bit library.

**-\$DB2PATH/include**  
Specify the location of the DB2 include files.

**-c** Perform compile only; no link. This script file has separate compile and link steps.

**-D\_REENTRANT**  
Defines `_REENTRANT`, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

Link options:

**\$CC** The gcc or xlc\_r compiler; use the compiler as a front end for the linker.

**\$LINK\_FLAGS**

Contains the value "\$EXTRA\_C\_FLAGS \$SHARED\_LIB\_FLAG"

**\$EXTRA\_C\_FLAGS**

Contains one of the following:

- -m31 on Linux for zSeries only, to build a 32-bit library;
- -m32 on Linux for x86, x64 and POWER, to build a 32-bit library;
- -m64 on Linux for zSeries, POWER, x64, to build a 64-bit library; or
- No value on Linux for IA64, to build a 64-bit library.

**\$SHARED\_LIB\_FLAG**

Contains -shared for gcc compiler or -qmksrobj for xlc\_r compiler.

**-o \$1** Specify the executable.

**\$1.o** Include the program object file.

**\$EXTRA\_LFLAG**

Specify the location of the DB2 shared libraries at run-time. For 32-bit it contains the value "-Wl,-rpath,\$DB2PATH/lib32". For 64-bit it contains the value "-Wl,-rpath,\$DB2PATH/lib64".

**-L\$DB2PATH/\$LIB**

Specify the location of the DB2 static and shared libraries at link-time. For example, for 32-bit: \$HOME/sql1ib/lib32, and for 64-bit: \$HOME/sql1ib/lib64.

**-ldb2** Link with the DB2 library.

**-lpthread**

Link with the POSIX thread library.

Refer to your compiler documentation for additional compiler options.

## Linux C++ routine compile and link options

These are the compile and link options recommended by DB2 for building C++ routines (stored procedures and user-defined functions) with the Linux C++ compiler, as demonstrated in the bldrtn build script.

## Compile and link options for bldrtn

Compile options:

**g++** The GNU/Linux C++ compiler.

### **\$EXTRA\_C\_FLAGS**

Contains one of the following:

- -m31 on Linux for zSeries only, to build a 32-bit library;
- -m32 on Linux for x86, x64 and POWER, to build a 32-bit library;
- -m64 on Linux for zSeries, POWER, x64, to build a 64-bit library; or
- No value on Linux for IA64, to build a 64-bit library.

**-fpic** Generate position independent code.

### **-\$DB2PATH/include**

Specify the location of the DB2 include files.

**-c** Perform compile only; no link. This script file has separate compile and link steps.

### **-D\_REENTRANT**

Defines `_REENTRANT`, needed as the routines can run in the same process as other routines (`THREADSAFE`) or in the engine itself (`NOT FENCED`).

Link options:

**g++** Use the compiler as a front end for the linker.

### **\$EXTRA\_C\_FLAGS**

Contains one of the following:

- -m31 on Linux for zSeries only, to build a 32-bit library;
- -m32 on Linux for x86, x64 and POWER, to build a 32-bit library;
- -m64 on Linux for zSeries, POWER, x64, to build a 64-bit library; or
- No value on Linux for IA64, to build a 64-bit library.

### **-shared**

Generate a shared library.

**-o \$1** Specify the executable.

**\$1.o** Include the program object file.

### **\$EXTRA\_LFLAG**

Specify the location of the DB2 shared libraries at run-time. For 32-bit it contains the value `"-Wl,-rpath,$DB2PATH/lib32"`. For 64-bit it contains the value `"-Wl,-rpath,$DB2PATH/lib64"`.

### **-\$DB2PATH/\$LIB**

Specify the location of the DB2 static and shared libraries at link-time. For example, for 32-bit: `$HOME/sql1lib/lib32`, and for 64-bit: `$HOME/sql1lib/lib64`.

**-ldb2** Link with the DB2 library.

### **-lpthread**

Link with the POSIX thread library.

Refer to your compiler documentation for additional compiler options.

## Solaris C routine compile and link options

These are the compile and link options recommended by DB2 for building C routines (stored procedures and user-defined functions) with the Forte C compiler, as demonstrated in the `bldrtn` build script.



## Compile and link options for bldrtn

Compile options:

**cc** The C compiler.

**-xarch=\$CFLAG\_ARCH**

This option ensures that the compiler will produce valid executables when linking with `libdb2.so`. The value for `$CFLAG_ARCH` is set as follows:

- "v8plusa" for 32-bit applications on Solaris SPARC
- "v9" for 64-bit applications on Solaris SPARC
- "sse2" for 32-bit applications on Solaris x64
- "amd64" for 64-bit applications on Solaris x64

**-mt** Allow multi-threaded support, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).

**-DUSE\_UI\_THREADS**

Allows Sun's "UNIX International" threads APIs.

**-Kpic** Generate position-independent code for shared libraries.

**-I\$DB2PATH/include**

Specify the location of the DB2 include files.

**-c** Perform compile only; no link. This script has separate compile and link steps.

Link options:

**cc** Use the compiler as a front end for the linker.

**-xarch=\$CFLAG\_ARCH**

This option ensures that the compiler will produce valid executables when linking with `libdb2.so`. The value for `$CFLAG_ARCH` is set to either "v8plusa" for 32-bit, or "v9" for 64-bit.

**-mt** This is required because the DB2 library is linked with `-mt`.

**-G** Generate a shared library.

**-o \$1** Specify the executable.

**\$1.o** Include the program object file.

**-L\$DB2PATH/\$LIB**

Specify the location of the DB2 static and shared libraries at link-time. For example, for 32-bit: `$HOME/sql1lib/lib32`, and for 64-bit: `$HOME/sql1lib/lib64`.

**\$EXTRA\_LFLAG**

Specify the location of the DB2 shared libraries at run-time. For 32-bit it contains the value `"-R$DB2PATH/lib32"`, and for 64-bit it contains the value `"-R$DB2PATH/lib64"`.

**-ldb2** Link with the DB2 library.

Refer to your compiler documentation for additional compiler options.

## Solaris C++ routine compile and link options

These are the compile and link options recommended by DB2 for building C++ routines (stored procedures and user-defined functions) with the Forte C++ compiler, as demonstrated in the `bldrtn` build script.

## Compile and link options for bldrtn

Compile options:

- CC** The C++ compiler.
- xarch=\$CFLAG\_ARCH**  
This option ensures that the compiler will produce valid executables when linking with `libdb2.so`. The value for `$CFLAG_ARCH` is set as follows:
- "v8plusa" for 32-bit applications on Solaris SPARC
  - "v9" for 64-bit applications on Solaris SPARC
  - "sse2" for 32-bit applications on Solaris x64
  - "amd64" for 64-bit applications on Solaris x64
- mt** Allow multi-threaded support, needed as the routines can run in the same process as other routines (THREADSAFE) or in the engine itself (NOT FENCED).
- DUSE\_UI\_THREADS**  
Allows Sun's "UNIX International" threads APIs.
- Kpic** Generate position-independent code for shared libraries.
- I\$DB2PATH/include**  
Specify the location of the DB2 include files.
- c** Perform compile only; no link. This script has separate compile and link steps.

Link options:

- CC** Use the compiler as a front end for the linker.
- xarch=\$CFLAG\_ARCH**  
This option ensures that the compiler will produce valid executables when linking with `libdb2.so`. The value for `$CFLAG_ARCH` is set to either "v8plusa" for 32-bit, or "v9" for 64-bit.
- mt** This is required because the DB2 library is linked with `-mt`.
- G** Generate a shared library.
- o \$1** Specify the executable.
- \$1.o** Include the program object file.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 static and shared libraries at link-time. For example, for 32-bit: `$HOME/sql1lib/lib32`, and for 64-bit: `$HOME/sql1lib/lib64`.
- \$EXTRA\_LFLAG**  
Specify the location of the DB2 shared libraries at run-time. For 32-bit it contains the value `"-R$DB2PATH/lib32"`, and for 64-bit it contains the value `"-R$DB2PATH/lib64"`.
- ldb2** Link with the DB2 library.

Refer to your compiler documentation for additional compiler options.

## Windows C and C++ routine compile and link options

The following are the compile and link options recommended by DB2 for building C and C++ routines (stored procedures and user-defined functions) on Windows with the Microsoft Visual C++ compiler, as demonstrated in the `bldrtn.bat` batch file.

## Compile and link options for bldrtn

Compile options:

**%BLDCOMP%**

Variable for the compiler. The default is `cl`, the Microsoft Visual C++ compiler. It can be also set to `icl`, the Intel C++ Compiler for 32-bit and 64-bit applications, or `ec1`, the Intel C++ Compiler for Itanium 64-bit applications.

**-Zi** Enable debugging information

**-Od** Disable optimization.

**-c** Perform compile only; no link. Compile and link are separate steps.

**-W2** Output warning, error, and severe and unrecoverable error messages.

**-DWIN32**

Compiler option necessary for Windows operating systems.

**-MD** Link using MSVCRT.LIB

Link options:

**link** Use the linker to link.

**-debug** Include debugging information.

**-out:%1.dll**

Build a .DLL file.

**%1.obj** Include the object file.

**db2api.lib**

Link with the DB2 library.

**-def:%1.def**

Module definition file.

Refer to your compiler documentation for additional compiler options.

## Building embedded SQL stored procedures in C or C++ with configuration files

### About this task

You can build DB2 embedded SQL stored procedures in C and C++ on AIX by using the configuration file, `stp.icc`, in `sqllib/samples/c` and `sqllib/samples/cpp`.

To use the configuration file to build the embedded SQL stored procedure shared library `spserver` from the source file `spserver.sqc`, do the following:

### Procedure

1. Set the STP environment variable to the program name by entering:
  - For bash or Korn shell:

```
export STP=spserver
```
  - For C shell:

```
setenv STP spserver
```
2. If you have an `stp.ics` file in your working directory, produced by building a different program with the `stp.icc` file, delete the `stp.ics` file with this command:

```
rm stp.ics
```

An existing `stp.ics` file produced for the same program you are going to build again does not have to be deleted.

3. Compile the sample program by entering:

```
vacbld stp.icc
```

**Note:** The `vacbld` command is provided by VisualAge C++.

## What to do next

The stored procedure shared library is copied to the server in the path `sqllib/function`.

Next, catalog the stored procedures in the shared library by running the `spcat` script on the server:

```
spcat
```

This script connects to the sample database, uncatalogs the stored procedures if they were previously cataloged by calling `spdrep.db2`, then catalogs them by calling `spcreate.db2`, and finally disconnects from the database. You can also call the `spdrep.db2` and `spcreate.db2` scripts individually.

Then, stop and restart the database to allow the new shared library to be recognized. If necessary, set the file mode for the shared library so the DB2 instance can access it.

Once you build the stored procedure shared library, `spserver`, you can build the client application, `spclient`, that calls the stored procedures in it. You can build `spclient` using the configuration file, `emb.icc`.

To call the stored procedures, run the sample client application by entering:  
`spclient database userid password`

where

**database**

Is the name of the database to which you want to connect. The name could be `sample`, or its remote alias, or some other name.

**userid** Is a valid user ID.

**password**

Is a valid password.

The client application accesses the shared library, `spserver`, and executes a number of stored procedure functions on the server database. The output is returned to the client application.

## Building user-defined functions in C or C++ with configuration files (AIX)

### About this task

The configuration file, `udf.icc`, in `sqllib/samples/c` and `sqllib/samples/cpp`, allows you to build user-defined functions in C and C++ on AIX.

To use the configuration file to build the user-defined function program `udfsrv` from the source file `udfsrv.c`, do the following:

### Procedure

1. Set the UDF environment variable to the program name by entering:

- For bash or Korn shell:

```
export UDF=udfsrv
```
- For C shell:

```
setenv UDF udfsrv
```

2. If you have a `udf.ics` file in your working directory, produced by building a different program with the `udf.icc` file, delete the `udf.ics` file with this command:

```
rm udf.ics
```

An existing `udf.ics` file produced for the same program you are going to build again does not have to be deleted.

3. Compile the sample program by entering:

```
vacbld udf.icc
```

**Note:** The `vacbld` command is provided by VisualAge C++.

### What to do next

The UDF library is copied to the server in the path `sqllib/function`.

If necessary, set the file mode for the user-defined function so the DB2 instance can run it.

Once you build `udfsrv`, you can build the client application, `udfcli`, that calls it. DB2 CLI and embedded SQL versions of this program are provided.

You can build the DB2 CLI `udfcli` program from the source file `udfcli.c`, in `sqllib/samples/cli`, by using the configuration file `cli.icc`.

You can build the embedded SQL `udfcli` program from the source file `udfcli.sqc`, in `sqllib/samples/c`, by using the configuration file `emb.icc`.

To call the UDF, run the sample calling application by entering the executable name:

```
udfcli
```

The calling application calls the `ScalarUDF` function from the `udfsrv` library.

## Rebuilding DB2 routine shared libraries

DB2 will cache the shared libraries used for stored procedures and user-defined functions once loaded. If you are developing a routine, you might want to test loading the same shared library a number of times, and this caching can prevent you from picking up the latest version of a shared library. The way to avoid caching problems depends on the type of routine:

1. **Fenced, not threadsafe routines.** The database manager configuration keyword `KEEPFENCED` has a default value of `YES`. This keeps the fenced mode process alive. This default setting can interfere with reloading the library. It is best to change the value of this keyword to `NO` while developing fenced, not threadsafe routines, and then change it back to `YES` when you are ready to load

the final version of your shared library. For more information, see “Updating the database manager configuration file.”

2. **Trusted or threadsafe routines.** Except for SQL routines (including SQL procedures), the only way to ensure that an updated version of a DB2 routine library is picked up when that library is used for trusted, or threadsafe routines, is to recycle the DB2 instance by entering **db2stop** followed by **db2start** on the command line. This is not needed for an SQL routine because when it is recreated, the compiler uses a new unique library name to prevent possible conflicts.

For routines other than SQL routines, you can also avoid caching problems by creating the new version of the routine with a differently named library (for example foo.a becomes foo.1.a), and then using either the ALTER PROCEDURE or ALTER FUNCTION SQL statement with the new library.

## Updating the database manager configuration file

### About this task

This file contains important settings for application development.

The keyword **KEEPFENCED** has the default value YES. For fenced, not threadsafe routines (stored procedures and UDFs), this keeps the routine process alive. It is best to change the value of this keyword to NO while developing these routines, and then change it back to YES when you are ready to load the final version of your shared library. For more information, see “Rebuilding DB2 routine shared libraries” on page 227.

**Note:** **KEEPFENCED** was known as **KEEPDARI** in previous versions of DB2 database products.

For Java application development, you need to update the **JDK\_PATH** keyword with the path where the Java Development Kit is installed.

**Note:** **JDK\_PATH** was known as **JDK11\_PATH** in previous versions of DB2 database products.

### Procedure

To change these settings enter:

```
db2 update dbm cfg using keyword value
```

For example, to set the keyword **KEEPFENCED** to NO:

```
db2 update dbm cfg using KEEPFENCED NO
```

To set the **JDK\_PATH** keyword to the directory /home/db2inst/jdk13:

```
db2 update dbm cfg using JDK_PATH /home/db2inst/jdk13
```

### Results

To view the current settings in the database manager configuration file, enter:

```
db2 get dbm cfg
```

**Note:** On Windows, you need to enter these commands in a DB2 command window.

---

## Chapter 6. COBOL procedures

COBOL procedures are to be written in a similar manner as COBOL subprograms.

### Handling parameters in a COBOL procedure

Each parameter to be accepted or passed by a procedure must be declared in the LINKAGE SECTION. For example, this code fragment comes from a procedure that accepts two IN parameters (one CHAR(15) and one INT), and passes an OUT parameter (an INT):

```
LINKAGE SECTION.  
01 IN-SPERSON    PIC X(15).  
01 IN-SQTY      PIC S9(9)  USAGE COMP-5.  
01 OUT-SALESSUM PIC S9(9)  USAGE COMP-5.
```

Ensure that the COBOL data types you declare map correctly to SQL data types. For a detailed list of data type mappings between SQL and COBOL, see "Supported SQL Data Types in COBOL".

Each parameter must then be listed in the PROCEDURE DIVISION. The following example shows a PROCEDURE DIVISION that corresponds to the parameter definitions from the previous LINKAGE SECTION example.

```
PROCEDURE DIVISION USING IN-SPERSON  
                        IN-SQTY  
                        OUT-SALESSUM.
```

### Exiting a COBOL procedure

To properly exit the procedure use the following commands:

```
MOVE SQLZ-HOLD-PROC TO RETURN-CODE.  
GOBACK.
```

With these commands, the procedure returns correctly to the client application. This is especially important when the procedure is called by a local COBOL client application.

When building a COBOL procedure, it is strongly recommended that you use the build script written for your operating system and compiler. Build scripts for Micro Focus COBOL are found in the `sqllib/samples/cobol_mf` directory. Build scripts for IBM COBOL are found in the `sqllib/samples/cobol` directory.

The following is an example of a COBOL procedure that accepts two input parameters, and then returns an output parameter and a result set:

```
IDENTIFICATION DIVISION.  
PROGRAM-ID.      "NEWSALE".  
DATA DIVISION.  
  
WORKING-STORAGE SECTION.  
01 INSERT-STMT.  
   05 FILLER    PIC X(24) VALUE "INSERT INTO SALES (SALES".  
   05 FILLER    PIC X(24) VALUE "_PERSON,SALES) VALUES ('".  
   05 SPERSON   PIC X(16).  
   05 FILLER    PIC X(2) VALUE "','".  
   05 SQTY      PIC S9(9).  
   05 FILLER    PIC X(1) VALUE ")".  
EXEC SQL BEGIN DECLARE SECTION END-EXEC.  
01 INS-SMT-INF.  
   05 INS-STMT.  
   49 INS-LEN   PIC S9(4) USAGE COMP.
```

```

    49 INS-TEXT PIC X(100).
01 SALESSUM PIC S9(9) USAGE COMP-5.
EXEC SQL END DECLARE SECTION END-EXEC.
EXEC SQL INCLUDE SQLCA END-EXEC.

LINKAGE SECTION.
01 IN-SPERSON PIC X(15).
01 IN-SQTY PIC S9(9) USAGE COMP-5.
01 OUT-SALESSUM PIC S9(9) USAGE COMP-5.

PROCEDURE DIVISION USING IN-SPERSON
                        IN-SQTY
                        OUT-SALESSUM.

MAINLINE.
    MOVE 0 TO SQLCODE.
    PERFORM INSERT-ROW.
    IF SQLCODE IS NOT EQUAL TO 0
        GOBACK
    END-IF.
    PERFORM SELECT-ROWS.
    PERFORM GET-SUM.
    GOBACK.
INSERT-ROW.
    MOVE IN-SPERSON TO SPERSON.
    MOVE IN-SQTY TO SQTY.
    MOVE          INSERT-STMT TO INS-TEXT.
    MOVE LENGTH OF INSERT-STMT TO INS-LEN.
    EXEC SQL EXECUTE IMMEDIATE :INS-STMT END-EXEC.
GET-SUM.
    EXEC SQL
        SELECT SUM(SALES) INTO :SALESSUM FROM SALES
    END-EXEC.
    MOVE SALESSUM TO OUT-SALESSUM.
SELECT-ROWS.
    EXEC SQL
        DECLARE CUR CURSOR WITH RETURN FOR SELECT * FROM SALES
    END-EXEC.
    IF SQLCODE = 0
        EXEC SQL OPEN CUR END-EXEC
    END-IF.

```

The corresponding CREATE PROCEDURE statement for this procedure is as follows:

```

CREATE PROCEDURE NEWSALE ( IN SALESPERSON CHAR(15),
                          IN SALESQTY INT,
                          OUT SALESSUM INT)

    RESULT SETS 1
    EXTERNAL NAME 'NEWSALE!NEWSALE'
    FENCED
    LANGUAGE COBOL
    PARAMETER STYLE SQL
    MODIFIES SQL DATA

```

The preceding statement assumes that the COBOL function exists in a library called NEWSALE.

**Note:** When registering a COBOL procedure on Windows operating systems, take the following precaution when identifying a stored procedure body in the CREATE statement's EXTERNAL NAME clause. If you use an absolute path id to identify the procedure body, you must append the .dll extension. For example:

```

CREATE PROCEDURE NEWSALE ( IN SALESPERSON CHAR(15),
                          IN SALESQTY INT,
                          OUT SALESSUM INT)

    RESULT SETS 1

```



```

EXTERNAL NAME 'NEWSALE!NEWSALE'
FENCED
LANGUAGE COBOL
PARAMETER STYLE SQL
MODIFIES SQL DATA
EXTERNAL NAME 'd:\mylib\NEWSALE.d11'

```

---

## Support for external procedure development in COBOL

To develop external procedures in COBOL you must use the supported COBOL development software.

All of the development software supported for database application development in COBOL can also be used for external procedure development in COBOL.

---

## Supported SQL data types in COBOL embedded SQL applications

Certain predefined COBOL data types correspond to DB2 database column types. Only these COBOL data types can be declared as host variables.

The following table shows the COBOL equivalent of each column type. When the precompiler finds a host variable declaration, it determines the appropriate SQL type value. The database manager uses this value to convert the data exchanged between the application and itself.

Not every possible data description for host variables is recognized. COBOL data items must be consistent with the ones described in the following table. If you use other data items, an error can result.

*Table 41. SQL Data Types Mapped to COBOL Declarations*

SQL Column Type <sup>1</sup>	COBOL Data Type	SQL Column Type Description
SMALLINT (500 or 501)	01 name PIC S9(4) COMP-5.	16-bit signed integer
INTEGER (496 or 497)	01 name PIC S9(9) COMP-5.	32-bit signed integer
BIGINT (492 or 493)	01 name PIC S9(18) COMP-5.	64-bit signed integer
DECIMAL( <i>p,s</i> ) (484 or 485)	01 name PIC S9( <i>m</i> )V9( <i>n</i> ) COMP-3.	Packed decimal
REAL <sup>2</sup> (480 or 481)	01 name USAGE IS COMP-1.	Single-precision floating point
DOUBLE <sup>3</sup> (480 or 481)	01 name USAGE IS COMP-2.	Double-precision floating point
CHAR( <i>n</i> ) (452 or 453)	01 name PIC X( <i>n</i> ).	Fixed-length character string

Table 41. SQL Data Types Mapped to COBOL Declarations (continued)

SQL Column Type <sup>1</sup>	COBOL Data Type	SQL Column Type Description
VARCHAR( <i>n</i> ) (448 or 449)	01 name. 49 length PIC S9(4) COMP-5. 49 name PIC X( <i>n</i> ).  1<= <i>n</i> <=32 672	Variable-length character string
LONG VARCHAR <sup>6</sup> (456 or 457)	01 name. 49 length PIC S9(4) COMP-5. 49 data PIC X( <i>n</i> ).  32 673<= <i>n</i> <=32 700	Long variable-length character string
CLOB( <i>n</i> ) (408 or 409)	01 MY-CLOB USAGE IS SQL TYPE IS CLOB( <i>n</i> ).  1<= <i>n</i> <=2 147 483 647	Large object variable-length character string
CLOB locator variable <sup>4</sup> (964 or 965)	01 MY-CLOB-LOCATOR USAGE IS SQL TYPE IS CLOB-LOCATOR.	Identifies CLOB entities residing on the server
CLOB file reference variable <sup>4</sup> (920 or 921)	01 MY-CLOB-FILE USAGE IS SQL TYPE IS CLOB-FILE.	Descriptor for file containing CLOB data
BLOB( <i>n</i> ) (404 or 405)	01 MY-BLOB USAGE IS SQL TYPE IS BLOB( <i>n</i> ).  1<= <i>n</i> <=2 147 483 647	Large object variable-length binary string
BLOB locator variable <sup>4</sup> (960 or 961)	01 MY-BLOB-LOCATOR USAGE IS SQL TYPE IS BLOB-LOCATOR.	Identifies BLOB entities residing on the server
BLOB file reference variable <sup>4</sup> (916 or 917)	01 MY-BLOB-FILE USAGE IS SQL TYPE IS BLOB-FILE.	Descriptor for file containing BLOB data
DATE (384 or 385)	01 identifier PIC X(10).	10-byte character string
TIME (388 or 389)	01 identifier PIC X(8).	8-byte character string
TIMESTAMP( <i>p</i> ) (392 or 393)	01 identifier PIC X( <i>p</i> +20).  0<= <i>p</i> <=12	19 to 32 byte character string  A 19 byte character string can be used, when <i>p</i> is 0.
XML <sup>5</sup> (988 or 989)	01 name USAGE IS SQL TYPE IS XML AS CLOB (size).	XML value

The following data types are only available in the DBCS environment.

Table 42. SQL Data Types Mapped to COBOL Declarations

SQL Column Type <sup>1</sup>	COBOL Data Type	SQL Column Type Description
GRAPHIC( <i>n</i> ) (468 or 469)	01 name PIC G( <i>n</i> ) DISPLAY-1.	Fixed-length double-byte character string
VARGRAPHIC( <i>n</i> ) (464 or 465)	01 name. 49 length PIC S9(4) COMP-5. 49 name PIC G( <i>n</i> ) DISPLAY-1.  1<= <i>n</i> <=16 336	Variable length double-byte character string with 2-byte string length indicator
LONG VARGRAPHIC <sup>6</sup> (472 or 473)	01 name. 49 length PIC S9(4) COMP-5. 49 name PIC G( <i>n</i> ) DISPLAY-1.  16 337<= <i>n</i> <=16 350	Variable length double-byte character string with 2-byte string length indicator
DBCLOB( <i>n</i> ) (412 or 413)	01 MY-DBCLOB USAGE IS SQL TYPE IS DBCLOB( <i>n</i> ).  1<= <i>n</i> <=1 073 741 823	Large object variable-length double-byte character string with 4-byte string length indicator
DBCLOB locator variable <sup>4</sup> (968 or 969)	01 MY-DBCLOB-LOCATOR USAGE IS SQL TYPE IS DBCLOB-LOCATOR.	Identifies DBCLOB entities residing on the server
DBCLOB file reference variable <sup>4</sup> (924 or 925)	01 MY-DBCLOB-FILE USAGE IS SQL TYPE IS DBCLOB-FILE.	Descriptor for file containing DBCLOB data

**Note:**

1. The first number under **SQL Column Type** indicates that an indicator variable is not provided, and the second number indicates that an indicator variable is provided. An indicator variable is needed to indicate NULL values, or to hold the length of a truncated string. These are the values that will be displayed in the SQLTYPE field of the SQLDA for these data types.
2. FLOAT(*n*) where  $0 < n < 25$  is a synonym for REAL. The difference between REAL and DOUBLE in the SQLDA is the length value (4 or 8).
3. The following SQL types are synonyms for DOUBLE:
  - FLOAT
  - FLOAT(*n*) where  $24 < n < 54$  is a synonym for DOUBLE.
  - DOUBLE PRECISION
4. This is not a column type but a host variable type.
5. The SQL\_TYP\_XML/SQL\_TYP\_NXML value is returned by DESCRIBE requests only. It cannot be used directly by the application to bind application resources to XML values.
6. The LONG VARCHAR and LONG VARGRAPHIC data types are deprecated and might be removed in a future release. Choose the CLOB or DBCLOB data type instead.

The following are additional rules for supported COBOL data types:

- PIC S9 and COMP-3/COMP-5 are required where shown.
- You can use level number 77 instead of 01 for all column types except VARCHAR, LONG VARCHAR, VARGRAPHIC, LONG VARGRAPHIC and all LOB variable types.

- Use the following rules when declaring host variables for DECIMAL(p,s) column types. See the following sample:
  - 01 identifier PIC S9(m)V9(n) COMP-3
  - Use V to denote the decimal point.
  - Values for *n* and *m* must be greater than or equal to 1.
  - The value for *n + m* cannot exceed 31.
  - The value for *s* equals the value for *n*.
  - The value for *p* equals the value for *n + m*.
  - The repetition factors (*n*) and (*m*) are optional. The following examples are all valid:
    - 01 identifier PIC S9(3)V COMP-3
    - 01 identifier PIC SV9(3) COMP-3
    - 01 identifier PIC S9V COMP-3
    - 01 identifier PIC SV9 COMP-3
  - PACKED-DECIMAL can be used instead of COMP-3.
- Arrays are *not* supported by the COBOL precompiler.

## Building COBOL routines

### Compile and link options for COBOL routines

#### AIX IBM COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures) with the IBM COBOL for AIX compiler on AIX, as demonstrated in the `bldrtn` build script.

#### Compile and link options for `bldrtn`

Compile Options:

**cob2** The IBM COBOL for AIX compiler.

**-qpgmname(mixed)**

Instructs the compiler to permit CALLs to library entry points with mixed-case names.

**-qlib** Instructs the compiler to process COPY statements.

**-c** Perform compile only; no link. Compile and link are separate steps.

**-I\$DB2PATH/include/cobol\_a**

Specify the location of the DB2 include files. For example: `$HOME/sql1lib/include/cobol_a`.

Link Options:

- cob2** Use the compiler to link edit.
- o \$1** Specify the output as a shared library file.
- \$1.o** Specify the stored procedure object file.
- checkerr.o**  
Include the utility object file for error-checking.
- bnoentry**  
Do not specify the default entry point to the shared library.
- bE:\$1.exp**  
Specify an export file. The export file contains a list of the stored procedures.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries. For example:  
\$HOME/sqllib/lib32.
- ldb2** Link with the database manager library.

Refer to your compiler documentation for additional compiler options.

## AIX Micro Focus COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures) with the Micro Focus COBOL compiler on AIX, as demonstrated in the `bldrtn` build script. Note that the DB2 MicroFocus COBOL include files are found by setting up the `COBCPY` environment variable, so no `-I` flag is needed in the compile step. Refer to the `bldapp` script for an example.

### Compile and link options for `bldrtn`

Compile options:

- cob** The MicroFocus COBOL compiler.
- c** Perform compile only; no link. Compile and link are separate steps.
- \$EXTRA\_COBOL\_FLAG="-C MFSYNC"**  
Enables 64-bit support.
- x** Compile to an object module when used with the `-c` option.

Link options:

- cob** Use the compiler as a front-end for the linker.
- x** Produce a shared library.
- o \$1** Specify the executable program.
- \$1.o** Specify the program object file.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries. For example:  
\$HOME/sqllib/lib32.
- ldb2** Link to the DB2 library.
- ldb2gmf**  
Link to the DB2 exception-handler library for Micro Focus COBOL.

Refer to your compiler documentation for additional compiler options.

## HP-UX Micro Focus COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures) with the Micro Focus COBOL compiler on HP-UX, as demonstrated in the `bldrtn` build script.

### Compile and link options for `bldrtn`

Compile options:

- cob** The COBOL compiler.
- \$EXTRA\_COBOL\_FLAG**  
Contains "-C MFSYNC" if the HP-UX platform is IA64 and 64-bit support is enabled.

Link options:

- y** Specify that the desired output is a shared library.
- o \$1** Specify the executable.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries.
- ldb2** Link to the DB2 shared library.
- ldb2gmf**  
Link to the DB2 exception-handler library for Micro Focus COBOL.

Refer to your compiler documentation for additional compiler options.

## Solaris Micro Focus COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures) with the Micro Focus COBOL compiler on Solaris, as demonstrated in the `bldrtn` build script.

## Compile and link options for bldrtn

Compile options:

- cob** The COBOL compiler.
- cx** Compile to object module.
- \$EXTRA\_COBOL\_FLAG**  
For 64-bit support, contains the value "-C MFSYNC"; otherwise it contains no value.

Link options:

- cob** Use the compiler as a front-end for the linker.
- y** Create a self-contained standalone shared library.
- o \$1** Specify the executable program.
- \$1.o** Specify the program object file.
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries. For example:  
\$HOME/sqllib/lib64.
- ldb2** Link to the DB2 library.
- ldb2gmf**  
Link to the DB2 exception-handler library for Micro Focus COBOL.

Refer to your compiler documentation for additional compiler options.

## Linux Micro Focus COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures) with the Micro Focus COBOL compiler on Linux, as demonstrated in the bldrtn build script.

### Compile and link options for bldrtn

Compile and Link options:

- cob** The COBOL compiler
- \$EXTRA\_COBOL\_FLAG**  
For 64-bit support, contains the value "-C MFSYNC"; otherwise it contains no value.
- y** Specify to compile to self-contained callable shared object
- o \$1** Specify the executable.
- \$1.cb1** Specify the source file
- L\$DB2PATH/\$LIB**  
Specify the location of the DB2 runtime shared libraries.
- ldb2** Link to the DB2 library.
- ldb2gmf**  
Link to the DB2 exception-handler library for Micro Focus COBOL.

Refer to your compiler documentation for additional compiler options.

**Note:** After compiling stored procedures, they must be copied or linked into /usr/lib. Editing ld.so.conf is not sufficient.

## Windows IBM COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures and user-defined functions) on Windows with the IBM VisualAge COBOL compiler, as demonstrated in the `bldrtn.bat` batch file.

### Compile and link options for `bldrtn`

Compile options:

**cob2** The IBM VisualAge COBOL compiler.

**-qpgmname(mixed)**

Instructs the compiler to permit CALLs to library entry points with mixed-case names.

**-c** Perform compile only; no link. This batch file has separate compile and link steps.

**-qlib** Instructs the compiler to process COPY statements.

**-Ipath** Specify the location of the DB2 include files. For example: `-I"%DB2PATH%\include\cobol_a"`.

**%EXTRA\_COMPFLAG%**

If `"set IBMCOB_PRECOMP=true"` is uncommented, the IBM COBOL precompiler is used to precompile the embedded SQL. It is invoked with one of the following formulations, depending on the input parameters:

**-q"SQL('database sample CALL\_RESOLUTION DEFERRED')"**

precompile using the default sample database, and defer call resolution.

**-q"SQL('database %2 CALL\_RESOLUTION DEFERRED')"**

precompile using a database specified by the user, and defer call resolution.

Link options:

**ilink** Use the IBM VisualAge COBOL linker.

**/free** Free format.

**/no1** No logo.

**/dll** Create the DLL with the source program name.

**db2api.lib**

Link with the DB2 library.

**%1.exp** Include the export file.

**%1.obj** Include the program object file.

**iwrwin3.obj**

Include the object file provided by IBM VisualAge COBOL.

Refer to your compiler documentation for additional compiler options.

## Windows Micro Focus COBOL routine compile and link options

The following are the compile and link options recommended by DB2 for building COBOL routines (stored procedures and user-defined functions) on Windows with the Micro Focus COBOL compiler, as demonstrated in the `bldrtn.bat` batch file.



## Compile and link options for bldrtn

Compile options:

**cobol** The Micro Focus COBOL compiler.

**/case** Prevent external symbols being converted to uppercase.

Link options:

**cbllink**

Use the Micro Focus COBOL linker to link edit.

**/d** Create a .dll file.

**db2api.lib**

Link with the DB2 API library.

Refer to your compiler documentation for additional compiler options.

## Building IBM COBOL routines on AIX

### About this task

DB2 provides build scripts for compiling and linking COBOL embedded SQL and DB2 administrative API programs. These are located in the `sqllib/samples/cobol` directory, along with sample programs that can be built with these files.

The script, `bldrtn`, in `sqllib/samples/cobol`, contains the commands to build routines (stored procedures). The script compiles the routines into a shared library that can be called by a client application.

The first parameter, `$1`, specifies the name of your source file. The second parameter, `$2`, specifies the name of the database to which you want to connect. Since the shared library must be built on the same instance where the database resides, there are no parameters for user ID and password.

Only the first parameter, source file name, is required. The script uses the source file name, `$1`, for the shared library name. Database name is optional. If no database name is supplied, the program uses the default `sample` database.

To build the sample program `outsrv` from the source file `outsrv.sqb`, connecting to the sample database, enter:

```
bldrtn outsrv
```

If connecting to another database, also include the database name:

```
bldrtn outsrv database
```

The script file copies the shared library to the server in the path `sqllib/function`.

Once you build the routine shared library, `outsrv`, you can build the client application, `outcli`, that calls the routine within the library. You can build `outcli` using the script file `bdapp`.

To call the routine, run the sample client application by entering:

```
outcli database userid password
```

where

**database**

Is the name of the database to which you want to connect. The name can be `sample`, or its remote alias, or some other name.

**userid** Is a valid user ID.

**password**

Is a valid password for the user ID.

The client application accesses the shared library, `outsrv`, and executes the routine of the same name on the server database, and then returns the output to the client application.

## Building UNIX Micro Focus COBOL routines

DB2 database products provide build scripts for compiling and linking Micro Focus COBOL embedded SQL and DB2 API programs. These are located in the `sqllib/samples/cobol_mf` directory, along with sample programs that can be built with these files.

### About this task

The script, `bldrtn`, contains the commands to build routines (stored procedures). The script compiles the routine source file into a shared library that can be called by a client application.

The first parameter, `$1`, specifies the name of your source file. The script uses the source file name for the shared library name. The second parameter, `$2`, specifies the name of the database to which you want to connect. Since the shared library must be built in the same instance where the database resides, there are no parameters for user ID and password.

Only the first parameter, source file name, is required. Database name is optional. If no database name is supplied, the program uses the default `sample` database.

### Procedure

1. Before building Micro Focus COBOL routines, you must run the following commands:

```
db2stop
db2set DB2LIBPATH=$LD_LIBRARY_PATH
db2set DB2ENVLIST="COBDIR LD_LIBRARY_PATH"
db2set
db2start
```

Ensure that **db2stop** stops the database. The last **db2set** command is issued to check your settings: make sure **DB2LIBPATH** and **DB2ENVLIST** are set correctly.

2. To build the sample program `outsrv` from the source file `outsrv.sqb`, if connecting to the sample database, enter: `bldrtn outsrv`.

If connecting to another database, also enter the database name. For example:

```
bldrtn outsrv database
```

The script file copies the shared library to the server in the path `sqllib/function`.

Once you build the stored procedure `outsrv`, you can build the client application `outcli` that calls it. You can build `outcli` using the script file, **bldapp**.

3. To call the stored procedure, run the sample client application by entering:  
`outcli database userid password`  
where

*database*

Is the name of the database to which you want to connect. The name could be `sample`, or its alias, or another name.

*userid* Is a valid user ID.

*password*

Is a valid password for the user ID.

The client application accesses the shared library, `outsrv`, and executes the stored procedure function of the same name on the server database. The output is then returned to the client application.

## Building IBM COBOL routines on Windows

### About this task

DB2 provides build scripts for compiling and linking DB2 API and embedded SQL programs in IBM COBOL. These are located in the `sql1lib\samples\cobol` directory, along with sample programs that can be built with these files.

DB2 supports two precompilers for building IBM COBOL applications on Windows, the DB2 precompiler and the IBM COBOL precompiler. The default is the DB2 precompiler. The IBM COBOL precompiler can be selected by uncommenting the appropriate line in the batch file you are using. Precompilation with IBM COBOL is done by the compiler itself, using specific precompile options.

The batch file, `bldrtn.bat`, contains the commands to build embedded SQL routines (stored procedures). The batch file compiles the routines into a DLL on the server. It takes two parameters, represented inside the batch file by the variables `%1` and `%2`.

The first parameter, `%1`, specifies the name of your source file. The batch file uses the source file name, `%1`, for the DLL name. The second parameter, `%2`, specifies the name of the database to which you want to connect. Since the stored procedure must be built on the same instance where the database resides, there are no parameters for user ID and password.

Only the first parameter, source file name, is required. Database name is optional. If no database name is supplied, the program uses the default `sample` database.

If using the default DB2 precompiler, `bldrtn.bat` passes the parameters to the precompile and bind file, `embprep.bat`.

If using the IBM COBOL precompiler, `bldrtn.bat` copies the `.sqb` source file to a `.cb1` source file. The compiler performs the precompile on the `.cb1` source file with specific precompile options.

To build the sample program `outsrv` from the source file `outsrv.sqb`, connecting to the sample database, enter:

```
bldrtn outsrv
```

If connecting to another database, also include the database name:

```
bldrtn outsrv database
```

The batch file copies the DLL to the server in the path `sqllib\function`.

Once you build the DLL `outsrv`, you can build the client application `outcli` that calls the routine within the DLL (which has the same name as the DLL). You can build `outcli` using the batch file `bdapp.bat`.

To call the `outsrv` routine, run the sample client application by entering:

```
outcli database userid password
```

where

**database**

Is the name of the database to which you want to connect. The name can be `sample`, or its remote alias, or some other name.

**userid** Is a valid user ID.

**password**

Is a valid password for the user ID.

The client application accesses the DLL, `outsrv`, and executes the routine of the same name on the server database, and then returns the output to the client application.

## Building Micro Focus COBOL routines on Windows

### About this task

DB2 provides build scripts for compiling and linking DB2 API and embedded SQL programs in Micro Focus COBOL. These are located in the `sqllib\samples\cobol_mf` directory, along with sample programs that can be built with these files.

The batch file `bldrtn.bat` contains the commands to build embedded SQL routines (stored procedures). The batch file compiles the routines into a DLL on the server. The batch file takes two parameters, represented inside the batch file by the variables `%1` and `%2`.

The first parameter, `%1`, specifies the name of your source file. The batch file uses the source file name, `%1`, for the DLL name. The second parameter, `%2`, specifies the name of the database to which you want to connect. Since the stored procedure must be built on the same instance where the database resides, there are no parameters for user ID and password.

Only the first parameter, source file name, is required. Database name is optional. If no database name is supplied, the program uses the default `sample` database.

To build the sample program `outsrv` from the source file `outsrv.sqb`, if connecting to the sample database, enter:

```
bldrtn outsrv
```

If connecting to another database, also enter the database name:

```
bldrtn outsrv database
```

The script file copies the DLL to the server in the path `sqllib/function`.

Once you build the DLL, `outsrv`, you can build the client application, `outcli`, that calls the routine within the DLL (which has the same name as the DLL). You can build `outcli` using the batch file, `bdapp.bat`.

To call the `outsrv` routine, run the sample client application by entering:

```
outcli database userid password
```

where

**database**

Is the name of the database to which you want to connect. The name could be `sample`, or its alias, or another name.

**userid** Is a valid user ID.

**password**

Is a valid password for the user ID.

The client application accesses the DLL, `outsrv`, which executes the routine of the same name on the server database. The output is then returned to the client application.



---

## Chapter 7. Java routines

Java routines are external routines that have a Java programming language implementation. Java routines are created in a database by executing a `CREATE PROCEDURE` or `CREATE FUNCTION` statement. This statement must indicate that the routine is implemented in Java with the `LANGUAGE JAVA` clause. It must also specify with the `EXTERNAL` clause, the Java class that implements it.

External procedures, functions, and methods can be created in Java.

Java routines can execute SQL statements.

The following terms are important in the context of Java routines:

**JDBC** An application programming interface for accessing data in databases that supports dynamic SQL execution.

**SQLJ** An application programming interface for accessing data in databases that supports dynamic and static SQL execution.

**CREATE statement**

The SQL language `CREATE` statement used to create the routine in the database.

**Routine-body source code**

The source code file containing the Java routine implementation. The Java routine can access the database using either JDBC or SQLJ application programming interfaces.

**JDBC** Application programming interface that provides support for dynamic SQL statement execution in Java code.

**SQLJ** Application programming interface that provides support for static SQL statement execution in Java code.

**SDK for Java**

Software development kit for Java provided and required for Java source code compilation.

**Routine class**

A Java source code file containing the compiled form of Java routine source code. Java class files can exist on their own or they can be one of a collection of Java class files within a JAR file.

---

## Supported Java routine development software

To develop and deploy external routines in Java you must use supported Java development software.

The minimum supported software development kit (SDK) version for Java routine development is the IBM SDK for Java 1.4.2. However, support for the IBM SDK for Java 1.4.2 is deprecated, and might be discontinued in a future release.

The maximum supported SDK version for Java routine development is:

- IBM SDK for Java 6

IBM SDK for Java 6 supports stored procedures and user-defined functions on these operating systems:

- AIX 5
- HP-UX for Itanium-based systems
- Linux on x86
- Linux on AMD64/EM64T
- Linux on POWER
- Windows on x86
- Windows on x64, for AMD64/EM64T

It is recommended that you use the SDK for Java that is installed with the DB2 Database for Linux, UNIX, and Windows product, however an alternative SDK for Java can be specified. If you specify an alternative SDK for Java, it must be of the same bit-width as the DB2 instance.

All other development software supported for DB2 database application development in Java can be used for external routine development in Java.

---

## JDBC and SQLJ application programming interface support for Java routines

External routines developed in Java can make use of the following application programming interfaces (APIs):

- JDBC
- SQLJ

Starting in DB2 Version 9.5, the default driver is the IBM Data Server Driver for JDBC and SQLJ. This supports both the JDBC and SQLJ APIs and can be used to develop external Java routines.

The IBM Data Server Type 2 Driver can also be used for Java routine development but only provides support for JDBC Type 2. It is strongly recommended that you use the IBM Data Server Driver for JDBC and SQLJ as the IBM Data Server Type 2 Driver is deprecated.

The procedures for implementing Java routines are the same regardless which API or driver is used.

---

## Specification of an SDK for Java routine development (UNIX)

### Before you begin

To build and run Java routine code in UNIX environments, the DB2 database manager configuration parameter **JDK\_PATH** must be set to the path of an SDK for Java that is installed on the DB2 database server. If the installation process for the DB2 Database for Linux, UNIX, and Windows product installs an SDK for Java, by default the **JDK\_PATH** parameter is set to the path of that SDK for Java:

- `$INSTDIR/sql1lib/java/jdk32` for DB2 database servers installed in Linux on x86 environments
- `$INSTDIR/sql1lib/java/jdk64` for DB2 database servers that provide an SDK installed in all other environments



The **JDK\_PATH** parameter value can be changed to specify another SDK for Java installed on the computer, however the SDK must be of the same bit-width as the DB2 instance.

- User must have access to the DB2 database server.
- User must have the authority to read and update the database manager configuration file.
- User must have authority to install an SDK for Java in the file system where the DB2 instance is installed.

## Procedure

1. Check the **JDK\_PATH** parameter value by issuing the following command from a DB2 Command Window:

```
db2 get dbm cfg
```

You might want to redirect the output to a file for easier viewing. The **JDK\_PATH** parameter value appears near the beginning of the output.

2. If you want to use a different SDK for Java, install it on the DB2 database server and note the installation path. You will require the install path value for the next step.
3. Update the **JDK\_PATH** parameter value by issuing the following command from a DB2 Command Window where *path* is the path where the other SDK for Java is installed:

```
db2 update dbm cfg using JDK_PATH path
```

4. Stop and restart your DB2 instance by issuing the following DB2 commands from a DB2 Command Window:

```
db2stop;
```

```
db2start;
```

5. Verify that the **JDK\_PATH** parameter value is correctly set by issuing the following command from a DB2 Command Window:

```
db2 get dbm cfg
```

## What to do next

After you complete these steps the specified SDK for Java will be used for building and running Java routines. The **CLASSPATH**, **PATH**, and **LIBPATH** environment variables within the environment are set automatically.

---

## Specification of a driver for Java routines

Java routine development and invocation requires that a JDBC or SQLJ driver be specified. Java routines can use one of the following two drivers:

- IBM Data Server Driver for JDBC and SQLJ Version 3.0
- DB2 Type 2 Driver

IBM Data Server Driver for JDBC and SQLJ Version 4.0 `db2jcc4.jar` includes a number of JDBC Version 4.0 capabilities. The driver is supported in DB2 Version 9.5 and higher. However, Java routines do not support IBM Data Server Driver for JDBC and SQLJ Version 4.0.

By default, DB2 uses the IBM Data Server Driver for JDBC and SQLJ. This driver is preferred because it is more robust, the DB2 Type 2 Driver is deprecated, and because it is a prerequisite if Java routines contain:

- Parameters of data type XML
- Variables of data type XML
- References to XML data
- References to XML functions
- Any other native-XML feature

If problems occur when upgrading existing Java routines, the DB2\_USE\_DB2JCCT2\_JROUTINE DB2 environment variable can be set to the value, NO, to use the legacy IBM DB2 Type 2 Driver. This can be done by issuing the following command from a DB2 command window:

```
db2set DB2_USE_DB2JCCT2_JROUTINE=NO
```

After issuing this command, you must stop and restart the DB2 instance in order for the change to take effect.

**Note:** The registry variable DB2\_USE\_DB2JCCT2\_JROUTINE has been deprecated and may be removed in a future release.

---

## Tools for developing Java (JDBC and SQLJ) routines

Tools make Java routine development go quickly and easily. The following DB2 tool provides graphical user-interface support for developing, debugging, and deploying Java routines:

- IBM Data Studio

The following command line interfaces can also be used for developing, debugging, and deploying Java routines:

- DB2 Command Line Processor
- DB2 Command Window

Other IBM software products provide graphical tools for developing Java routines including:

- IBM Optim Development Studio
- IBM Rational Application Developer
- Distributed Unified Debugger

---

## Designing Java routines

Designing Java routines is a task that should precede creating Java routines. Designing Java routines is related to both designing external routines implemented in other programming languages and designing Java database applications.

### Before you begin

Knowledge and experience with embedded SQL application development as well as general knowledge of external routines. The following topics can provide you with some of the required prerequisite information.

For more information on the features and uses of external routines, see:

- “External routine implementation” on page 21

For more information about how to program a basic Java application using either the JDBC or SQLJ application programming interfaces, see:

- “Example of a simple JDBC application” in *Developing Java Applications*
- “Example of a simple SQLJ application” in *Developing Java Applications*

### About this task

With the prerequisite knowledge, designing Java routines consists mainly of learning about the unique features and characteristics of Java routines:

### Procedure

- “Supported SQL data types in Java routines”
- “Parameters in Java routines” on page 251
- “Parameter style JAVA procedures” on page 252
- “Parameter style JAVA Java functions and methods” on page 253
- “Returning result sets from JDBC procedures” on page 263
- “Returning result sets from SQLJ procedures” on page 264
- “Restrictions on Java routines” on page 267
- “Table function execution model for Java” on page 64

### What to do next

After having learned about the Java characteristics, you might want to refer to:

- “Creating Java routines from the command line” on page 269

## Supported SQL data types in Java routines

Java programming language data types must be used in Java source code to store SQL data type values according to the JDBC and SQLJ application programming interface specification. The DB2 Driver for JDBC and SQLJ converts the data exchanged between Java source code and a DB2 database according to specific data type mappings.

The data mappings are valid for:

- Java database applications
- Java routines defined as and implemented using PARAMETER STYLE JAVA

The Java data types that map to SQL data types are as follows:

Table 43. SQL Data Types Mapped to Java Declarations

SQL Column Type	Java Data Type	SQL Column Type Description
SMALLINT (500 or 501)	short, boolean	16-bit, signed integer
INTEGER (496 or 497)	int	32-bit, signed integer
BIGINT <sup>1</sup> (492 or 493)	long	64-bit, signed integer
REAL (480 or 481)	float	Single precision floating point
DOUBLE (480 or 481)	double	Double precision floating point
DECIMAL( <i>p,s</i> ) (484 or 485)	java.math.BigDecimal	Packed decimal

Table 43. SQL Data Types Mapped to Java Declarations (continued)

SQL Column Type	Java Data Type	SQL Column Type Description
CHAR( <i>n</i> ) (452 or 453)	java.lang.String	Fixed-length character string of length <i>n</i> where <i>n</i> is from 1 to 254
CHAR( <i>n</i> ) FOR BIT DATA	byte[]	Fixed-length character string of length <i>n</i> where <i>n</i> is from 1 to 254
VARCHAR( <i>n</i> ) (448 or 449)	java.lang.String	Variable-length character string
VARCHAR( <i>n</i> ) FOR BIT DATA	byte[]	Variable-length character string
LONG VARCHAR (456 or 457)	java.lang.String	Long variable-length character string
LONG VARCHAR FOR BIT DATA	byte[]	Long variable-length character string
BLOB( <i>n</i> ) (404 or 405)	java.sql.Blob	Large object variable-length binary string
CLOB( <i>n</i> ) (408 or 409)	java.sql.Clob	Large object variable-length character string
DBCLOB( <i>n</i> ) (412 or 413)	java.sql.Clob	Large object variable-length double-byte character string
DATE (384 or 385)	java.sql.Date	10-byte character string
TIME (388 or 389)	java.sql.Time	8-byte character string
TIMESTAMP (392 or 393)	java.sql.Timestamp	<p>The character string can be from 19 - 32 bytes in length depending on the number of fractional seconds specified.</p> <p>The fractional seconds of the TIMESTAMP data type can be optionally specified with 0-12 digits of timestamp precision.</p> <p>When a timestamp value is assigned to a timestamp variable with a different number of fractional seconds, the value is either truncated or padded with zeros to match the format of the variable.</p>
GRAPHIC( <i>n</i> ) (468 or 469)	java.lang.String	Fixed-length double-byte character string
VARGRAPHIC( <i>n</i> ) (464 or 465)	java.lang.String	Non-null-terminated varying double-byte character string with 2-byte string length indicator
LONGVARGRAPHIC (472 or 473)	java.lang.String	Non-null-terminated varying double-byte character string with 2-byte string length indicator
XML( <i>n</i> ) (408 or 409)	java.sql.Clob	The XML data type is represented in the same way as a CLOB data type; that is as a large object variable-length character string
ARRAY	java.sql.Array	An array of SQL data.

**Note:**

1. For Java applications connected from a DB2 Universal Database Version 8.1 client to a DB2 Universal Database Version 7.1 (or 7.2) server, note the following: when the getObject() method is used to retrieve a BIGINT value, a java.math.BigDecimal object is returned.
2. Parameters of an SQL array data type are mapped to class com.ibm.db2.ARRAY.
3. LONG VARCHAR, LONG VARGRAPHIC, XML, REFERENCE, UDT and ARRAY are not supported for the ARRAY data type.

## Connection contexts in SQLJ routines

With the introduction of multithreaded routines in DB2 Universal Database, Version 8, it is important that SQLJ routines avoid the use of the default connection context. That is, each SQL statement must explicitly indicate the ConnectionContext object, and that context must be explicitly instantiated in the Java method. For instance, in previous releases of DB2, a SQLJ routine could be written as follows:

```
class myClass
{
    public static void myRoutine( short myInput )
    {
        DefaultContext ctx = DefaultContext.getDefaultContext();
        #sql { some SQL statement };
    }
}
```

This use of the default context causes all threads in a multithreaded environment to use the same connection context, which, in turn, will result in unexpected failures.

The SQLJ routine above must be changed as follows:

```
#context MyContext;

class myClass
{
    public static void myRoutine( short myInput )
    {
        MyContext ctx = new MyContext( "jdbc:default:connection", false );
        #sql [ctx] { some SQL statement };
        ctx.close();
    }
}
```

This way, each invocation of the routine will create its own unique ConnectionContext (and underlying JDBC connection), which avoids unexpected interference by concurrent threads.

## Parameters in Java routines

Parameter declaration in Java routines must conform to the requirements of one of the supported parameter styles. The following two parameter styles are supported for Java routines:

- PARAMETER STYLE JAVA
- PARAMETER STYLE DB2GENERAL

It is strongly recommended that you specify the PARAMETER STYLE JAVA clause in the routine CREATE statement. With PARAMETER STYLE JAVA, a routine will use a parameter passing convention that conforms to the Java language and SQLJ Routines specification.

There are some Java routine features that cannot be implemented or used with PARAMETER STYLE JAVA. These are as follows:

- table functions
- scratchpads in functions
- access to the DBINFO structure in functions
- the ability to make a FINAL CALL (and a separate first call) to a function or method

If you need to implement the above features you can implement your routine in C, or write it in Java, using parameter style DB2GENERAL.

Aside from these specific cases, you should always create and implement your Java routines using PARAMETER STYLE JAVA.

### Parameter style JAVA procedures

The recommended parameter style for Java procedure implementations is PARAMETER STYLE JAVA.

The signature of PARAMETER STYLE JAVA stored procedures follows this format:

```
public static void method-name ( SQL-arguments, ResultSet[] result-set-array )  
                                throws SQLException
```

#### *method-name*

Name of the method. During routine registration, this value is specified with the class name in the EXTERNAL NAME clause of the CREATE PROCEDURE statement.

#### *SQL-arguments*

Corresponds to the list of input parameters in the CREATE PROCEDURE statement. OUT or INOUT mode parameters are passed as single-element arrays. For each result set that is specified in the DYNAMIC RESULT SETS clause of the CREATE PROCEDURE statement, a single-element array of type ResultSet is appended to the parameter list.

#### *result-set-array*

Name of the array of ResultSet objects. For every result set declared in the DYNAMIC RESULT SETS parameter of the CREATE PROCEDURE statement, a parameter of type ResultSet[] must be declared in the Java method signature.

The following is an example of a Java stored procedure that accepts an input parameter, and then returns an output parameter and a result set:

```
public static void javastp( int inparm,  
                           int[] outparm,  
                           ResultSet[] rs  
                           )  
                        throws SQLException  
{  
    Connection con = DriverManager.getConnection( "jdbc:default:connection" );  
    PreparedStatement stmt = null;  
    String sql = "SELECT value FROM table01 WHERE index = ?";  
  
    //Prepare the query with the value of index  
    stmt = con.prepareStatement( sql );
```

```

stmt.setInt( 1, inparm );

//Execute query and set output parm
rs[0] = stmt.executeQuery();
outparm[0] = inparm + 1;

//Close open resources
if (stmt != null) stmt.close();
if (con != null) con.close();

return;
}

```

The corresponding CREATE PROCEDURE statement for this stored procedure is as follows:

```

CREATE PROCEDURE javaproc( IN in1 INT, OUT out1 INT )
LANGUAGE java
PARAMETER STYLE java
DYNAMIC RESULT SETS 1
FENCED THREADSAFE
EXTERNAL NAME 'myjar:stpclass.javastp'

```

The preceding statement assumes that the method is in a class called `stpclass`, located in a JAR file that has been cataloged to the database with the Jar ID `myjar`.

**Note:**

1. PARAMETER STYLE JAVA routines use exceptions to pass error data back to the invoker. For complete information, including the exception call stack, refer to administration notification log. Other than this detail, there are no other special considerations for invoking PARAMETER STYLE JAVA routines.
2. JNI calls are not supported in Java routines. However, it is possible to invoke C functionality from Java routines by nesting an invocation of a C routine. This involves moving the desired C functionality into a routine, registering it, and invoking it from within the Java routine.

### Parameter style JAVA Java functions and methods

The recommended parameter style for Java functions and methods is PARAMETER STYLE JAVA.

The signature of PARAMETER STYLE JAVA functions and methods follows this format:

```
public static return-type method-name ( SQL-arguments ) throws SQLException
```

*return-type*

The data type of the value to be returned by the scalar routine. Inside the routine, the return value is passed back to the invoker through a return statement.

*method-name*

Name of the method. During routine registration, this value is specified with the class name in the EXTERNAL NAME clause of the routine's CREATE statement.

*SQL-arguments*

Corresponds to the list of input parameters in the routine's CREATE statement.

The following is an example of a Java function that returns the product of its two input arguments:

```
public static double product( double in1, double in2 ) throws SQLException
{
    return in1 * in2;
}
```

The corresponding CREATE FUNCTION statement for this scalar function is as follows:

```
CREATE FUNCTION product( in1 DOUBLE, in2 DOUBLE )
    RETURNS DOUBLE
    LANGUAGE java
    PARAMETER STYLE java
    NO SQL
    FENCED THREADSAFE
    DETERMINISTIC
    RETURNS NULL ON NULL INPUT
    NO EXTERNAL ACTION
    EXTERNAL NAME 'myjar:udfclass.product'
```

The preceding statement assumes that the method is in a class called `udfclass` that is located in a JAR file that has been installed to the database server with the Jar ID `myjar`. JAR files can be installed to a database server using the `INSTALL_JAR` system-defined procedure.

## DB2GENERAL routines

PARAMETER STYLE DB2GENERAL routines are written in Java. Creating DB2GENERAL routines is very similar to creating routines in other supported programming languages. Once you have created and registered them, you can call them from programs in any language. Typically, you can call JDBC APIs from your stored procedures, but you cannot call them from UDFs.

When developing routines in Java, it is strongly recommended that you register them using the PARAMETER STYLE JAVA clause in the CREATE statement. PARAMETER STYLE DB2GENERAL is still available to enable the implementation of the following features in Java routines:

- table functions
- scratchpads
- access to the DBINFO structure
- the ability to make a FINAL CALL (and a separate first call) to the function or method

If you have PARAMETER STYLE DB2GENERAL routines that do not use any of the above features, it is recommended that you port them to PARAMETER STYLE JAVA.

**DB2GENERAL UDFs:** You can create and use UDFs in Java just as you would in other languages, with only a few minor differences when compared to C UDFs. After you code the UDF, you register it with the database. You can then refer to it in your applications.

In general, if you declare a UDF taking arguments of SQL types *t1*, *t2*, and *t3*, returning type *t4*, it will be called as a Java method with the expected Java signature:

```
public void name ( T1 a, T2 b, T3 c, T4 d ) {.....}
```

Where:

- *name* is the Java method name
- *T1* through *T4* are the Java types that correspond to SQL types *t1* through *t4*.



- *a*, *b*, and *c* are variable names for the input arguments.
- *d* is an variable name that represents the output argument.

For example, given a UDF called `sample!test3` that returns `INTEGER` and takes arguments of type `CHAR(5)`, `BLOB(10K)`, and `DATE`, DB2 expects the Java implementation of the UDF to have the following signature:

```
import COM.ibm.db2.app.*;
public class sample extends UDF {
    public void test3(String arg1, Blob arg2, String arg3,
                    int result) {... }
}
```

Java routines that implement table functions require more arguments. Beside the variables representing the input, an additional variable appears for each column in the resulting row. For example, a table function can be declared as:

```
public void test4(String arg1, int result1,
                Blob result2, String result3);
```

SQL `NULL` values are represented by Java variables that are not initialized. These variables have a value of zero if they are primitive types, and Java `null` if they are object types, in accordance with Java rules. To tell an SQL `NULL` apart from an ordinary zero, you can call the function `isNull` for any input argument:

```
{ ....
  if (isNull(1)) { /* argument #1 was a SQL NULL */ }
  else          { /* not NULL */ }
}
```

In the above example, the argument numbers start at one. The `isNull()` function, like the other functions that follow, are inherited from the `COM.ibm.db2.app.UDF` class.

To return a result from a scalar or table UDF, use the `set()` method in the UDF, as follows:

```
{ ....
  set(2, value);
}
```

Where '2' is the index of an output argument, and `value` is a literal or variable of a compatible type. The argument number is the index in the argument list of the selected output. In the first example in this section, the `int result` variable has an index of 4; in the second, `result1` through `result3` have indices of 2 through 4.

Like C modules used in UDFs and stored procedures, you cannot use the Java standard I/O streams (`System.in`, `System.out`, and `System.err`) in Java routines.

Remember that all the Java class files (or the JARs that contain the classes) that you use to implement a routine must reside in the `sqllib/function` directory, or in a directory specified in the database manager's **CLASSPATH**.

Typically, DB2 calls a UDF many times, once for each row of an input or result set in a query. If `SCRATCHPAD` is specified in the `CREATE FUNCTION` statement of the UDF, DB2 recognizes that some "continuity" is needed between successive invocations of the UDF, and therefore the implementing Java class is not instantiated for each call, but generally speaking once per UDF reference per statement. Generally it is instantiated before the first call and used thereafter, but

can for table functions be instantiated more often. If, however, NO SCRATCHPAD is specified for a UDF, either a scalar or table function, then a clean instance is instantiated for each call to the UDF.

A scratchpad can be useful for saving information across calls to a UDF. While Java and OLE UDFs can either use instance variables or set the scratchpad to achieve continuity between calls, C and C++ UDFs must use the scratchpad. Java UDFs access the scratchpad with the getScratchPad() and setScratchPad() methods available in COM.ibm.db2.app.UDF.

For Java table functions that use a scratchpad, control when you get a new scratchpad instance by using the FINAL CALL or NO FINAL CALL option on the CREATE FUNCTION statement.

The ability to achieve continuity between calls to a UDF by means of a scratchpad is controlled by the SCRATCHPAD and NO SCRATCHPAD option of CREATE FUNCTION, regardless of whether the DB2 scratchpad or instance variables are used.

For scalar functions, you use the same instance for the entire statement.

Note that every reference to a Java UDF in a query is treated independently, even if the same UDF is referenced multiple times. This is the same as what happens for OLE, C and C++ UDFs as well. At the end of a query, if you specify the FINAL CALL option for a scalar function then the object's close() method is called. For table functions the close() method will always be invoked as indicated in the subsection which follows this one. If you do not define a close() method for your UDF class, then a stub function takes over and the event is ignored.

If you specify the ALLOW PARALLEL clause for a Java UDF in the CREATE FUNCTION statement, DB2 may elect to evaluate the UDF in parallel. If this occurs, several distinct Java objects may be created on different partitions. Each object receives a subset of the rows.

As with other UDFs, Java UDFs can be FENCED or NOT FENCED. NOT FENCED UDFs run inside the address space of the database engine; FENCED UDFs run in a separate process. Although Java UDFs cannot inadvertently corrupt the address space of their embedding process, they can terminate or slow down the process. Therefore, when you debug UDFs written in Java, you should run them as FENCED UDFs.

#### **Supported SQL data types in DB2GENERAL routines:**

When you call PARAMETER STYLE DB2GENERAL routines, DB2 converts SQL types to and from Java types for you. Several of these classes are provided in the Java package COM.ibm.db2.app.

*Table 44. DB2 SQL Types and Java Objects*

SQL Column Type	Java Data Type
SMALLINT	short
INTEGER	int
BIGINT	long
REAL <sup>1</sup>	float
DOUBLE	double

Table 44. DB2 SQL Types and Java Objects (continued)

SQL Column Type	Java Data Type
DECIMAL(p,s)	java.math.BigDecimal
NUMERIC(p,s)	java.math.BigDecimal
CHAR(n)	java.lang.String
CHAR(n) FOR BIT DATA	COM.ibm.db2.app.Blob
VARCHAR(n)	java.lang.String
VARCHAR(n) FOR BIT DATA	COM.ibm.db2.app.Blob
LONG VARCHAR	java.lang.String
LONG VARCHAR FOR BIT DATA	COM.ibm.db2.app.Blob
GRAPHIC(n)	java.lang.String
VARGRAPHIC(n)	String
LONG VARGRAPHIC <sup>2</sup>	String
BLOB(n) <sup>2</sup>	COM.ibm.db2.app.Blob
CLOB(n) <sup>2</sup>	COM.ibm.db2.app.Clob
DBCLOB(n) <sup>2</sup>	COM.ibm.db2.app.Clob
DATE <sup>3</sup>	String
TIME <sup>3</sup>	String
TIMESTAMP <sup>3</sup>	String
<b>Note:</b>	
<ol style="list-style-type: none"> <li>1. The difference between REAL and DOUBLE in the SQLDA is the length value (4 or 8).</li> <li>2. The Blob and Clob classes are provided in the COM.ibm.db2.app package. Their interfaces include routines to generate an InputStream and OutputStream for reading from and writing to a Blob, and a Reader and Writer for a Clob.</li> <li>3. SQL DATE, TIME, and TIMESTAMP values use the ISO string encoding in Java, as they do for UDFs coded in C.</li> </ol>	

Instances of classes COM.ibm.db2.app.Blob and COM.ibm.db2.app.Clob represent the LOB data types (BLOB, CLOB, and DBCLOB). These classes provide a limited interface to read LOBs passed as inputs, and write LOBs returned as outputs. Reading and writing of LOBs occur through standard Java I/O stream objects. For the Blob class, the routines getInputStream() and getOutputStream() return an InputStream or OutputStream object through which the BLOB content can be processed bytes-at-a-time. For a Clob, the routines getReader() and getWriter() will return a Reader or Writer object through which the CLOB or DBCLOB content can be processed characters-at-a-time.

If such an object is returned as an output using the set() method, code page conversions might be applied in order to represent the Java Unicode characters in the database code page.

#### Java classes for DB2GENERAL routines:

This interface provides the following routine to fetch a JDBC connection to the embedding application context:

```
public java.sql.Connection getConnection()
```

You can use this handle to run SQL statements. Other methods of the StoredProc interface are listed in the file `sqllib/samples/java/StoredProc.java`.

There are five classes/interfaces that you can use with Java Stored Procedures or UDFs:

- `COM.ibm.db2.app.StoredProc`
- `COM.ibm.db2.app.UDF`
- `COM.ibm.db2.app.Lob`
- `COM.ibm.db2.app.Blob`
- `COM.ibm.db2.app.Clob`

*DB2GENERAL Java class: `COM.ibm.db2.app.StoredProc`:*

A Java class that contains methods intended to be called as PARAMETER STYLE DB2GENERAL stored procedures must be public and must implement this Java interface. You must declare such a class as follows:

```
public class user-STP-class extends COM.ibm.db2.app.StoredProc{ ... }
```

You can only call inherited methods of the `COM.ibm.db2.app.StoredProc` interface in the context of the currently executing stored procedure. For example, you cannot use operations on LOB arguments, result-setting or status-setting calls after a stored procedure returns. A Java exception will be thrown if you violate this rule.

Argument-related calls use a column index to identify the column being referenced. These start at 1 for the first argument. All arguments of a PARAMETER STYLE DB2GENERAL stored procedure are considered INOUT and thus are both inputs and outputs.

Any exception returned from the stored procedure is caught by the database and returned to the caller with SQLCODE -4302, SQLSTATE 38501. A JDBC SQLException or SQLWarning is handled specially and passes its own SQLCODE, SQLSTATE etc. to the calling application verbatim.

The following methods are associated with the `COM.ibm.db2.app.StoredProc` class:

```
public StoredProc() [default constructor]
```

This constructor is called by the database before the stored procedure call.

```
public boolean isNull(int) throws Exception
```

This function tests whether an input argument with the given index is an SQL NULL.

```
public void set(int, short) throws Exception
public void set(int, int) throws Exception
public void set(int, double) throws Exception
public void set(int, float) throws Exception
public void set(int, java.math.BigDecimal) throws Exception
public void set(int, String) throws Exception
public void set(int, COM.ibm.db2.app.Blob) throws Exception
public void set(int, COM.ibm.db2.app.Clob) throws Exception
```

This function sets the output argument with the given index to the given value. The index has to refer to a valid output argument, the data type must match, and the value must have an acceptable length and contents. Strings with Unicode characters must be representable in the database code page. Errors result in an exception being thrown.

```
public java.sql.Connection getConnection() throws Exception
```

This function returns a JDBC object that represents the calling application's connection to the database. It is analogous to the result of a `SQLConnect()` call in a C stored procedure.

*DB2GENERAL Java class: COM.ibm.db2.app.UDF:*

A Java class that contains methods intended to be called as PARAMETER STYLE DB2GENERAL UDFs must be public and must implement this Java interface. You must declare such a class as follows:

```
public class user-UDF-class extends COM.ibm.db2.app.UDF{ ... }
```

You can only call methods of the `COM.ibm.db2.app.UDF` interface in the context of the currently executing UDF. For example, you cannot use operations on LOB arguments, result- or status-setting calls, etc., after a UDF returns. A Java exception will be thrown if this rule is violated.

Argument-related calls use a column index to identify the column being set. These start at 1 for the first argument. Output arguments are numbered higher than the input arguments. For example, a scalar UDF with three inputs uses index 4 for the output.

Any exception returned from the UDF is caught by the database and returned to the caller with `SQLCODE -4302`, `SQLSTATE 38501`.

The following methods are associated with the `COM.ibm.db2.app.UDF` class:

```
public UDF() [default constructor]
```

This constructor is called by the database at the beginning of a series of UDF calls. It precedes the first call to the UDF.

```
public void close()
```

This function is called by the database at the end of a UDF evaluation, if the UDF was created with the `FINAL CALL` option. It is analogous to the final call for a C UDF. For table functions, `close()` is called after the `CLOSE` call to the UDF method (if `NO FINAL CALL` is coded or defaulted), or after the `FINAL` call (if `FINAL CALL` is coded). If a Java UDF class does not implement this function, a no-op stub will handle and ignore this event.

```
public int getCallType() throws Exception
```

Table function UDF methods use `getCallType()` to find out the call type for a particular call. It returns a value as follows (symbolic defines are provided for these values in the `COM.ibm.db2.app.UDF` class definition):

- -2 FIRST call
- -1 OPEN call
- 0 FETCH call
- 1 CLOSE call
- 2 FINAL call

```
public boolean isNull(int) throws Exception
```

This function tests whether an input argument with the given index is an SQL NULL.

```
public boolean needToSet(int) throws Exception
```

This function tests whether an output argument with the given index needs to be set. This can be false for a table UDF declared with DBINFO, if that column is not used by the UDF caller.

```
public void set(int, short) throws Exception
public void set(int, int) throws Exception
public void set(int, double) throws Exception
public void set(int, float) throws Exception
public void set(int, java.math.BigDecimal) throws Exception
public void set(int, String) throws Exception
public void set(int, COM.ibm.db2.app.Blob) throws Exception
public void set(int, COM.ibm.db2.app.Clob) throws Exception
```

This function sets the output argument with the given index to the given value. The index has to refer to a valid output argument, the data type must match, and the value must have an acceptable length and contents. Strings with Unicode characters must be representable in the database code page. Errors result in an exception being thrown.

```
public void setSQLstate(String) throws Exception
```

This function can be called from a UDF to set the SQLSTATE to be returned from this call. A table UDF should call this function with "02000" to signal the end-of-table condition. If the string is not acceptable as an SQLSTATE, an exception will be thrown.

```
public void setSQLmessage(String) throws Exception
```

This function is similar to the setSQLstate function. It sets the SQL message result. If the string is not acceptable (for example, longer than 70 characters), an exception will be thrown.

```
public String getFunctionName() throws Exception
```

This function returns the name of the executing UDF.

```
public String getSpecificName() throws Exception
```

This function returns the specific name of the executing UDF.

```
public byte[] getDBinfo() throws Exception
```

This function returns a raw, unprocessed DBINFO structure for the executing UDF, as a byte array. You must first declare it with the DBINFO option.

```
public String getDBname() throws Exception
public String getDBauthid() throws Exception
public String getDBtbschema() throws Exception
public String getDBtbname() throws Exception
public String getDBcolname() throws Exception
public String getDBver_rel() throws Exception
public String getDBplatform() throws Exception
public String getDBapplid() throws Exception
```

These functions return the value of the appropriate field from the DBINFO structure of the executing UDF.

```
public int getDBprocid() throws Exception
```

This function returns the routine id of the procedure which directly or indirectly invoked this routine. The routine id matches the ROUTINEID column in SYSCAT.ROUTINES which can be used to retrieve the name of the invoking procedure. If the executing routine is invoked from an application, getDBprocid() returns 0.

```
public int[] getDBcodepg() throws Exception
```

This function returns the SBCS, DBCS, and composite code page numbers for the database, from the DBINFO structure. The returned integer array has the respective numbers as its first three elements.

```
public byte[] getScratchpad() throws Exception
```

This function returns a copy of the scratchpad of the currently executing UDF. You must first declare the UDF with the SCRATCHPAD option.

```
public void setScratchpad(byte[]) throws Exception
```

This function overwrites the scratchpad of the currently executing UDF with the contents of the given byte array. You must first declare the UDF with the SCRATCHPAD option. The byte array must have the same size as getScratchpad() returns.

*DB2GENERAL Java class: COM.ibm.db2.app.Lob:*

This class provides utility routines that create temporary Blob or Clob objects for computation inside routines.

The following methods are associated with the COM.ibm.db2.app.Lob class:

```
public static Blob newBlob() throws Exception
```

This function creates a temporary Blob. It will be implemented using a LOCATOR if possible.

```
public static Clob newClob() throws Exception
```

This function creates a temporary Clob. It will be implemented using a LOCATOR if possible.

*DB2GENERAL Java class: COM.ibm.db2.app.Blob:*

An instance of this class is passed by the database to represent a BLOB as routine input, and can be passed back as output. The application might create instances, but only in the context of an executing routine. Uses of these objects outside such a context will throw an exception.

The following methods are associated with the COM.ibm.db2.app.Blob class:

```
public long size() throws Exception
```

This function returns the length (in bytes) of the BLOB.

```
public java.io.InputStream getInputStream() throws Exception
```

This function returns a new InputStream to read the contents of the BLOB. Efficient seek/mark operations are available on that object.

```
public java.io.OutputStream getOutputStream() throws Exception
```

This function returns a new OutputStream to append bytes to the BLOB. Appended bytes become immediately visible on all existing InputStream instances produced by this object's getInputStream() call.

*DB2GENERAL Java class: COM.ibm.db2.app.Clob:*

An instance of this class is passed by the database to represent a CLOB or DBCLOB as routine input, and can be passed back as output. The application

might create instances, but only in the context of an executing routine. Uses of these objects outside such a context will throw an exception.

Clob instances store characters in the database code page. Some Unicode characters cannot not be represented in this code page, and can cause an exception to be thrown during conversion. This can happen during an append operation, or during a UDF or StoredProc set() call. This is necessary to hide the distinction between a CLOB and a DBCLOB from the Java programmer.

The following methods are associated with the `COM.ibm.db2.app.Clob` class:

```
public long size() throws Exception
```

This function returns the length (in characters) of the CLOB.

```
public java.io.Reader getReader() throws Exception
```

This function returns a new Reader to read the contents of the CLOB or DBCLOB. Efficient seek/mark operations are available on that object.

```
public java.io.Writer getWriter() throws Exception
```

This function returns a new Writer to append characters to this CLOB or DBCLOB. Appended characters become immediately visible on all existing Reader instances produced by this object's `GetReader()` call.

## Passing parameters of data type ARRAY to Java routines

The ability to pass parameters of data type ARRAY to and from Java procedures is supported in DB2 9.5.

### About this task

You would choose to implement the use of arrays being passed between applications and Java stored procedures if you want to pass:

- large amounts of homogenous data to a procedure using a single parameter.
- a variable number of inputs of the same data type to a procedure using only a single parameter.

For example, you can pass all the names of students in a class to a procedure without knowing the number of students using a single parameter. If you did not use the ARRAY data type, to do this, you would require one parameter per student name.

### Procedure

To pass a parameter of type ARRAY:

1. The ARRAY data type must be already defined. To define an array type, the `CREATE TYPE` statement must be executed.
2. The procedure definition must include a parameter of the defined type. For example, if an ARRAY data type named `IntArray` is created by executing the `CREATE TYPE` statement, to pass a parameter of this type to a procedure, do the following:



## Example

```
CREATE PROCEDURE inArray (IN input IntArray)
LANGUAGE JAVA
PARAMETER STYLE JAVA
EXTERNAL NAME 'MyProcs:MyArrayProcs!inArray';
```

In the procedure definition, the array parameter is typed as `java.sql.Array`. Within the procedure, the argument is mapped to a Java array using the `getArray()` method, as shown in the example below. Notice the use of `Integer` rather than `int` (or other primitive types) for arrays.

```
static void inArray(java.sql.Array input)
{
    Integer[] inputArr = (Integer [])input.getArray();
    int sum = 0;
    for(int i=0, i < inputArr.length; i++)
    {
        sum += inputArr[i];
    }
}
```

## Returning result sets from JDBC procedures

You can develop JDBC procedures that return result sets to the invoking routine or application. In JDBC procedures, the returning of result sets is handled with `ResultSet` objects.

### Procedure

To return a result set from a JDBC procedure:

1. For each result set that is to be returned, include a parameter of type `ResultSet[]` in the procedure declaration. For example, the following function signature accepts an array of `ResultSet` objects:

```
public static void getHighSalaries(
    double inSalaryThreshold,    // double input
    int[] errorCode,             // SQLCODE output
    ResultSet[] rs)              // ResultSet output
```

2. Open the invoker's database connection (using a `Connection` object):

```
Connection con =
    DriverManager.getConnection("jdbc:default:connection");
```

3. Prepare the SQL statement that will generate the result set (using a `PreparedStatement` object). In the following example, the prepare is followed by the assignment of an input variable (called `inSalaryThreshold` - see the function signature example above) to the value of the parameter marker in the query statement. A parameter marker is indicated with a "?" or a colon, followed by a name (`:name`).

```
String query =
    "SELECT name, job, CAST(salary AS DOUBLE) FROM staff " +
    " WHERE salary > ? " +
    " ORDER BY salary";
```

```
PreparedStatement stmt = con.prepareStatement(query);
stmt.setDouble(1, inSalaryThreshold);
```

4. Execute the statement:

```
rs[0] = stmt.executeQuery();
```

5. End the procedure body.

## What to do next

If you have not done so already, develop a client application or caller routine that will accept result sets from your stored procedure.

## Returning result sets from SQLJ procedures

You can develop SQLJ procedures that return result sets to the invoking routine or application. In SQLJ procedures, the returning of result sets is handled with `ResultSet` objects.

### Procedure

To return a result set from an SQLJ procedure:

1. Declare an iterator class to handle query data. For example:

```
#sql iterator SpServerEmployees(String, String, double);
```

2. For each result set that is to be returned, include a parameter of type `ResultSet[]` in the procedure declaration. For example the following function signature accepts an array of `ResultSet` objects:

```
public static void getHighSalaries(  
    double inSalaryThreshold,      // double input  
    int[] errorCode,              // SQLCODE output  
    ResultSet[] rs)                // ResultSet output
```

3. Instantiate an iterator object. For example:

```
SpServerEmployees c1;
```

4. Assign the SQL statement that will generate the result set to an iterator. In the following example, a host variable (called `inSalaryThreshold` -- see the function signature example above) is used in the query's `WHERE` clause:

```
#sql c1 = {SELECT name, job, CAST(salary AS DOUBLE)  
          FROM staff  
          WHERE salary > :inSalaryThreshold  
          ORDER BY salary};
```

5. Execute the statement and get the result set:

```
rs[0] = c1.getResultSet();
```

## What to do next

If you have not done so already, develop a client application or caller routine that will accept result sets from your procedure.

## Receiving procedure result sets in JDBC applications and routines

You can receive result sets from procedures you invoke from a JDBC routine or application.

### About this task

To accept procedure result sets from within a JDBC routine or application:

### Procedure

1. Open a database connection (using a `Connection` object):

```
Connection con =  
    DriverManager.getConnection("jdbc:db2:sample", userid, passwd);
```

- Prepare the CALL statement that will invoke a procedure that returns result sets (using a CallableStatement object). In the following example, a procedure named GET\_HIGH\_SALARIES is invoked. The prepare is followed by the assignment of an input variable (called inSalaryThreshold -- a numeric value to be passed to the procedure) to the value of the parameter marker in the previous statement. A parameter marker is indicated with a "?" or by a colon followed by a name (:name).

```
String query = "CALL GET_HIGH_SALARIES(?)";

CallableStatement stmt = con.prepareCall(query);
stmt.setDouble(1, inSalaryThreshold);
```

- Call the procedure:
 

```
stmt.execute();
```
- Use the CallableStatement object's getResultSet() method to accept the first result set from the procedure and fetch the rows from the result sets using the fetchAll() method:

```
ResultSet rs = stmt.getResultSet();

// Result set rows are fetched and printed to screen.
while (rs.next())
{
    r++;
    System.out.print("Row: " + r + ": ");
    for (int i=1; i <= numOfColumns; i++)
    {
        System.out.print(rs.getString(i));
        if (i != numOfColumns)
        {
            System.out.print(", ");
        }
    }
    System.out.println();
}
```

- For multiple result sets, use the CallableStatement object's getNextResultSet() method to enable the following result set to be read. Then repeat the process in the previous step, where the ResultSet object accepts the current result set, and fetches the result set rows. For example:

```
while (callStmt.getMoreResults())
{
    rs = callStmt.getResultSet()

    ResultSetMetaData stmtInfo = rs.getMetaData();
    int numOfColumns = stmtInfo.getColumnCount();
    int r = 0;

    // Result set rows are fetched and printed to screen.
    while (rs.next())
    {
        r++;
        System.out.print("Row: " + r + ": ");
        for (int i=1; i <= numOfColumns; i++)
        {
            System.out.print(rs.getString(i));
            if (i != numOfColumns)
            {
                System.out.print(", ");
            }
        }
        System.out.println();
    }
}
```

6. Close the ResultSet object with its close() method:

```
rs.close();
```

## Receiving procedure result sets in SQLJ applications and routines

You can receive result sets from procedures you invoke from an SQLJ routine or application.

### Procedure

To accept procedure result sets from within an SQLJ routine or application:

1. Open a database connection (using a Connection object):

```
Connection con =  
    DriverManager.getConnection("jdbc:db2:sample", userid, passwd);
```

2. Set the default context (using a DefaultContext object):

```
DefaultContext ctx = new DefaultContext(con);  
DefaultContext.setDefaultContext(ctx);
```

3. Set the execution context (using an ExecutionContext object):

```
ExecutionContext execCtx = ctx.getExecutionContext();
```

4. Invoke a procedure that returns result sets. In the following example, a procedure named GET\_HIGH\_SALARIES is invoked, and is passed an input variable (called inSalaryThreshold):

```
#sql {CALL GET_HIGH_SALARIES(:in inSalaryThreshold, :out outErrorCode)};
```

5. Declare a ResultSet object, and use the ExecutionContext object's getNextResultSet() method to accept result sets from the procedure. For multiple result sets, put the getNextResultSet() call in a loop structure. Each result set returned by the procedure will spawn a loop iteration. Inside the loop, you can fetch the result set rows method, and then close the result set object (with the ResultSet object's close() method). For example:

```
ResultSet rs = null;  
  
while ((rs = execCtx.getNextResultSet()) != null)  
{  
    ResultSetMetaData stmtInfo = rs.getMetaData();  
    int numOfColumns = stmtInfo.getColumnCount();  
    int r = 0;  
  
    // Result set rows are fetched and printed to screen.  
    while (rs.next())  
    {  
        r++;  
        System.out.print("Row: " + r + ": ");  
        for (int i=1; i <= numOfColumns; i++)  
        {  
            System.out.print(rs.getString(i));  
            if (i != numOfColumns)  
            {  
                System.out.print(", ");  
            }  
        }  
        System.out.println();  
    }  
    rs.close();  
}
```

## Restrictions on Java routines

The following restrictions apply to Java routines:

- The system-defined procedure `install_jar` used to deploy Java routine code in JAR files to the database server file system cannot be called in a Java database application when using the DB2 Universal JDBC Driver. This driver does not support this procedure.

The recommended alternative is to use the DB2 Command Line Processor.

- The `PROGRAM TYPE MAIN` clause is not supported in `CREATE PROCEDURE` or `CREATE FUNCTION` statements for Java routines regardless of the `PARAMETER STYLE` clause value specified.
- The following features are not supported with parameter style `JAVA`:
  - table functions
  - scratchpads in functions
  - access to the `DBINFO` structure in functions
  - `FINAL CALL` invocation in functions

The recommended alternative if you need these features is to create a Java function using parameter style `DB2GENERAL` or to create the function using either the C or C++ programming language.

- Java Native Interface (JNI) calls from Java routines are not supported. If you need to invoke C or C++ code from a Java routine, you can do so by invoking a separately defined C or C++ routine.
- `NOT FENCED` Java routines are currently not supported. A Java routine defined as `NOT FENCED` will be invoked as if it had been defined as `FENCED THREADSAFE`.
- Java stored procedures cannot depend on any non-system resources, such as properties files. If you call a Java stored procedure that depends on non-system resources, those resources are not loaded, and no error is returned.

## Table function execution model for Java

For table functions written in Java and using `PARAMETER STYLE DB2GENERAL`, it is important to understand what happens at each point in DB2's processing of a given statement. The following table details this information for a typical table function. Covered are both the `NO FINAL CALL` and the `FINAL CALL` cases, assuming `SCRATCHPAD` in both cases.

Point in scan time	NO FINAL CALL LANGUAGE JAVA SCRATCHPAD	FINAL CALL LANGUAGE JAVA SCRATCHPAD
Before the first <code>OPEN</code> for the table function	<ul style="list-style-type: none"> <li>• No calls.</li> </ul>	<ul style="list-style-type: none"> <li>• Class constructor is called (means new scratchpad). UDF method is called with <code>FIRST</code> call.</li> <li>• Constructor initializes class and scratchpad variables. Method connects to Web server.</li> </ul>

Point in scan time	NO FINAL CALL LANGUAGE JAVA SCRATCHPAD	FINAL CALL LANGUAGE JAVA SCRATCHPAD
At each OPEN of the table function	<ul style="list-style-type: none"> <li>• Class constructor is called (means new scratchpad). UDF method is called with OPEN call.</li> <li>• Constructor initializes class and scratchpad variables. Method connect to Web server, and opens the scan for Web data.</li> </ul>	<ul style="list-style-type: none"> <li>• UDF method is opened with OPEN call.</li> <li>• Method opens the scan for whatever Web data it wants. (Might be able to avoid reopen after a CLOSE reposition, depending on what is saved in the scratchpad.)</li> </ul>
At each FETCH for a new row of table function data	<ul style="list-style-type: none"> <li>• UDF method is called with FETCH call.</li> <li>• Method fetches and returns next row of data, or EOT.</li> </ul>	<ul style="list-style-type: none"> <li>• UDF method is called with FETCH call.</li> <li>• Method fetches and returns new row of data, or EOT.</li> </ul>
At each CLOSE of the table function	<ul style="list-style-type: none"> <li>• UDF method is called with CLOSE call. <code>close()</code> method if it exists for class.</li> <li>• Method closes its Web scan and disconnects from the Web server. <code>close()</code> does not need to do anything.</li> </ul>	<ul style="list-style-type: none"> <li>• UDF method is called with CLOSE call.</li> <li>• Method might reposition to the top of the scan, or close the scan. It can save any state in the scratchpad, which will persist.</li> </ul>
After the last CLOSE of the table function	<ul style="list-style-type: none"> <li>• No calls.</li> </ul>	<ul style="list-style-type: none"> <li>• UDF method is called with FINAL call. <code>close()</code> method is called if it exists for class.</li> <li>• Method disconnects from the Web server. <code>close()</code> method does not need to do anything.</li> </ul>

**Note:**

1. The term "UDF method" refers to the Java class method that implements the UDF. This is the method identified in the EXTERNAL NAME clause of the CREATE FUNCTION statement.

---

## Creating Java routines

### Before you begin

Creating Java routines consists of:

- Executing a CREATE statement that defines the routine in a DB2 database server
- Developing the routine implementation that corresponds to the routine definition

The ways in which you can create Java routines follow:

- Using IBM Data Studio
- Using IBM Optim Development Studio
- Using the DB2 routine development features in IBM Rational Application Developer
- Using the DB2 Command Window

In general it is easiest to create Java routines using the IBM Data Studio, although many developers enjoy the ability to create Java routines from within the

integrated Java development environment provided by IBM Rational Application Developer. If these graphical tools are not available for use, the DB2 Command Window provides similar support through a command line interface.

- Review Chapter 7, “Java routines,” on page 245.
- Ensure that you have access to a DB2 Version 9 server, including instances and databases.
- Ensure that the operating system is at a version level that is supported by DB2 database products.
- Ensure that the “Supported Java routine development software” on page 245 is at a version level that is supported for Java routine development.
- Ensure a valid “Specification of a driver for Java routines” on page 247 development.
- Authority to execute the CREATE PROCEDURE or CREATE FUNCTION statement.

For a list of restrictions associated with Java routines see:

- “Restrictions on Java routines” on page 267

### **About this task**

Create Java routines using one of the following procedures:

#### **Procedure**

- Creating Java routines using IBM Data Studio
- Creating Java routines using Rational Application Developer
- “Creating Java routines from the command line”

## **Creating Java routines from the command line**

Procedures and functions that reference a Java class are created in a similar way to external routines with other implementations. This task comprises a few steps including the formulation of the CREATE statement for the routine, the coding and compilation (translation) of the routine implementation, and the deployment of the Java class to a DB2 database server.

### **Before you begin**

- Review Chapter 7, “Java routines,” on page 245.
- Ensure that you have access to a DB2 Version 9 database server, including instances and databases.
- Ensure that the operating system is at a version level that is supported by DB2 database products.
- Ensure that the “Supported Java routine development software” on page 245 is at a version level that is supported for Java routine development.
- Ensure a valid “Specification of a driver for Java routines” on page 247 development.
- Authority to execute the CREATE PROCEDURE or CREATE FUNCTION statement.

### **About this task**

You would choose to implement a Java routine if:

- You want to encapsulate complex logic into a routine that accesses the database or that performs an action outside of the database.
- You require the encapsulated logic to be invoked from any of: multiple applications, the CLP, another routine (procedure, function (UDF), or method), or a trigger.
- You are most comfortable coding this logic using Java and one of the JDBC or SQLJ application programming interfaces.

## Procedure

1. Code the routine logic in Java.
  - For general information about Java routines and Java routine features, see the topics referenced in the Prerequisites section.
  - A routine parameter signature must be implemented using one of the supported parameter styles. It is strongly recommended that parameter style JAVA be used for all Java routines. For more on parameter signatures and parameter implementations see:
    - “Parameters in Java routines” on page 251
    - “Parameter style JAVA procedures” on page 252
    - “Parameter style JAVA Java functions and methods” on page 253
  - Declare variables in the same manner as is done for Java database applications. Be careful to correctly use data types that map to DB2 SQL data types. For more on data type mapping between DB2 and Java data types see:
    - “Data types that map to database data types in Java applications” in *Developing Java Applications*
  - Include routine logic. Routine logic can consist of any code supported in the Java programming language. It can also include the execution of SQL statements in the same manner as is done in Java database applications. For more on executing SQL statements in Java code see:
    - “JDBC interfaces for executing SQL” in *Developing Java Applications*
    - “SQL statement execution in SQLJ applications” in *Developing Java Applications*
  - If the routine is a procedure and you might want to return a result set to the caller of the routine, you do not require any parameters for the result set. For more on returning result sets from Java routines:
    - “Returning result sets from JDBC procedures” on page 263
    - “Returning result sets from SQLJ procedures” on page 264
  - Set a routine return value at the end of the routine.
2. Build your code to produce a Java class file or JAR file containing a collection of Java class files. For information on how to build Java routine code, see:
  - “Building JDBC routines” in *Developing Java Applications*
  - “Building SQL routines” in *Developing Java Applications*
3. Copy the class file to the DB2 database server or install the JAR file to the DB2 database server. For information on how to do this, see:
  - “Deploying Java routine class files to DB2 database servers” on page 274
  - “JAR file administration on the database server” on page 276

It is recommended that you store class files associated with DB2 routines in the *function directory*. To find out more about the function directory, see information related to the the EXTERNAL clause in one of the following statements: CREATE PROCEDURE or CREATE FUNCTION.



You can copy the library to another directory on the server if you wish, but to successfully invoke the routine you must note the fully qualified path name of your library as you will require it for the next step.

4. Execute either dynamically or statically the appropriate CREATE statement for the routine type: CREATE PROCEDURE or CREATE FUNCTION.
  - Specify the LANGUAGE clause with: JAVA
  - Specify the PARAMETER STYLE clause with the name of the supported parameter style that was implemented in the routine code. It is strongly recommended that PARAMETER STYLE JAVA be used unless the features you require are only supported when PARAMETER STYLE DB2GENERAL is used.
  - Specify the EXTERNAL clause with the name of the JAR file or Java class to be associated with the routine using one of the following values:
    - the fully qualified path name of the Java class file
    - the relative path name of the routine Java class file relative to the function directory.
    - the JAR file ID of the JAR file on the database server that contains the Java class

By default DB2 will look for the library in the function directory unless a JAR file ID and class, fully qualified path name, or relative path name for it is specified in the EXTERNAL clause.

- Specify DYNAMIC RESULT SETS with a numeric value if your routine is a procedure and it will return one or more result sets to the caller.
- Specify any other non-default clause values in the CREATE statement to be used to characterize the routine.

## What to do next

To invoke your Java routine, see Chapter 10, “Invoking routines,” on page 295

---

## Building Java routine code

Once Java routine implementation code has been written, it must be built before the routine assembly can be deployed and the routine invoked. The steps required to build Java routines are similar to those required to build any external routine however there are some differences.

### Procedure

There are a few ways to build Java routines:

- Using the graphical tools provided with IBM Data Studio
- Using the graphical tools provided within IBM Optim Development Studio
- Using the graphical tools provided within IBM Rational Application Developer
- Using DB2 sample build scripts
- Entering commands from a DB2 Command Window

The graphical tools and DB2 can be customized to build Java routines for a variety of operating systems and with a variety of settings. The sample build scripts and batch files for routines are designed for building DB2 sample routines (procedures and user-defined functions) for a particular operating system using the default supported development software.

There is a separate set of DB2 sample build scripts and batch files for Java routines created with JDBC and SQLJ. In general it is easiest to build Java routines using

the graphical tools or the build scripts which can easily be modified if required, however it is often helpful to know how to build routines from DB2 Command Window as well.

## Building JDBC routines

You can use a Java `makefile` or the `javac` command to build JDBC routines. After you build those routines, you need to catalog them.

### About this task

The following steps demonstrate how to build and run these routines:

- The `SpServer` sample JDBC stored procedure
- The `UDFsrv` sample user-defined function, which has no SQL statements
- The `UDFsqlsv` sample user-defined function, which has SQL statements

### Procedure

- To build and run the `SpServer.java` stored procedure on the server, from the command line:
  1. Compile `SpServer.java` to produce the file `SpServer.class` with this command:

```
javac SpServer.java
```
  2. Copy `SpServer.class` to the `sqllib\function` directory on Windows operating systems, or to the `sqllib/function` directory on UNIX.
  3. Catalog the routines by running the `spcat` script on the server. The `spcat` script connects to the sample database, uncatalogs the routines if they were previously cataloged by calling `SpDrop.db2`, then catalogs them by calling `SpCreate.db2`, and finally disconnects from the database. You can also run the `SpDrop.db2` and `SpCreate.db2` scripts individually.
  4. Stop and restart the database to allow the new class file to be recognized. If necessary, set the file mode for the class file to "read" so it is readable by the fenced user.
  5. Compile and run the `SpClient` client application to access the stored procedure class.
- To build and run the `UDFsrv.java` user-defined function program (user-defined function with no SQL statements) on the server, from the command line:
  1. Compile `UDFsrv.java` to produce the file `UDFsrv.class` with this command:

```
javac UDFsrv.java
```
  2. Copy `UDFsrv.class` to the `sqllib\function` directory on Windows operating systems, or to the `sqllib/function` directory on UNIX.
  3. Compile and run a client program that calls `UDFsrv`.

To access the `UDFsrv` library, you can use the `UDFcli.java` JDBC application, or the `UDFcli.sqlj` SQLJ client application. Both versions of the client program contain the `CREATE FUNCTION` SQL statement that you use to register the user-defined functions with the database, and also contain SQL statements that use the user-defined functions.
- To build and run the `UDFsqlsv.java` user-defined function program (user-defined function with SQL statements) on the server, from the command line:
  1. Compile `UDFsqlsv.java` to produce the file `UDFsqlsv.class` with this command:

```
javac UDFsqlsv.java
```
  2. Copy `UDFsqlsv.class` to the `sqllib\function` directory on Windows operating systems, or to the `sqllib/function` directory on UNIX.

3. Compile and run a client program that calls UDFsqlsv.

To access the UDFsqlsv library, you can use the UDFsqlcl.java JDBC application. The client program contains the CREATE FUNCTION SQL statement that you use to register the user-defined functions with the database, and also contains SQL statements that use the user-defined functions.

## Building SQL routines

You can use a Java makefile or the bldsqljs build file to build SQLJ routines. After you build those routines, you need to catalog them.

### About this task

The following steps demonstrate how to build and run the SpServer sample SQLJ stored procedure. These steps use the build file, bldsqljs (UNIX), or bldsqljs.bat (Windows), which contains commands to build either an SQLJ applet or application.

The build file takes up to six parameters: \$1, \$2, \$3, \$4, \$5, and \$6 on UNIX, and %1, %2, %3, %4, %5, and %6 on Windows. The first parameter specifies the name of your program. The second parameter specifies the user ID for the database instance, the third parameter specifies the password. The fourth parameter specifies the server name. The fifth parameter specifies the port number. And the sixth parameter specifies the database name. For all but the first parameter, program name, default values can be used. See the build file for details about using default parameter values.

### Procedure

1. Build the stored procedure application with this command:

```
bldsqljs SpServer <userid> <password> <server_name> <port_number> <db_name>
```

2. Catalog the stored procedure with this command:

```
spcat
```

This script connects to the sample database, uncatalogs the routines if they were previously cataloged by calling SpDrop.db2, then catalogs them by calling SpCreate.db2, and finally disconnects from the database. You can also run the SpDrop.db2 and SpCreate.db2 scripts individually.

3. Stop and restart the database to allow the new class file to be recognized. If necessary, set the file mode for the class file to read, so it is readable by the fenced user.
4. Compile and run the SpClient client application to access the stored procedure class. You can build SpClient with the application build file, bldsqlj (UNIX) or bldsqlj.bat (Windows).

## Compile and link options for Java (SQLJ) routines

### SQLJ routine options for UNIX

The bldsqljs build script builds SQLJ routines on UNIX operating systems. bldsqljs specifies a set of SQLJ translator and customizer options.

**Recommendation:** Use the same SQLJ translator and customizer options that bldsqljs uses when you build your SQLJ routines on UNIX platforms.

The options that bldsqljs includes are:

**sqlj** The SQLJ translator (also compiles the program).

**"\${progname}.sqlj"**

The SQLJ source file. The `progname=${1%.sqlj}` command removes the extension if it was included in the input file name, so when the extension is added back again, it is not duplicated.

**db2sqljcustomize**

The SQLJ profile customizer.

**-url** Specifies a JDBC URL for establishing a database connection, such as `jdbc:db2://servername:50000/sample`.

**-user** Specifies a user ID.

**-password**

Specifies a password.

**"\${progname}\_SJProfile0"**

Specifies a serialized profile for the program.

### SQLJ routine options for Windows

The `bldsqljs.bat` batch file builds SQLJ routines on Windows operating systems. `bldsqljs.bat` specifies a set of SQLJ translator and customizer options.

**Recommendation:** Use the same SQLJ translator and customizer options that `bldsqljs.bat` uses when you build your SQLJ routines on Windows operating systems.

The following SQLJ translator and customizer options are used in the `bldsqljs.bat` batch file on Windows operating systems. These are the options that DB2 recommends that you use to build SQLJ routines (stored procedures and user-defined functions).

**sqlj** The SQLJ translator (also compiles the program).

**%1.sqlj**

The SQLJ source file.

**db2sqljcustomize**

The DB2 for Java profile customizer.

**-url** Specifies a JDBC URL for establishing a database connection, such as `jdbc:db2://servername:50000/sample`.

**-user** Specifies a user ID.

**-password**

Specifies a password.

**%1\_SJProfile0**

Specifies a serialized profile for the program.

---

## Deploying Java routine class files to DB2 database servers

Java routine implementations must be deployed to the DB2 database server file system so that they can be located, loaded, and run upon routine invocation.

One or more Java routine implementations can be included in an individual Java class file. Java class files containing Java routine implementations can be collected together into JAR files. The Java class files that you use to implement a routine must reside in a JAR file you have installed in the DB2 database.

Prerequisites:

- Identify the DB2 data server to which you want to deploy the routine class.
- On UNIX operating systems, identify the user ID of the DB2 instance owner. If this is not known, see your database administrator.

To deploy individual Java routine class files:

- Copy the Java routine class into the DB2 function directory.

On UNIX operating systems, the function directory is defined as: *install\_path/function* where *install\_path* is the DB2 database manager installation path. For example, *\$HOME/sql1lib/function*, where *\$HOME* is the home directory of the instance owner.

On Windows operating systems, the function directory is defined as: *instance\_profile\_path\function* where the *instance\_profile\_path* is the path which was specified in the **db2icrt** (create instance) command. You can find the instance profile path name by issuing the **db2set** command as follows:

```
db2set DB2INSTPROF
```

For example, C:\Documents and Settings\All Users\Application Data\IBM\DB2\db2copy1\function

If you declare a class to be part of a Java package, create subdirectories in the function directory that correspond to the fully qualified class names and place the related class files in the corresponding subdirectory. For example, if you create a class called *ibm.tests.test1* for a Linux operating system, store the corresponding Java bytecode file (named *test1.class*) in *\$HOME/sql1lib/function/ibm/tests*, where *\$HOME* is the home directory of the instance owner.

To deploy JAR files containing Java routine class files:

- You must install the JAR file containing Java routine class files to the DB2 database server file system. Refer to “JAR file administration on the database server” on page 276.

Once the Java routine class files have been deployed and the CREATE statement has been executed to define the routine in the database, you can invoke the routine.

### Deploying Java routine class files to DB2 database servers with dependent classes

When the Java routine class files have dependencies on classes that are not part of the standard Java or DB2 classes, repeat the steps identified in the previous section for each dependent class.

Alternatively, the DB2 database can be configured to search the directories in the **CLASSPATH** environment variable in order to detect dependant classes. On Windows operating systems, the database server will automatically search the specified directories in the **CLASSPATH** system environment variable. On UNIX operating systems, the database server will search the instance owner's **CLASSPATH** environment variable if the text " **CLASSPATH** " is specified as part of the **DB2ENVLIST** environment variable. It is strongly recommended that dependant classes be installed rather than relying on the **CLASSPATH** environment variable.

## JAR file administration on the database server

To deploy JAR files that contain Java routine class files, you must install the JAR file to the DB2 database server. This can be done from an IBM Data Server Client by using system-defined routines that install, replace, or remove JAR files on the DB2 database server.

To install, replace, or remove a JAR file in a DB2 instance, use the stored procedures provided with DB2:

### Install

```
sqlj.install_jar( jar-url, jar-id )
```

**Note:** The privileges held by the authorization ID of the caller of `sqlj.install_jar` must include at least one of the following:

- CREATEIN privilege for the implicitly or explicitly specified schema
- DBADM authority

### Replace

```
sqlj.replace_jar( jar-url, jar-id )
```

### Remove

```
sqlj.remove_jar( jar-id )
```

- *jar-url*: The URL containing the JAR file to be installed or replaced. The only URL scheme supported is 'file:'.
- *jar-id*: A unique string identifier, up to 128 bytes in length. It specifies the JAR identifier in the database associated with the *jar-url* file.

**Note:** When invoked from applications, the stored procedures `sqlj.install_jar` and `sqlj.remove_jar` have an additional parameter. It is an integer value that dictates the use of the deployment descriptor in the specified JAR file. At present, the deployment parameter is not supported, and any invocation specifying a nonzero value will be rejected.

Following are a series of examples of how to use the preceding JAR file management stored procedures.

To register a JAR located in the path `/home/bob/bobsjar.jar` with the database instance as MYJAR:

```
CALL sqlj.install_jar( 'file:/home/bob/bobsjar.jar', 'MYJAR' )
```

Subsequent SQL commands that use the `bobsjar.jar` file refer to it with the name MYJAR.

To replace MYJAR with a different JAR containing some updated classes:

```
CALL sqlj.replace_jar( 'file:/home/bob/bobsnewjar.jar', 'MYJAR' )
```

To remove MYJAR from the database catalogs:

```
CALL sqlj.remove_jar( 'MYJAR' )
```

**Note:** On Windows operating systems, DB2 stores JAR files in the path specified by the **DB2INSTPROF** instance-specific registry setting. To make JAR files unique for an instance, you must specify a unique value for **DB2INSTPROF** for that instance.

## Updating Java routine classes

### About this task

If you want to change the logic of a Java routine, you must update the routine source code, compile (translate) the code, and then update the version of the Java class or JAR file that is deployed to the DB2 database server. To ensure that DB2 database manager uses the new version of the Java routine, you must execute a system-defined procedure that will load the new version of the Java class into memory.

### Procedure

To update Java routine classes:

1. Deploy the new Java class or JAR file to the DB2 database server.
2. Execute the following system-defined procedure for fenced routines:

```
CALL SQLJ.REFRESH_CLASSES()
```

This will force the DB2 database manager to load the new class into memory upon the next commit or rollback operation.

For unfenced routines, this step will not work. For unfenced routines, you must explicitly stop and re-start the DB2 database manager in order for new versions of Java routine classes to be loaded and used.

### Results

If you do not perform the steps above, after you update Java routine classes, the DB2 database manager will continue to use the previous versions of the classes.

---

## Examples of Java (JDBC) routines

### About this task

When developing Java routines that use the JDBC application programming interface, it is helpful to refer to examples to get a sense of what the CREATE statement and the Java routine code should look like. The following topics contain examples of Java procedures and functions:

### Procedure

- Examples of Java (JDBC) procedures
- Examples of Java (JDBC) procedures with XML features
- Examples of Java (JDBC) functions

## Example: Array data type in Java (JDBC) procedure

An example of a Java routine using the array data type.

The example below illustrates the skeleton of a Java routine with an IN and an OUT parameter of the array data type.

```
CREATE TYPE phonenumbers AS VARCHAR(20) ARRAY[10] %
CREATE PROCEDURE javaproc( IN in1 phonenumbers,
                          OUT out1 phonenumbers)
LANGUAGE java
PARAMETER STYLE java
FENCED THREADSAFE
EXTERNAL NAME 'myjar:stpclass.javastp' %
```

```

import java.sql.Array;

public static void javaprocedure(Array input, Array[] output)
{
    output[0] = input;
}

```

## Example: XML and XQuery support in Java (JDBC) procedure

Once the basics of Java procedures, programming in Java using the JDBC application programming interface (API), and XQuery are understood, you can start creating and using Java procedures that query XML data.

This example of a Java procedure illustrates:

- the CREATE PROCEDURE statement for a parameter style JAVA procedure
- the source code for a parameter style JAVA procedure
- input and output parameters of data type XML
- use of an XML input parameter in a query
- assignment of the result of an XQuery, an XML value, to an output parameter
- assignment of the result of an SQL statement, an XML value, to an output parameter

### Prerequisites

Before working with this Java procedure example you might want to read the following topics:

- Java routines
- Routines
- Building Java routine code

The examples below makes use of a table named `xmlDataTable` defined and containing data as follows:

```

CREATE TABLE xmlDataTable
(
    num INTEGER,
    xdata XML
)@

INSERT INTO xmlDataTable VALUES
(1, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Pontiac</make>
                    <model>Sunfire</model>
                    </doc>' PRESERVE WHITESPACE)),
(2, XMLPARSE(DOCUMENT '<doc>
                    <type>car</type>
                    <make>Mazda</make>
                    <model>Miata</model>
                    </doc>' PRESERVE WHITESPACE)),
(3, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mary</name>
                    <town>Vancouver</town>
                    <street>Waterside</street>
                    </doc>' PRESERVE WHITESPACE)),
(4, XMLPARSE(DOCUMENT '<doc>
                    <type>person</type>
                    <name>Mark</name>
                    <town>Edmonton</town>
                    <street>Oak</street>
                    </doc>' PRESERVE WHITESPACE)),
(5, XMLPARSE(DOCUMENT '<doc>

```



```

        <type>animal</type>
        <name>dog</name>
        </doc>' PRESERVE WHITESPACE)),
(6, NULL),
(7, XMLPARSE(DOCUMENT '<doc>
        <type>car</type>
        <make>Ford</make>
        <model>Taurus</model>
        </doc>' PRESERVE WHITESPACE)),
(8, XMLPARSE(DOCUMENT '<doc>
        <type>person</type>
        <name>Kim</name>
        <town>Toronto</town>
        <street>Elm</street>
        </doc>' PRESERVE WHITESPACE)),
(9, XMLPARSE(DOCUMENT '<doc>
        <type>person</type>
        <name>Bob</name>
        <town>Toronto</town>
        <street>Oak</street>
        </doc>' PRESERVE WHITESPACE)),
(10, XMLPARSE(DOCUMENT '<doc>
        <type>animal</type>
        <name>bird</name>
        </doc>' PRESERVE WHITESPACE))@

```

### Procedure

Use the following example as references when making your own Java procedures:

- Table 45
- Table 46 on page 280

## The Java external code file

The example shows a Java procedure implementation. The example consists of two parts: the CREATE PROCEDURE statement and the external Java code implementation of the procedure from which the associated Java class can be built.

The Java source file that contains the procedure implementations of the following examples is named `stpclass.java` included in a JAR file named `myJAR`. The file has the following format:

*Table 45. Java external code file format*

```

using System;
import java.lang.*;
import java.io.*;
import java.sql.*;
import java.util.*;
import com.ibm.db2.jcc.DB2Xml;

public class stpclass
{
    ...
    // Java procedure implementations
    ...
}

```

The Java class file imports are indicated at the top of the file. The `com.ibm.db2.jcc.DB2Xml` import is required if any of the procedures in the file contain parameters or variables of type XML will be used.

It is important to note the name of the class file and JAR name that contains a given procedure implementation. These names are important, because the EXTERNAL clause of the CREATE PROCEDURE statement for each procedure must specify this information so that DB2 can locate the class at run time.

### Example 1: Parameter style JAVA procedure with XML parameters

This example shows the following:

- CREATE PROCEDURE statement for a parameter style JAVA procedure
- Java code for a parameter style JAVA procedure with XML parameters

This procedure takes an input parameter, inXML, inserts a row including that value into a table, queriesXML data using both an SQL statement and an XQuery expression, and sets two output parameters, outXML1, and outXML2.

*Table 46. Code to create a parameter style JAVA procedure with XML parameters*

```
CREATE PROCEDURE xmlProc1 ( IN inNUM INTEGER,
                           IN inXML XML as CLOB (1K),
                           OUT out1XML XML as CLOB (1K),
                           OUT out2XML XML as CLOB (1K)
                           )
DYNAMIC RESULT SETS 0
DETERMINISTIC
LANGUAGE JAVA
PARAMETER STYLE JAVA
MODIFIES SQL DATA
FENCED
THREADSAFE
DYNAMIC RESULT SETS 0
PROGRAM TYPE SUB
NO DBINFO
EXTERNAL NAME 'myJar:stpclass.xmlProc1'@
```

Table 46. Code to create a parameter style JAVA procedure with XML parameters (continued)

```

//*****
// Stored Procedure: XMLPROC1
//
// Purpose:  Inserts XML data into XML column; queries and returns XML data
//
// Parameters:
//
// IN:      inNum -- the sequence of XML data to be insert in xmldata table
//          inXML -- XML data to be inserted
// OUT:     out1XML -- XML data to be returned
//          out2XML -- XML data to be returned
//
//*****
public void xmlProc1(int inNum,
                    DB2Xml inXML ,
                    DB2Xml[] out1XML,
                    DB2Xml[] out2XML
                    )
throws Exception
{
    Connection con = DriverManager.getConnection("jdbc:default:connection");

    // Insert data including the XML parameter value into a table
    String query = "INSERT INTO xmlDataTable (num, inXML ) VALUES ( ?, ? )" ;
    String xmlString = inXML.getDB2String() ;

    stmt = con.prepareStatement(query);
    stmt.setInt(1, inNum);
    stmt.setString (2, xmlString );
    stmt.executeUpdate();
    stmt.close();

    // Query and retrieve a single XML value from a table using SQL
    query = "SELECT xdata from xmlDataTable WHERE num = ? " ;

    stmt = con.prepareStatement(query);
    stmt.setInt(1, inNum);
    ResultSet rs = stmt.executeQuery();

    if ( rs.next() )
    { out1Xml[0] = (DB2Xml) rs.getObject(1); }

    rs.close() ;
    stmt.close();

    // Query and retrieve a single XML value from a table using XQuery
    query = "XQUERY for $x in db2-fn:xmlcolumn(\"xmlDataTable.xdata\")/doc
            where $x/make = \'Mazda\'
            return <carInfo>{$x/make}{$x/model}</carInfo>";

    stmt = con.createStatement();

    rs = stmt.executeQuery( query );

    if ( rs.next() )
    { out2Xml[0] = (DB2Xml) rs.getObject(1) ; }

    rs.close();
    stmt.close();
    con.close();

    return ;
}

```



---

## Chapter 8. OLE automation routine design

Object Linking and Embedding (OLE) automation is part of the OLE 2.0 architecture from Microsoft Corporation. With OLE automation, your applications, regardless of the language in which they are written, can expose their properties and methods in OLE automation objects. Other applications, such as Lotus Notes® or Microsoft Exchange, can then integrate these objects by taking advantage of these properties and methods through OLE automation.

The applications exposing the properties and methods are called OLE automation servers or objects, and the applications that access those properties and methods are called OLE automation controllers. OLE automation servers are COM components (objects) that implement the OLE IDispatch interface. An OLE automation controller is a COM client that communicates with the automation server through its IDispatch interface. COM is the foundation of OLE. For OLE automation routines, DB2 acts as an OLE automation controller. Through this mechanism, DB2 can invoke methods of OLE automation objects as external routines.

Note that all OLE automation topics assume that you are familiar with OLE automation terms and concepts. For an overview of OLE automation, refer to *Microsoft Corporation: The Component Object Model Specification*, October 1995. For details on OLE automation, refer to *OLE Automation Programmer's Reference*, Microsoft Press, 1996, ISBN 1-55615-851-3.

---

### Creating OLE automation routines

#### About this task

OLE automation routines are implemented as public methods of OLE automation objects. The OLE automation objects must be externally creatable by an OLE automation controller, in this case DB2, and support late binding (also called IDispatch-based binding). OLE automation objects must be registered in the Windows registry with a class identifier (CLSID), and optionally, an OLE programmatic ID (progID) to identify the automation object. The progID can identify an in-process (.DLL) or local (.EXE) OLE automation server, or a remote server through DCOM (Distributed COM).

#### Procedure

To register OLE automation routines:

After you code an OLE automation object, you need to create the methods of the object as routines using the CREATE statement. Creating OLE automation routines is very similar to registering C or C++ routines, but you must use the following options:

- LANGUAGE OLE
- FENCED NOT THREADSAFE, because OLE automation routines must run in FENCED mode, but cannot be run as THREADSAFE.

The external name consists of the OLE progID identifying the OLE automation object and the method name separated by ! (exclamation mark):

```

CREATE FUNCTION bcounter () RETURNS INTEGER
EXTERNAL NAME 'bert.bcounter!increment'
LANGUAGE OLE
FENCED
NOT THREADSAFE
SCRATCHPAD
FINAL CALL
NOT DETERMINISTIC
NULL CALL
PARAMETER STYLE DB2SQL
NO SQL
NO EXTERNAL ACTION
DISALLOW PARALLEL;

```

The calling conventions for OLE method implementations are identical to the conventions for routines written in C or C++. An implementation of the previous method in the BASIC language looks like the following (notice that in BASIC the parameters are by default defined as call by reference):

```

Public Sub increment(output As Long, _
                    indicator As Integer, _
                    sqlstate As String, _
                    fname As String, _
                    fspecname As String, _
                    sqlmsg As String, _
                    scratchpad() As Byte, _
                    calltype As Long)

```

---

## OLE routine object instances and scratchpad considerations

OLE automation UDFs and methods (methods of OLE automation objects) are applied on instances of OLE automation objects. DB2 creates an object instance for each UDF or method reference in an SQL statement. An object instance can be reused for subsequent method invocations of the UDF or method reference in an SQL statement, or the instance can be released after the method invocation and a new instance is created for each subsequent method invocation. The proper behavior can be specified with the SCRATCHPAD option in the CREATE statement. For the LANGUAGE OLE clause, the SCRATCHPAD option has the additional semantic compared to C or C++, that a single object instance is created and reused for the entire query, whereas if NO SCRATCHPAD is specified, a new object instance can be created each time a method is invoked.

Using the scratchpad allows a method to maintain state information in instance variables of the object, across function or method invocations. It also increases performance as an object instance is only created once and then reused for subsequent invocations.

---

## Supported SQL data types in OLE automation

DB2 handles type conversion between SQL types and OLE automation types. The following table summarizes the supported data types and how they are mapped.

*Table 47. Mapping of SQL and OLE Automation Datatypes*

SQL Type	OLE Automation Type	OLE Automation Type Description
SMALLINT	short	16-bit signed integer
INTEGER	long	32-bit signed integer
REAL	float	32-bit IEEE floating-point number
FLOAT or DOUBLE	double	64-bit IEEE floating-point number

Table 47. Mapping of SQL and OLE Automation Datatypes (continued)

SQL Type	OLE Automation Type	OLE Automation Type Description
DATE	DATE	64-bit floating-point fractional number of days since December 30, 1899
TIME	DATE	
TIMESTAMP	DATE	
CHAR( <i>n</i> )	BSTR	Length-prefixed string as described in the <i>OLE Automation Programmer's Reference</i> .
VARCHAR( <i>n</i> )	BSTR	
LONG VARCHAR	BSTR	
CLOB( <i>n</i> )	BSTR	
GRAPHIC( <i>n</i> )	BSTR	Length-prefixed string as described in the <i>OLE Automation Programmer's Reference</i> .
VARGRAPHIC( <i>n</i> )	BSTR	
LONG GRAPHIC	BSTR	
DBCLOB( <i>n</i> )	BSTR	
CHAR( <i>n</i> )	SAFEARRAY[unsigned char]	1-dim Byte() array of 8-bit unsigned data items. (SAFEARRAYs are described in the <i>OLE Automation Programmer's Reference</i> .)
VARCHAR( <i>n</i> )	SAFEARRAY[unsigned char]	
LONG VARCHAR	SAFEARRAY[unsigned char]	
CHAR( <i>n</i> ) FOR BIT DATA	SAFEARRAY[unsigned char]	
VARCHAR( <i>n</i> ) FOR BIT DATA	SAFEARRAY[unsigned char]	
LONG VARCHAR FOR BIT DATA	SAFEARRAY[unsigned char]	
BLOB( <i>n</i> )	SAFEARRAY[unsigned char]	

Data passed between DB2 and OLE automation routines is passed as call by reference. SQL types such as BIGINT, DECIMAL, or LOCATORS, or OLE automation types such as Boolean or CURRENCY that are not listed in the table are not supported. Character and graphic data mapped to BSTR is converted from the database code page to the UCS-2 scheme. (UCS-2 is also known as Unicode, IBM code page 13488). Upon return, the data is converted back to the database code page from UCS-2. These conversions occur regardless of the database code page. If these code page conversion tables are not installed, you receive SQLCODE -332 (SQLSTATE 57017).

## OLE automation routines in BASIC and C++

You can implement OLE automation routines in any language. This section shows you how to implement OLE automation routines using BASIC or C++ as two sample languages. The following table shows the mapping of OLE automation types to data types in BASIC and C++.

Table 48. Mapping of SQL and OLE Data Types to BASIC and C++ Data Types

SQL Type	OLE Automation Type	BASIC Type	C++ Type
SMALLINT	short	Integer	short
INTEGER	long	Long	long
REAL	float	Single	float
FLOAT or DOUBLE	double	Double	double
DATE, TIME, TIMESTAMP	DATE	Date	DATE

Table 48. Mapping of SQL and OLE Data Types to BASIC and C++ Data Types (continued)

SQL Type	OLE Automation Type	BASIC Type	C++ Type
CHAR( <i>n</i> )	BSTR	String	BSTR
CHAR( <i>n</i> ) FOR BIT DATA	SAFEARRAY[unsigned char]	Byte()	SAFEARRAY
VARCHAR( <i>n</i> )	BSTR	String	BSTR
VARCHAR( <i>n</i> ) FOR BIT DATA	SAFEARRAY[unsigned char]	Byte()	SAFEARRAY
LONG VARCHAR	BSTR	String	BSTR
LONG VARCHAR FOR BIT DATA	SAFEARRAY[unsigned char]	Byte()	SAFEARRAY
BLOB( <i>n</i> )	BSTR	String	BSTR
BLOB( <i>n</i> ) FOR BIT DATA	SAFEARRAY[unsigned char]	Byte()	SAFEARRAY
GRAPHIC( <i>n</i> ), VARGRAPHIC( <i>n</i> ), LONG GRAPHIC, DBCLOB( <i>n</i> )	BSTR	String	BSTR

## OLE Automation in BASIC

To implement OLE automation routines in BASIC you need to use the BASIC data types corresponding to the SQL data types mapped to OLE automation types.

The BASIC declaration of the OLE automation UDF, bcounter, looks like the following:

```
Public Sub increment(output As Long, _
                    indicator As Integer, _
                    sqlstate As String, _
                    fname As String, _
                    fspecname As String, _
                    sqlmsg As String, _
                    scratchpad() As Byte, _
                    calltype As Long)
```

## OLE Automation in C++

The C++ declaration of the OLE automation UDF, increment, is as follows:

```
STDMETHODIMP Ccounter::increment (long *output,
                                  short *indicator,
                                  BSTR *sqlstate,
                                  BSTR *fname,
                                  BSTR *fspecname,
                                  BSTR *sqlmsg,
                                  SAFEARRAY **scratchpad,
                                  long *calltype );
```

OLE supports type libraries that describe the properties and methods of OLE automation objects. Exposed objects, properties, and methods are described in the Object Description Language (ODL). The ODL description of the above C++ method is as follows:

```
HRESULT increment ([out] long *output,
                  [out] short *indicator,
                  [out] BSTR *sqlstate,
                  [in] BSTR *fname,
                  [in] BSTR *fspecname,
                  [out] BSTR *sqlmsg,
                  [in,out] SAFEARRAY (unsigned char) *scratchpad,
                  [in] long *calltype);
```



The ODL description allows you to specify whether a parameter is an input (in), output (out), or input/output (in,out) parameter. For an OLE automation routine, the routine input parameters and input indicators are specified as [in] parameters, and routine output parameters and output indicators as [out] parameters. For the routine trailing arguments, sqlstate is an [out] parameter, fname and fspecname are [in] parameters, scratchpad is an [in,out] parameter, and calltype is an [in] parameter.

OLE automation defines the BSTR data type to handle strings. BSTR is defined as a pointer to OLECHAR: typedef OLECHAR \*BSTR. For allocating and freeing BSTRs, OLE imposes the rule that the called routine frees a BSTR passed in as a by-reference parameter before assigning the parameter a new value. The same rule applies for one-dimensional byte arrays that are received by the called routine as SAFEARRAY\*\*. This rule means the following for DB2 and OLE automation routines:

- [in] parameters: DB2 allocates and frees [in] parameters.
- [out] parameters: DB2 passes in a pointer to NULL. The [out] parameter must be allocated by the invoked routine and is freed by DB2.
- [in,out] parameters: DB2 initially allocates [in,out] parameters. They can be freed and re-allocated by the invoked routine. As is true for [out] parameters, DB2 frees the final returned parameter.

All other parameters are passed as pointers. DB2 allocates and manages the referenced memory.

OLE automation provides a set of data manipulation functions for dealing with BSTRs and SAFEARRAYs. The data manipulation functions are described in the *OLE Automation Programmer's Reference*.

The following C++ routine returns the first 5 characters of a CLOB input parameter:

```
// UDF DDL: CREATE FUNCTION crunch (CLOB(5k)) RETURNS CHAR(5)

STDMETHODIMP Cobj::crunch (BSTR *in,          // CLOB(5K)
                           BSTR *out,        // CHAR(5)
                           short *indicator1, // input indicator
                           short *indicator2, // output indicator
                           BSTR *sqlstate,    // pointer to NULL
                           BSTR *fname,      // pointer to function name
                           BSTR *fspecname,  // pointer to specific name
                           BSTR *msgtext)    // pointer to NULL
{
    // Allocate BSTR of 5 characters
    // and copy 5 characters of input parameter

    // out is an [out] parameter of type BSTR, that is,
    // it is a pointer to NULL and the memory does not have to be freed.
    // DB2 will free the allocated BSTR.

    *out = SysAllocStringLen (*in, 5);
    return NOERROR;
};
```

An OLE automation server can be implemented as *creatable single-use* or *creatable multi-use*. With creatable single-use, each client (that is, a DB2 FENCED process) connecting with CoGetObject to an OLE automation object will use its own instance of a class factory, and run a new copy of the OLE automation server if necessary. With creatable multi-use, many clients connect to the same class factory. That is, each instantiation of a class factory is supplied by an already running copy

of the OLE server, if any. If there are no copies of the OLE server running, a copy is automatically started to supply the class object. The choice between single-use and multi-use OLE automation servers is yours, when you implement your automation server. A single-use server is recommended for better performance.

---

## Chapter 9. OLE DB user-defined table functions

Microsoft OLE DB is a set of OLE/COM interfaces that provide applications with uniform access to data stored in diverse information sources. The OLE DB component DBMS architecture defines OLE DB consumers and OLE DB providers. An OLE DB consumer is any system or application that consumes OLE DB interfaces; an OLE DB provider is a component that exposes OLE DB interfaces. There are two classes of OLE DB providers: *OLE DB data providers*, which own data and expose their data in tabular format as a rowset; and *OLE DB service providers*, which do not own their own data, but encapsulate some services by producing and consuming data through OLE DB interfaces.

The DB2 database system simplifies the creation of OLE DB applications by enabling you to define table functions that access an OLE DB data source. DB2 is an OLE DB consumer that can access any OLE DB data or service provider. You can perform operations including GROUP BY, JOIN, and UNION on data sources that expose their data through OLE DB interfaces. For example, you can define an OLE DB table function to return a table from a Microsoft Access database or a Microsoft Exchange address book, then create a report that seamlessly combines data from this OLE DB table function with data in your DB2 database.

Using OLE DB table functions reduces your application development effort by providing built-in access to any OLE DB provider. For C, Java, and OLE automation table functions, the developer needs to implement the table function, whereas in the case of OLE DB table functions, a generic built-in OLE DB consumer interfaces with any OLE DB provider to retrieve data. You only need to register a table function as LANGUAGE OLEDB, and refer to the OLE DB provider and the relevant rowset as a data source. You do not have to do any UDF programming to take advantage of OLE DB table functions.

To use OLE DB table functions with the DB2 database, you must install OLE DB 2.0 or later, available from Microsoft at <http://www.microsoft.com>. If you attempt to invoke an OLE DB table function without first installing OLE DB, DB2 issues SQLCODE -465, SQLSTATE 58032, reason code 35. For the system requirements and OLE DB providers available for your data sources, refer to your data source documentation. For the OLE DB specification, see the *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998.

**Restrictions on using OLE DB table functions:** OLE DB table functions cannot connect to a DB2 database.

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### Creating an OLE DB table UDF

#### Procedure

To define an OLE DB table function with a single CREATE FUNCTION statement, you must:

- define the table that the OLE DB provider returns
- specify LANGUAGE OLEDB
- identify the OLE DB rowset and provide an OLE DB provider connection string in the EXTERNAL NAME clause

OLE DB data sources expose their data in tabular form, called a *rowset*. A rowset is a set of rows, each having a set of columns. The RETURNS TABLE clause includes only the columns relevant to the user. The binding of table function columns to columns of a rowset at an OLE DB data source is based on column names. If the OLE DB provider is case sensitive, place the column names in quotation marks; for example, "UPPERcase".

The EXTERNAL NAME clause can take either of the following forms:

```
'server!rowset'  
or  
'!rowset!connectstring'
```

where:

*server* identifies a server registered with the CREATE SERVER statement

*rowset* identifies a rowset, or table, exposed by the OLE DB provider; this value should be empty if the table has an input parameter to pass through command text to the OLE DB provider.

*connectstring*

contains initialization properties needed to connect to an OLE DB provider. For the complete syntax and semantics of the connection string, see the "Data Link API of the OLE DB Core Components" in the *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998.

You can use a *connection string* in the EXTERNAL NAME clause of a CREATE FUNCTION statement, or specify the CONNECTSTRING option in a CREATE SERVER statement.

For example, you can define an OLE DB table function and return a table from a Microsoft Access database with the following CREATE FUNCTION and SELECT statements:

```
CREATE FUNCTION orders ()  
  RETURNS TABLE (orderid INTEGER, ...)  
  LANGUAGE OLEDB  
  EXTERNAL NAME '!orders!Provider=Microsoft.Jet.OLEDB.3.51;  
                Data Source=c:\msdasdk\bin\oledb\nwind.mdb';  
  
SELECT orderid, DATE(orderdate) AS orderdate,  
       DATE(shippeddate) AS shippeddate  
FROM TABLE(orders()) AS t  
WHERE orderid = 10248;
```

Instead of putting the connection string in the EXTERNAL NAME clause, you can create and use a server name. For example, assuming you have defined the server Nwind, you could use the following CREATE FUNCTION statement:

```
CREATE FUNCTION orders ()  
  RETURNS TABLE (orderid INTEGER, ...)  
  LANGUAGE OLEDB  
  EXTERNAL NAME 'Nwind!orders';
```

OLE DB table functions also allow you to specify one input parameter of any character string data type. Use the input parameter to pass command text directly to the OLE DB provider. If you define an input parameter, do not provide a rowset name in the EXTERNAL NAME clause. DB2 passes the command text to the OLE DB provider for execution and the OLE DB provider returns a rowset to DB2. Column names and data types of the resulting rowset need to be compatible with the RETURNS TABLE definition in the CREATE FUNCTION statement. You must ensure that you name the columns properly, because binding of the column names of the rowset is based on matching column names.

The following example registers an OLE DB table function, which retrieves store information from a Microsoft SQL Server 7.0 database. The connection string is provided in the EXTERNAL NAME clause. The table function has an input parameter to pass through command text to the OLE DB provider, so the rowset name is not specified in the EXTERNAL NAME clause. The query example passes in a SQL command text that retrieves information about the top three stores from a SQL Server database.

```
CREATE FUNCTION favorites (VARCHAR(600))
  RETURNS TABLE (store_id CHAR (4), name VARCHAR (41), sales INTEGER)
  SPECIFIC favorites
  LANGUAGE OLEDB
  EXTERNAL NAME '!!Provider=SQLOLEDB.1;Persist Security Info=False;
  User ID=sa;Initial Catalog=pubs;Data Source=WALTZ;
  Locale Identifier=1033;Use Procedure for Prepare=1;
  Auto Translate=False;Packet Size=4096;Workstation ID=WALTZ;
  OLE DB Services=CLIENTCURSOR;';

SELECT *
FROM TABLE (favorites (' select top 3 sales.stor_id as store_id, '
                        ' stores.stor_name as name, '
                        ' sum(sales.qty) as sales '
                        ' from sales, stores '
                        ' where sales.stor_id = stores.stor_id '
                        ' group by sales.stor_id, stores.stor_name '
                        ' order by sum(sales.qty) desc')) as f;
```

---

## Fully qualified rowset names

Some rowsets need to be identified in the EXTERNAL NAME clause through a *fully qualified name*. A fully qualified name incorporates either or both of the following:

- the associated catalog name, which requires the following information:
  - whether the provider supports catalog names
  - where to put the catalog name in the fully qualified name
  - which catalog name separator to use
- the associated schema name, which requires the following information:
  - whether the provider supports schema names
  - which schema name separator to use

For information on the support offered by your OLE DB provider for catalog and schema names, refer to the documentation of the literal information of your OLE DB provider.

If DBLITERAL\_CATALOG\_NAME is not NULL in the literal information of your provider, use a catalog name and the value of DBLITERAL\_CATALOG\_SEPARATOR as a separator. To determine whether the catalog name goes at the beginning or the end of the fully qualified name, refer to the value of DBPROP\_CATALOGLOCATION in the property set DBPROPSET\_DATASOURCEINFO of your OLE DB provider.

If DBLITERAL\_SCHEMA\_NAME is not NULL in the literal information of your provider, use a schema name and the value of DBLITERAL\_SCHEMA\_SEPARATOR as a separator.

If the names contain special characters or match keywords, enclose the names in the quote characters specified for your OLE DB provider. The quote characters are defined in the literal information of your OLE DB provider as DBLITERAL\_QUOTE\_PREFIX and DBLITERAL\_QUOTE\_SUFFIX. For example, in the

following EXTERNAL NAME the specified rowset includes catalog name *pubs* and schema name *dbo* for a rowset called *authors*, with the quote character " used to enclose the names.

```
EXTERNAL NAME '! "pubs"."dbo"."authors"!Provider=SQLOLEDB.1;...';
```

For more information on constructing fully qualified names, refer to *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998, and the documentation for your OLE DB provider.

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## Supported SQL data types in OLE DB

The following table shows how DB2 data types map to the OLE DB data types as described in *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998. Use the mapping table to define the appropriate RETURNS TABLE columns in your OLE DB table functions. For example, if you define an OLE DB table function with a column of data type INTEGER, DB2 requests the data from the OLE DB provider as DBTYPE\_I4.

For mappings of OLE DB provider source data types to OLE DB data types, refer to the OLE DB provider documentation. For examples of how the ANSI SQL, Microsoft Access, and Microsoft SQL Server providers might map their respective data types to OLE DB data types, refer to the *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998.

*Table 49. Mapping DB2 Data Types to OLE DB*

DB2 Data Type	OLE DB Data Type
SMALLINT	DBTYPE_I2
INTEGER	DBTYPE_I4
BIGINT	DBTYPE_I8
REAL	DBTYPE_R4
FLOAT/DOUBLE	DBTYPE_R8
DEC (p, s)	DBTYPE_NUMERIC (p, s)
DATE	DBTYPE_DBDATE
TIME	DBTYPE_DBTIME
TIMESTAMP	DBTYPE_DBTIMESTAMP
CHAR(N)	DBTYPE_STR
VARCHAR(N)	DBTYPE_STR
LONG VARCHAR	DBTYPE_STR
CLOB(N)	DBTYPE_STR
CHAR(N) FOR BIT DATA	DBTYPE_BYTES
VARCHAR(N) FOR BIT DATA	DBTYPE_BYTES
LONG VARCHAR FOR BIT DATA	DBTYPE_BYTES
BLOB(N)	DBTYPE_BYTES
GRAPHIC(N)	DBTYPE_WSTR
VARGRAPHIC(N)	DBTYPE_WSTR
LONG GRAPHIC	DBTYPE_WSTR
DBCLOB(N)	DBTYPE_WSTR

**Note:** OLE DB data type conversion rules are defined in the *Microsoft OLE DB 2.0 Programmer's Reference and Data Access SDK*, Microsoft Press, 1998. For example:

- To retrieve the OLE DB data type DBTYPE\_CY, the data can get converted to OLE DB data type DBTYPE\_NUMERIC(19,4), which maps to DB2 data type DEC(19,4).
- To retrieve the OLE DB data type DBTYPE\_I1, the data can get converted to OLE DB data type DBTYPE\_I2, which maps to DB2 data type SMALLINT.
- To retrieve the OLE DB data type DBTYPE\_GUID, the data can get converted to OLE DB data type DBTYPE\_BYTES, which maps to DB2 data type CHAR(12) FOR BIT DATA.





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## Chapter 10. Invoking routines

Once a routine has been developed and created in the database by issuing the CREATE statement, if the appropriate routine privileges have been granted to the routine definer and routine invoker, the routine can be invoked.

Each routine type serves a different purpose and is used in a different way. The prerequisites for invoking routines is common, but the implementation of the invocation differs for each.

### Prerequisites for routine invocation

- The routine must have been created in the database using the CREATE statement.
- For an external routine, the library or class file must be installed in location specified by the EXTERNAL clause of the CREATE statement, or an error (SQLCODE SQL0444, SQLSTATE 42724) will occur.
- The routine invoker must have the EXECUTE privilege on the routine. If the invoker is not authorized to execute the routine, an error (SQLSTATE 42501) will occur.

### Procedure invocation

Procedures are invoked by executing the CALL statement with a reference to a procedure.

The CALL statement enables the procedure invocation, the passing of parameters to the procedure, and the receiving of parameters returned from the procedure. Any accessible result sets returned from a procedure can be processed once the procedure has successfully returned.

Procedures can be invoked from anywhere that the CALL statement is supported including:

- client applications
- External routines (procedure, UDF, or method)
- SQL routines (procedure, UDF, or method)
- Triggers (before triggers, after triggers, or instead of triggers)
- Dynamic compound statements
- Command line processor (CLP)

If you choose to invoke a procedure from a client application or from an external routine, the client application or external routine can be written in a language other than that of the procedure. For example, a client application written in C++ can use the CALL statement to invoke a procedure written in Java. This provides programmers with great flexibility to program in their language of choice and to integrate code pieces written in different languages.

In addition, the client application that invokes the procedure can be executed on a different operating system than the one where the procedure resides. For example a client application running on a Windows operating system can use the CALL statement to invoke a procedure residing on a Linux database server.

Depending on where a procedure is invoked from there might be some additional considerations.

## Function invocation

Functions are intended to be referenced within SQL statements.

Built-in functions, sourced aggregate functions, and scalar user-defined can be referenced wherever an expression is allowed within an SQL statement. For example within the select-list of a query or within the VALUES clause of an INSERT statement. Table functions can only be referenced in the FROM clause. For example in the FROM clause of a query or a data change statement.

## Method invocation

Methods are similar to scalar functions except that they are used to give behavior to structured types. Method invocation is the same as scalar user-defined function invocation, except that one of the parameters to the method must be the structured type that the method operates on.

## Routine invocation related-tasks

To invoke a particular type of routine:

- “Calling procedures from applications or external routines” on page 303
- “Calling procedures from triggers or SQL routines” on page 304
- See “Call a procedure from a CLI application” in *Call Level Interface Guide and Reference, Volume 1*
- “Calling procedures from the Command Line Processor (CLP)” on page 306
- “Invoking scalar functions or methods” on page 318
- “Invoking user-defined table functions” on page 319

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## Authorizations and binding of routines that contain SQL

When discussing routine level authorization it is important to define some roles related to routines, the determination of the roles, and the privileges related to these roles:

### Package Owner

The owner of a particular package that participates in the implementation of a routine. The package owner is the user who executes the BIND command to bind a package with a database, unless the OWNER precompile/BIND option is used to override the package ownership and set it to an alternate user. Upon execution of the BIND command, the package owner is granted EXECUTE WITH GRANT privilege on the package. A routine library or executable can be comprised of multiple packages and therefore can have multiple package owners associated with it.

### Routine Definer

The ID that issues the CREATE statement to register a routine. The routine definer is generally a DBA, but is also often the routine package owner. When a routine is invoked, at package load time, the authorization to run the routine is checked against the definer's authorization to execute the package or packages associated with the routine (not against the

authorization of the routine invoker). For a routine to be successfully invoked, the routine definer must have one of:

- EXECUTE privilege on the package or packages of the routine and EXECUTE privilege on the routine
- DATAACCESS authority

If the routine definer and the routine package owner are the same user, then the routine definer will have the required EXECUTE privileges on the packages. If the definer is not the package owner, the definer must be explicitly granted EXECUTE privilege on the packages by any user with ACCESSCTRL or SECADM authority, CONTROL or EXECUTE WITH GRANT OPTION privilege on the package. (The creator of a package automatically receives CONTROL and EXECUTE WITH GRANT OPTION on the package.)

Upon issuing the CREATE statement that registers the routine, the definer is implicitly granted the EXECUTE WITH GRANT OPTION privilege on the routine.

The routine definer's role is to encapsulate under one authorization ID, the privileges of running the packages associated with a routine and the privilege of granting EXECUTE privilege on the routine to PUBLIC or to specific users that need to invoke the routine.

**Note:** For SQL routines the routine definer is also implicitly the package owner. Therefore the definer will have EXECUTE WITH GRANT OPTION on both the routine and on the routine package upon execution of the CREATE statement for the routine.

### **Routine Invoker**

The ID that invokes the routine. To determine which users will be invokers of a routine, it is necessary to consider how a routine can be invoked. Routines can be invoked from a command window or from within an embedded SQL application. In the case of methods and UDFs the routine reference will be embedded in another SQL statement. A procedure is invoked by using the CALL statement. For dynamic SQL in an application, the invoker is the runtime authorization ID of the immediately higher-level routine or application containing the routine invocation (however, this ID can also depend on the DYNAMICRULES option with which the higher-level routine or application was bound). For static SQL, the invoker is the value of the OWNER precompile/BIND option of the package that contains the reference to the routine. To successfully invoke the routine, these users will require EXECUTE privilege on the routine. This privilege can be granted by any user with EXECUTE WITH GRANT OPTION privilege on the routine (this includes the routine definer unless the privilege has been explicitly revoked), ACCESSCTRL, or SECADM authority, by explicitly issuing a GRANT statement.

As an example, if a package associated with an application containing dynamic SQL was bound with DYNAMICRULES BIND, then its runtime authorization ID will be its package owner, not the person invoking the package. Also, the package owner will be the actual binder or the value of the OWNER precompile/bind option. In this case, the invoker of the routine assumes this value rather than the ID of the user who is executing the application.

**Note:**

1. For static SQL within a routine, the package owner's privileges must be sufficient to execute the SQL statements in the routine body. These SQL statements might require table access privileges or execute privileges if there are any nested references to routines.
2. For dynamic SQL within a routine, the userid whose privileges will be validated are governed by the DYNAMICRULES option of the BIND of the routine body.
3. The routine package owner must GRANT EXECUTE on the package to the routine definer. This can be done before or after the routine is registered, but it must be done before the routine is invoked otherwise an error (SQLSTATE 42051) will be returned.

The steps involved in managing the execute privilege on a routine are detailed in the diagram and text that follows:

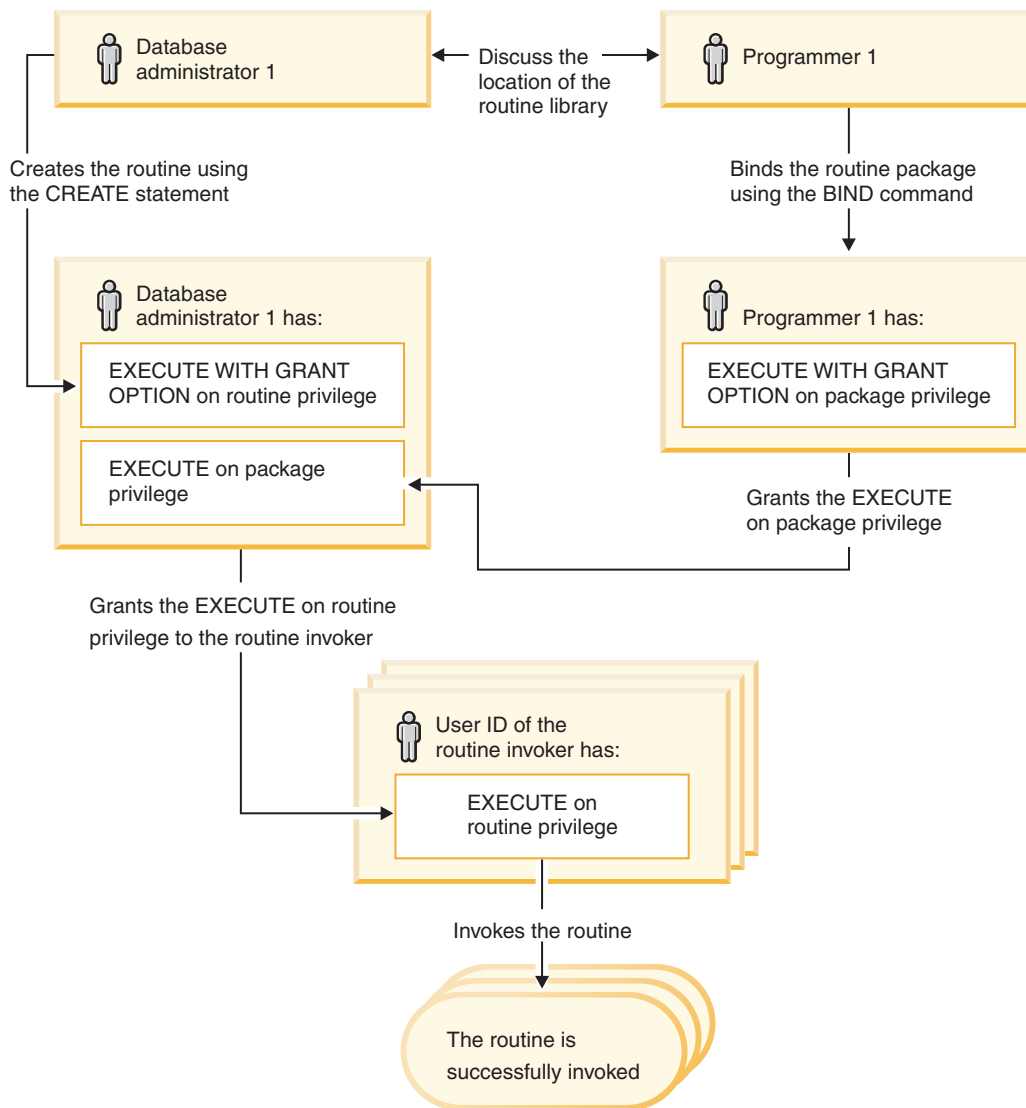


Figure 3. Managing the EXECUTE privilege on routines

1. Definer performs the appropriate CREATE statement to register the routine. This registers the routine in DB2 with its intended level of SQL access,

establishes the routine signature, and also points to the routine executable. The definer, if not also the package owner, needs to communicate with the package owners and authors of the routine programs to be clear on where the routine libraries reside so that this can be correctly specified in the EXTERNAL clause of the CREATE statement. By virtue of a successful CREATE statement, the definer has EXECUTE WITH GRANT privilege on the routine, however the definer does not yet have EXECUTE privilege on the packages of the routine.

2. Definer must grant EXECUTE privilege on the routine to any users who are to be permitted use of the routine. (If the package for this routine will recursively call this routine, then this step must be done before the next step.)
3. Package owners precompile and bind the routine program, or have it done on their behalf. Upon a successful precompile and bind, the package owner is implicitly granted EXECUTE WITH GRANT OPTION privilege on the respective package. This step follows step one in this list only to cover the possibility of SQL recursion in the routine. If such recursion does not exist in any particular case, the precompile/bind could precede the issuing of the CREATE statement for the routine.
4. Each package owner must explicitly grant EXECUTE privilege on their respective routine package to the definer of the routine. This step must come at some time after the previous step. If the package owner is also the routine definer, this step can be skipped.
5. Static usage of the routine: the bind owner of the package referencing the routine must have been given EXECUTE privilege on the routine, so the previous step must be completed at this point. When the routine executes, DB2 verifies that the definer has the EXECUTE privilege on any package that is needed, so step 3 must be completed for each such package.
6. Dynamic usage of the routine: the authorization ID as controlled by the DYNAMICRULES option for the invoking application must have EXECUTE privilege on the routine (step 4), and the definer of the routine must have the EXECUTE privilege on the packages (step 3).

---

## Routine names and paths

The qualified name of a stored procedure or UDF is `schema-name.routine-name`. You can use this qualified name anywhere you refer to a stored procedure or UDF. For example:

```
SANDRA.BOAT_COMPARE SMITH.FOO SYSIBM.SUBSTR SYSFUN.FLOOR
```

However, you can also omit the `schema-name.`, in which case, DB2 will attempt to identify the stored procedure or UDF to which you are referring. For example:

```
BOAT_COMPARE FOO SUBSTR FLOOR
```

The qualified name of a method is `schema-name.type.method-name`.

The concept of *SQL path* is central to DB2's resolution of *unqualified* references that occur when you do not use the `schema-name`. The SQL path is an ordered list of schema names. It provides a set of schemas for resolving unqualified references to stored procedures, UDFs, and types. In cases where a reference matches a stored procedure, type, or UDF in more than one schema in the path, the order of the schemas in the path is used to resolve this match. The SQL path is established by means of the FUNCPATH option on the precompile and bind commands for static SQL. The SQL path is set by the SET PATH statement for dynamic SQL. The SQL path has the following default value:

```
"SYSIBM", "SYSFUN", "SYSPROC", "ID"
```

This applies to both static and dynamic SQL, where *ID* represents the current statement authorization ID.

Routine names can be *overloaded*, which means that multiple routines, even in the same schema, can have the same name. Multiple functions or methods with the same name can have the same number of parameters, as long as the data types differ. This is not true for stored procedures, where multiple stored procedures with the same name must have different numbers of parameters. Instances of different routine types do not overload one-another, except for methods, which are able to overload functions. For a method to overload a function, the method must be registered using the WITH FUNCTION ACCESS clause.

A function, a stored procedure, and a method can have identical *signatures* and be in the same schema without overloading each other. In the context of routines, signatures are the qualified routine name concatenated with the defined data types of all the parameters in the order in which they are defined.

Methods are invoked against instances of their associated structured type. When a subtype is created, among the attributes it inherits are the methods defined for the supertype. Hence, a supertype's methods can also be run against any instances of its subtypes. When defining a subtype you can *override* the supertype's method. To override a method means to reimplement it specifically for a given subtype. This facilitates the dynamic dispatch of methods (also known as polymorphism), where an application will execute the most specific method depending on the type of the structured type instance (for example, where it is situated in the structured type hierarchy).

Each routine type has its own selection algorithm that takes into account the facts of overloading (in the case of methods, and overriding) and SQL path to choose the most appropriate match for every routine reference.

---

## Nested routine invocations

In the context of routines, *nesting* refers to the situation where one routine invokes another. That is to say, the SQL issued by one routine can reference another routine, which could issue SQL that again references another routine, and so on. If the series of routines that is referenced contains a routine that was previously referenced this is said to be a *recursive* nesting situation.

You can use nesting and recursion in your DB2 routines under the following restrictions:

### 64 levels of nesting

You can nest routine invocations up to 64 levels deep. Consider a scenario in which routine A calls routine B, and routine B calls routine C. In this example, the execution of routine C is at nesting level 3. A further 61 levels of nesting are possible.

### Other restrictions

A routine cannot call a target routine that is cataloged with a higher SQL data access level. For example, a UDF created with the CONTAINS SQL clause can call stored procedures created with either the CONTAINS SQL clause or the NO SQL clause. However, this routine cannot call stored procedures created with either the READS SQL DATA clause or the MODIFIES SQL DATA clause (SQLCODE -577, SQLSTATE 38002). This is because the invoker's SQL level does not allow any read or modify operations to occur (this is inherited by the routine being invoked).

Another limitation when nesting routines is that access to tables is restricted to prevent conflicting read and write operations between routines.

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## Invoking 32-bit routines on a 64-bit database server

### About this task

In 64-bit DB2 instances, it is possible to invoke C and COBOL routines that reference 32-bit external routine libraries, however these routines must be specified to run as fenced and not threadsafe. This is done by including both the `FENCED` clause and `NOT THREADSAFE` clause in the routine `CREATE` statement when creating a new routine. For routines that have already been created in the 64-bit instance, the `ALTER FUNCTION` or `ALTER PROCEDURE` statements can be used to modify the routine definition. The first time such a 32-bit routine is invoked in a 64-bit environment, there will be a performance degradation. Subsequent invocations of the 32-bit stored procedure will perform as well as an equivalent 64-bit routine. Use of 32-bit routines in 64-bit DB2 instances is discouraged.

To successfully invoke Java procedures in a 64-bit DB2 instance on a 64-bit database server, a 64-bit Java Virtual Machine (JVM) is required. 32-bit JVMs are not supported for running routines in 64-bit DB2 instances. As Java classes are platform independent, a Java class compiled with a 32-bit software development kit can run successfully with a 64-bit JVM. Routine performance is not impacted by doing this.

### Procedure

To invoke existing 32-bit routines on a 64-bit server:

1. Copy the routine class or library to the database routines directory:
  - UNIX: `sqllib/function`
  - Windows: `sqllib\function`
2. Register the stored procedure with the `CREATE PROCEDURE` statement.
3. Invoke the stored procedure with the `CALL` statement.

---

## References to procedures

Stored Procedures are invoked from the `CALL` statement where they are referenced by a qualified name (schema and stored procedure name), followed by a list of arguments enclosed by parentheses. A stored procedure can also be invoked without the schema name, resulting in a choice of possible stored procedures in different schemas with the same number of parameters.

Each parameter passed to the stored procedure can be composed of a host variable, parameter marker, expression, or `NULL`. The following are restrictions for stored procedure parameters:

- `OUT` and `INOUT` parameters must be host variables.
- `NULLs` cannot be passed to Java stored procedures unless the SQL data type maps to a Java class type.
- `NULLs` cannot be passed to `PARAMETER STYLE GENERAL` stored procedures.

The position of the arguments is important and must conform to the stored procedure definition for the semantics to be correct. Both the position of the arguments and the stored procedure definition must conform to the stored

procedure body itself. DB2 does not attempt to shuffle arguments to better match a stored procedure definition, and DB2 does not understand the semantics of the individual stored procedure parameters.

## Calling procedures

### About this task

Once the activities required to create a procedure (also called a stored procedure) have been completed, a procedure can be invoked by using the CALL statement. The CALL statement is an SQL statement that enables the procedure invocation, the passing of parameters to the procedure, and the receiving of parameters returned from the procedure. Any accessible result sets returned from a procedure can be processed once the procedure has successfully returned. Procedures can be invoked from anywhere that the CALL statement is supported including:

- an embedded SQL client application
- an external routine (procedure, UDF, or method)
- an SQL routine (procedure, UDF, or method)
- an SQL trigger (BEFORE TRIGGER, AFTER TRIGGER, or INSTEAD OF TRIGGER)
- an SQL dynamic compound statement
- from the Command Line Processor (CLP)

If you choose to invoke a procedure from a client application or from an external routine, the client application or external routine can be written in a language other than that of the procedure. For example, a client application written in C++ can use the CALL statement to invoke a procedure written in Java. This provides programmers with great flexibility to program in their language of choice and to integrate code pieces written in different languages.

In addition, the client application that invokes the procedure can be executed on a different platform than the one where the procedure resides. For example a client application running on a Windows platform can use the CALL statement to invoke a procedure residing on a Linux database server.

An autonomous procedure is a procedure that, when called, executes inside a new transaction independent of the original transaction. When the autonomous procedure successfully completes, it will commit the work performed within the procedure, but if it is unsuccessful, the procedure rolls back any work it performed. Whatever the result of the autonomic procedure, the transaction which called the autonomic procedure is unaffected. To specify a procedure as autonomous, specify the AUTONOMOUS keyword on the CREATE PROCEDURE statement.

When you call a procedure, certain rules apply about exactly which procedure is selected. Procedure selection depends partly on whether you qualify the procedure by specifying the schema name. The DB2 database manager also performs checks based on the number of arguments and any argument names specified in the call to the procedure. See information about the CALL statement for more details about procedure selection.



## Calling procedures from applications or external routines

Invoking a procedure (also called a stored procedure) that encapsulates logic from a client application or from an application associated with an external routine is easily done with some simple setup work in the application and by using the CALL statement.

### Before you begin

The procedure must have been created in the database by executing the CREATE PROCEDURE statement.

For external procedures, the library or class file must exist in the location specified by the EXTERNAL clause in the CREATE PROCEDURE statement.

The procedure invoker must have the privileges required to execute the CALL statement. The procedure invoker in this case is the user ID executing the application, however special rules apply if the DYNAMICRULES bind option is used for the application.

### Procedure

Certain elements must be included in your application if you want that application to invoke a procedure. In writing your application you must do the following:

1. Declare, allocate, and initialize storage for the optional data structures and host variables or parameter markers required for the CALL statement. To do this:
  - Assign a host variable or parameter marker to be used for each parameter of the procedure.
  - Initialize the host variables or parameter markers that correspond to IN or INOUT parameters.
2. Establish a database connection. Do this by executing an embedded SQL language CONNECT TO statement, or by coding an implicit database connection.
3. Code the procedure invocation. After the database connection code, you can code the procedure invocation. Do this by executing the SQL language CALL statement. Be sure to specify a host variable, constant, or parameter marker for each IN, INOUT, OUT parameter that the procedure expects.
4. Add code to process the OUT and INOUT parameters, and result sets. This code must come after the CALL statement execution.
5. Code a database COMMIT or ROLLBACK. Subsequent to the CALL statement and evaluation of output parameter values or data returned by the procedure, you might want your application to commit or roll back the transaction. This can be done by including a COMMIT or ROLLBACK statement. A procedure can include a COMMIT or ROLLBACK statement, however it is recommended practice that transaction management be done within the client application.

**Note:** Procedures invoked from an application that established a type 2 connection to the database, cannot issue COMMIT or ROLLBACK statements.

6. Disconnect from the database.
7. Prepare, compile, link, and bind your application. If the application is for an external routine, issue the CREATE statement to create the routine and locate your external code library in the appropriate function path for your operating system so that the database manager can find it.

8. Run your application or invoke your external routine. The CALL statement that you embedded in your application will be invoked.

## Results

**Note:** You can code SQL statements and routine logic at any point between steps 2 and 5.

## Calling procedures from triggers or SQL routines

Calling a procedure from an SQL routine, a trigger, or dynamic compound statement is essentially the same. The same steps are used to implement this call. This topic explains the steps using a trigger scenario. Any prerequisites or steps that differ when calling a procedure from a routine or dynamic compound statement are stated.

### Before you begin

- The procedure must have been created in the database by executing the CREATE PROCEDURE statement.
- For external procedures, the library or class files must be in the location specified by the EXTERNAL clause of the CREATE PROCEDURE statement.
- The creator of a trigger that contains a CALL statement must have the privilege to execute the CALL statement. At runtime when a trigger is activated it is the authorization of the creator of the trigger that is checked for the privilege to execute the CALL statement. A user that executes a dynamic compound statement that contains a CALL statement, must have the privilege to execute the CALL statement for that procedure.
- To invoke a trigger, a user must have the privilege to execute the data change statement associated with the trigger event. Similarly, to successfully invoke an SQL routine or dynamic compound statement a user must have the EXECUTE privilege on the routine.

### Restrictions

When invoking a procedure from within an SQL trigger, an SQL routine, or a dynamic compound statement the following restrictions apply:

- In partitioned database environments procedures cannot be invoked from triggers or SQL UDFs.
- On symmetric multi-processor (SMP) machines, procedure calls from triggers are executed on a single processor.
- A procedure that is to be called from a trigger must not contain a COMMIT statement or a ROLLBACK statement that attempts to rollback the unit of work. The ROLLBACK TO SAVEPOINT statement is supported within the procedure however the specified savepoint must be in the procedure.
- A rollback of a CALL statement from within a trigger will not rollback any external actions effected by the procedures, such as writing to the file system.
- The procedure must not modify any federated table. This means that the procedure must not contain a searched UPDATE of a nickname, a searched DELETE from a nickname or an INSERT to a nickname.
- Result sets specified for the procedure will not be accessible from inline SQL PL statements.
- If a cursor defined as **WITH RETURN TO CLIENT** is opened during the execution of a compiled trigger, result sets from the cursor will be discarded.

BEFORE triggers can not be created if they contain a CALL statement that references a procedure created with an access level of MODIFIES SQL DATA. The execution of a CREATE TRIGGER statement for such a trigger will fail with error (SQLSTATE 42987). For more about SQL access levels in routines see:

- “SQL access levels in routines” on page 41
- “SQL statements that can be executed in routines” on page 36

## Procedure

This procedure section explains how to create and invoke a trigger that contains a CALL statement. The SQL required to call a procedure from a trigger is the same SQL required to call a procedure from an SQL routine or dynamic compound statement.

1. Write a basic CREATE TRIGGER statement specifying the desired trigger attributes. See the CREATE TRIGGER statement.
2. In the trigger action portion of the trigger you can declare SQL variables for any IN, INOUT, OUT parameters that the procedure specifies. See the DECLARE statement. To see how to initialize or set these variables see the assignment statement. Trigger transition variables can also be used as parameters to a procedure.
3. In the trigger action portion of the trigger add a CALL statement for the procedure. Specify a value or expression for each of the procedure's IN, INOUT, and OUT parameters
4. For SQL procedures you can optionally capture the return status of the procedure by using the GET DIAGNOSTICS statement. To do this you will need to use an integer type variable to hold the return status. Immediately after the CALL statement, simply add a GET DIAGNOSTICS statement that assigns RETURN\_STATUS to your local trigger return status variable.
5. Having completed writing your CREATE TRIGGER statement you can now execute it statically (from within an application) or dynamically (from the CLP, or from the Control Center) to formally create the trigger in the database.
6. Invoke your trigger. Do this by executing against the appropriate data change statement that corresponds to your trigger event.
7. When the data change statement is executed against the table, the appropriate triggers defined for that table are fired. When the trigger action is executed, the SQL statements contained within it, including the CALL statement, are executed.

## Results

### Run-time errors

If the procedure attempts to read or write to a table that the trigger also reads or writes to, an error might be raised if a read or write conflict is detected. The set of tables that the trigger modifies, including the table for which the trigger was defined must be exclusive from the tables modified by the procedure.

### Example: Calling an SQL procedure from a trigger

This example illustrates how you can embed a CALL statement to invoke a procedure within a trigger and how to capture the return status of the procedure call using the GET DIAGNOSTICS statement. The SQL below creates the necessary tables, an SQL PL language procedure, and an after trigger.

```

CREATE TABLE T1 (c1 INT, c2 CHAR(2))@
CREATE TABLE T2 (c1 INT, c2 CHAR(2))@

CREATE PROCEDURE proc(IN val INT, IN name CHAR(2))
LANGUAGE SQL
DYNAMIC RESULTSETS 0
MODIFIES SQL DATA
BEGIN
    DECLARE rc INT DEFAULT 0;
    INSERT INTO TABLE T2 VALUES (val, name);
    GET DIAGNOSTICS rc = ROW_COUNT;
    IF ( rc > 0 ) THEN
        RETURN 0;
    ELSE
        RETURN -200;
    END IF;
END@

CREATE TRIGGER trig1 AFTER UPDATE ON t1
REFERENCING NEW AS n
FOR EACH ROW
WHEN (n.c1 > 100);
BEGIN ATOMIC
    DECLARE rs INTEGER DEFAULT 0;
    CALL proc(n.c1, n.c2);
    GET DIAGNOSTICS rs = RETURN_STATUS;
    VALUES(CASE WHEN rc < 0 THEN RAISE_ERROR('70001', 'PROC CALL failed'));
END@

```

Issuing the following SQL statement will cause the trigger to fire and the procedure will be invoked.

```
UPDATE T1 SET c1 = c1+1 WHERE c2 = 'CA'@
```

## Calling procedures from the Command Line Processor (CLP) About this task

You can call stored procedures by using the CALL statement from the DB2 command line processor interface. The stored procedure being called must be defined in the DB2 system catalog tables.

### Procedure

To call the stored procedure, first connect to the database:

```
db2 connect to sample user userid using password
```

where *userid* and *password* are the user ID and password of the instance where the sample database is located.

To use the CALL statement, enter the stored procedure name plus any IN or INOUT parameter values, as well as '?' as a place-holder for each OUT parameter value. The parameters for a stored procedure are given in the CREATE PROCEDURE statement for the stored procedure in the program source file.

### Example

#### SQL procedure examples

##### Example 1.

In the whiles.db2 file, the CREATE PROCEDURE statement for the DEPT\_MEDIAN procedure signature is as follows:

```
CREATE PROCEDURE DEPT_MEDIAN
(IN deptNumber SMALLINT, OUT medianSalary DOUBLE)
```

To invoke this procedure, use the CALL statement in which you must specify the procedure name and appropriate parameter arguments, which in this case are the value for the IN parameter, and a question mark, '?', for the value of the OUT parameter. The procedure's SELECT statement uses the deptNumber value on the DEPT column of the STAFF table, so to get meaningful output the IN parameter needs to be a valid value from the DEPT column; for example, the value "51":

```
db2 call dept_median (51, ?)
```

**Note:** On UNIX platforms the parentheses have special meaning to the command shell, so they must be preceded with a "\" character or surrounded with quotation marks, as follows:

```
db2 "call dept_median (51, ?)"
```

You do not use quotation marks if you are using the interactive mode of the command line processor.

After running the above command, you should receive this result:

```
Value of output parameters
-----
Parameter Name   : MEDIANSALARY
Parameter Value  : +1.76545000000000E+004

Return Status = 0
```

## Example 2.

This example illustrates how to call a procedure with array parameters. Type phonenumbers is defined as:

```
CREATE TYPE phonenumbers AS VARCHAR(12) ARRAY[1000]
```

Procedure find\_customers, defined below, has an IN and an OUT parameter of type phonenumbers. The procedure searches for numbers in numbers\_in that begin with the given area\_code, and reports them in numbers\_out.

```
CREATE PROCEDURE find_customers(
  IN numbers_in phonenumbers,
  IN area_code CHAR(3),
  OUT numbers_out phonenumbers)
BEGIN
  DECLARE i, j, max INTEGER;

  SET i = 1;
  SET j = 1;
  SET numbers_out = NULL;
  SET max = CARDINALITY(numbers_in);

  WHILE i <= max DO
    IF substr(numbers_in[i], 1, 3) = area_code THEN
      SET numbers_out[j] = numbers_in[i];
      SET j = j + 1;
    END IF;
    SET i = i + 1;
  END WHILE;
END
```

To invoke the procedure, you can use the following CALL statement:

```
db2 CALL find_customers(ARRAY['416-305-3745',
                              '905-414-4565',
                              '416-305-3746'],
                        '416',
                        ?)
```

As shown in the CALL statement, when a procedure has an input parameter of an array data type, the input argument can be specified with an array constructor containing a list of literal values.

After running the command, you should receive a result like this:

```
Value of output parameters
-----
Parameter Name : OUT_PHONENUMBERS
Parameter Value : ['416-305-3745',
                  '416-305-3746']
```

```
Return Status = 0
```

### C stored procedure example

You can also call stored procedures created from supported host languages with the Command Line Processor. In the `samples/c` directory on UNIX, and the `samples\c` directory on Windows, DB2 provides files for creating stored procedures. The `spserver` shared library contains a number of stored procedures that can be created from the source file, `spserver.sqc`. The `spcreate.db2` file catalogs the stored procedures.

In the `spcreate.db2` file, the CREATE PROCEDURE statement for the `MAIN_EXAMPLE` procedure begins:

```
CREATE PROCEDURE MAIN_EXAMPLE (IN job CHAR(8),
                              OUT salary DOUBLE,
                              OUT errorcode INTEGER)
```

To call this stored procedure, you need to put in a CHAR value for the IN parameter, `job`, and a question mark, '?', for each of the OUT parameters. The procedure's SELECT statement uses the `job` value on the JOB column of the EMPLOYEE table, so to get meaningful output the IN parameter needs to be a valid value from the JOB column. The C sample program, `spclient`, that calls the stored procedure, uses 'DESIGNER' for the JOB value. We can do the same, as follows:

```
db2 "call MAIN_EXAMPLE ('DESIGNER', ?, ?)"
```

After running the above command, you should receive this result:

```
Value of output parameters
-----
Parameter Name : SALARY
Parameter Value : +2.37312500000000E+004

Parameter Name : ERRORCODE
Parameter Value : 0

Return Status = 0
```

An ERRORCODE of zero indicates a successful result.

### Calling stored procedures from CLI applications

CLI applications invoke stored procedures by executing the CALL procedure SQL statement. This topic describes how to call stored procedures from CLI applications.

#### Before you begin

Before calling a stored procedure, ensure that you have initialized your CLI application.

## About this task

If the stored procedure being called is uncataloged, ensure that it does not call any of the CLI schema functions. Calling CLI schema functions from uncataloged stored procedures is not supported.

The CLI schema functions are: `SQLColumns()`, `SQLColumnPrivileges()`, `SQLForeignKeys()`, `SQLPrimaryKeys()`, `SQLProcedureColumns()`, `SQLProcedures()`, `SQLSpecialColumns()`, `SQLStatistics()`, `SQLTables()`, and `SQLTablePrivileges()`.

## Procedure

To call a stored procedure:

1. Declare application host variables corresponding to each of the IN, INOUT, and OUT parameters of the stored procedure. Ensure the application variable data types and lengths match the data types and lengths of the arguments in the stored procedure signature. CLI supports calling stored procedures with all SQL types as parameter markers.
2. Initialize the IN, INOUT, and OUT parameter application variables.
3. Issue the CALL SQL statement. For example:

```
SQLCHAR *stmt = (SQLCHAR *)"CALL OUT_LANGUAGE (?)";
```

or

```
SQLCHAR *stmt = (SQLCHAR *)"CALL OUT_LANGUAGE (:language)";
```

**Remember:** To use named parameter markers (for example, `:language`), you must explicitly enable named parameter processing by setting the **EnableNamedParameterSupport** configuration keyword to TRUE.

For optimal performance, applications should use parameter markers for stored procedure arguments in the CALL procedure string, and then bind the host variables to those parameter markers. If inbound stored procedure arguments must be specified as string literals rather than parameter markers, however, include the ODBC call escape clause delimiters `{ }` in the CALL procedure statement. For example:

```
SQLCHAR *stmt = (SQLCHAR *)"{CALL IN_PARAM (123, 'Hello World!')}";
```

When string literals and the ODBC escape clause are used in a CALL procedure statement, the string literals can only be specified as IN mode stored procedure arguments. INOUT and OUT mode stored procedure arguments must still be specified using parameter markers.

4. Optional: Prepare the CALL statement by calling `SQLPrepare()`.
5. Bind each parameter of the CALL procedure statement by calling `SQLBindParameter()`.

**Note:** Ensure each parameter is bound correctly (to `SQL_PARAM_INPUT`, `SQL_PARAM_OUTPUT`, or `SQL_PARAM_INPUT_OUTPUT`), otherwise unexpected results could occur when the CALL procedure statement is executed. This would happen, for example, if an input parameter was incorrectly bound with an *InputOutputType* of `SQL_PARAM_OUTPUT`.

**Note:** The CALL procedure statement does not support an array input for a parameter marker using the `SQL_ATTR_PARAMSET_SIZE` attribute.

6. Execute the CALL procedure statement using `SQLExecuteDirect()`, or if the CALL procedure statement was prepared in step 4, `SQLExecute()`.

**Note:** If an application or thread that has invoked a stored procedure is terminated before the stored procedure completes, execution of the stored procedure will also be terminated. It is important that a stored procedure contain logic to ensure that the database is in both a consistent and desirable state if the stored procedure is terminated prematurely.

7. Check the return code of `SQLExecDirect()` or `SQLExecute()` when the function has returned to determine if any errors occurred during execution of either the `CALL` procedure statement or the stored procedure. If the return code is `SQL_SUCCESS_WITH_INFO` or `SQL_ERROR`, use the CLI diagnostic functions `SQLGetDiagRec()` and `SQLGetDiagField()` to determine why the error occurred. If a stored procedure has executed successfully, any variables bound as `OUT` parameters may contain data that the stored procedure has passed back to the CLI application. If applicable, the stored procedure may also return one or more result sets through non-scrollable cursors. CLI applications should process stored procedure result sets as they would process result sets generated by executing `SELECT` statements.

**Note:** If a CLI application is unsure of the number or type of columns in a result set returned by a stored procedure, the `SQLNumResultCols()`, `SQLDescribeCol()`, and `SQLColAttribute()` functions can be called (in this order) on the result set to determine this information.

## Results

Once you have executed the `CALL` statement, you can retrieve result sets from the stored procedure if applicable.

### Note:

The numeric month and day parts of a `DATETIME` data type value will appear to be reversed in procedure result sets that are returned to DB2 CLI applications if the values are not returned in ISO format. For example, this can happen if a local format is used instead. To ensure that `DATETIME` data type value information is correctly interpreted by a client application, the procedures should be bound to the database with a locale-independent `DATETIME` format such as ISO. For example:

```
db2set DB2_SQLROUTINE_PREPOPTS="DATETIME ISO"
```

### Note:

CLI packages are automatically bound to databases when the databases are created or upgraded.

## Resultsets from Anonymous blocks

Starting in Version 9.7 FixPack 2, CLI will be prepared for resultsets whenever a SQL statement that starts with `BEGIN`, but not `BEGIN COMPOUND`, is sent by the application. CLI will interpret the returned cursor from the server and allow application to retrieve the resultsets.

### Example 1: Using `SQLExecDirect`

```
opt caller on
opt echo on

quickc 1 1 sample

SQLAllocStmt 1 1
getmem 1 1 SQL_C_LONG
```



```

SQLExecDirect 1 "drop table t1" -3
SQLExecDirect 1 "create table t1 (c1 int)" -3
SQLExecDirect 1 "insert into t1 values (10)" -3
SQLExecDirect 1 "insert into t1 values (20)" -3
SQLExecDirect 1 "insert into t1 values (30)" -3

SQLExecDirect 1 "begin declare c1 cursor with return to client with hold
for select c1 from t1; end" -3
SQLBindCol 1 1 sql_c_long 1
FetchAll 1

SQLFreeStmt 1 SQL_DROP
SQLTransact 1 1 SQL_COMMIT

killenv 1

```

## Procedure result sets

In addition to exchanging parameters, procedures can pass information to invokers by returning result sets. Result sets can be accepted by SQL-bodied routines, and routines and applications programmed in the following interfaces:

- CLI
- JDBC
- SQLJ
- ODBC

Stored procedures pass result sets to their invokers through cursors. The procedure body must contain a cursor for every result set you need to return. While you can fetch rows from a result set cursor within the procedure, only unfetched rows are passed to the invoker as the result set. When exiting a procedure, leave the cursors that correspond to the result sets open. Multiple result sets are returned in the order in which you open their cursors.

When declaring a cursor for a result set, it is strongly recommended that you specify the destination in the WITH RETURN TO clause of the DECLARE CURSOR statement (for SQL procedures, this is mandatory). To return the result set to the invoker, whether the invoker is an application or a routine, specify WITH RETURN TO CALLER. To return the result set directly to the application, bypassing any intermediate nested routines, specify WITH RETURN TO CLIENT. In external routines, cursors are defined as WITH RETURN TO CALLER by default, unless they are explicitly defined as WITH RETURN TO CLIENT.

When registering a procedure with the CREATE PROCEDURE statement, indicate the number of result sets that it returns with the DYNAMIC RESULT SETS clause. This value is in the RESULT\_SETS column in the SYSCAT.ROUTINES view. If the number of result sets returned from a procedure is different than the number specified in the CREATE PROCEDURE statement, a warning is issued (SQLCODE +464, SQLSTATE 0100E). For PARAMETER STYLE JAVA stored procedures, the number of result sets in the CREATE PROCEDURE statement must match the number of ResultSet[] parameters in the Java method signature.

The invoker can DESCRIBE the received result sets. Note that if the same cursor is opened on multiple nesting levels, applications running on DB2 Universal Database Version 7 clients can only DESCRIBE the first result set that is opened.

Result sets must be processed in a serial fashion by the invoker (if the invoker is not an SQL-bodied routine). A cursor is automatically opened on the first result set and a special call (SQLMoreResults for DB2 CLI, getMoreResults for JDBC, getNextResultSet for SQLJ) is provided to both close the cursor on one result set and to open it on the next.

To receive result sets in SQL-bodied routines, you must DECLARE and ASSOCIATE result set locators to the procedure you expect will return result sets. You must then ALLOCATE each cursor you expect will be returned to a result set locator. Once this is done, you can fetch rows from the result sets.

If a procedure is invoked within a trigger, a dynamic compound statement, an SQL function or a SQL method, any result sets will not be accessible.

**Note:** A COMMIT issued from within the procedure or from the application will close any result sets that are not for WITH HOLD cursors. A ROLLBACK issued from the application or from the stored procedure will close all result set cursors. After a COMMIT or a ROLLBACK is made from within a procedure, cursors can be opened and returned as result sets.

**Retrieval of result sets from an SQL data change statement:** Applications that modify tables with INSERT, UPDATE, or DELETE statements might require additional processing on the modified rows. To facilitate this processing, you can embed SQL data-change operations in the FROM clause of SELECT and SELECT INTO statements. Within a single unit of work, applications can retrieve a result set containing the modified rows from a table or view modified by an SQL data-change operation.

For example, the following statement updates the salaries of all the records in the EMPLOYEE table in the SAMPLE database and then returns the employee number and new salary for all the updated rows.

```
SELECT empno, salary FROM FINAL TABLE
  (UPDATE employee SET salary = salary * 1.10 WHERE job = 'CLERK')
```

To return data successfully, SELECT statements that retrieve result sets FROM SQL data-change operations require the SQL data-change operations to run successfully. The success of SQL data-change operations includes the processing of all constraints and triggers, if applicable.

For instance, suppose a user with SELECT privileges, but without INSERT privileges on the EMPLOYEE table attempts a SELECT FROM INSERT statement on the EMPLOYEE table. The INSERT operation fails because of the missing privileges, and as a result, the entire SELECT statement fails.

Consider the following query, where records from the EMPLOYEE table are selected and then inserted into a different table, named EMP. This SELECT statement will fail.

```
SELECT empno FROM FINAL TABLE
  (INSERT INTO emp(name, salary)
   SELECT firstnme || midinit || lastname, salary
   FROM employee)
```

If the EMPLOYEE table has 100 rows and row 90 has a SALARY value of \$9,999,000.00, then the addition of \$10,000.00 would cause a decimal overflow to occur. The overflow would force the database manager to rollback the insertions into the EMP table.

### Intermediate result tables

The modified rows of the table or view targeted by an SQL data-change operation in the FROM clause of a SELECT statement compose an intermediate result table. The intermediate result table includes all the columns of the target table or view, in

addition to any include columns defined in the SQL data-change operation. You can reference all of the columns in an intermediate result table by name in the select list, the ORDER BY clause, or the WHERE clause.

The contents of the intermediate result table are dependant on the qualifier specified in the FROM clause. You must include one of the following FROM clause qualifiers in SELECT statements that retrieve result sets as intermediate result tables.

#### **OLD TABLE**

The rows in the intermediate result table will contain values of the target table rows at the point immediately preceding the execution of before triggers and the SQL data-change operation. The OLD TABLE qualifier applies to UPDATE and DELETE operations.

#### **NEW TABLE**

The rows in the intermediate result table will contain values of the target table rows at the point immediately after the SQL data-change statement has been executed, but before referential integrity evaluation and the firing of any after triggers. The NEW TABLE qualifier applies to UPDATE and INSERT operations.

#### **FINAL TABLE**

This qualifier returns the same intermediate result table as NEW TABLE. In addition, the use of FINAL TABLE guarantees that no after trigger or referential integrity constraint will further modify the target of the UPDATE or INSERT operation. The FINAL TABLE qualifier applies to UPDATE and INSERT operations.

The FROM clause qualifiers determine what version of the targeted data is in the intermediate result table. These qualifiers do not affect the insertion, deletion, or updates of target table rows.

#### **Target tables and views**

When selecting result sets FROM SQL data-change operations, the target can be either a table or a view.

In SQL data-change operations against views, the result table cannot include rows that no longer satisfy the view definition for NEW TABLE and FINAL TABLE. If you embed an INSERT or UPDATE statement that references a view in a SELECT statement, the view must be defined as WITH CASCADED CHECK OPTION. Alternatively, the view must satisfy the restrictions that would allow you to define it as WITH CASCADED CHECK OPTION.

If the target of SQL data-change operations embedded in the FROM clause of a SELECT statement is a fullselect, the result table can include rows that no longer qualify in the fullselect. This is because the predicates in the WHERE clause are not re-evaluated against the updated values.

#### **Result set sorting based on INPUT SEQUENCE**

To SELECT rows in the same order as they are inserted into the target table or view, use the INPUT SEQUENCE keywords in the ORDER BY clause. Use of the INPUT SEQUENCE keywords does not force rows to be inserted in the same order they are provided.

The following example demonstrates the use of the INPUT SEQUENCE keywords in the ORDER BY clause to sort the result set of an INSERT operation.

```
CREATE TABLE orders (purchase_date DATE,
                    sales_person VARCHAR(16),
                    region VARCHAR(10),
                    quantity SMALLINT,
                    order_num INTEGER NOT NULL
                    GENERATED ALWAYS AS IDENTITY (START WITH 100,
                    INCREMENT BY 1))

SELECT * FROM FINAL TABLE
  (INSERT INTO orders
   (purchase_date, sales_person, region, quantity)
  VALUES (CURRENT DATE, 'Judith', 'Beijing', 6),
          (CURRENT DATE, 'Marieke', 'Medway', 5),
          (CURRENT DATE, 'Hanneke', 'Halifax', 5))
 ORDER BY INPUT SEQUENCE
```

PURCHASE_DATE	SALES_PERSON	REGION	QUANTITY	ORDER_NUM
07/18/2003	Judith	Beijing	6	100
07/18/2003	Marieke	Medway	5	101
07/18/2003	Hanneke	Halifax	5	102

You can also sort result set rows using include columns.

**Retrieval of result sets from SQL data change statements using cursors:** You can declare cursors for queries that retrieve result sets from SQL data-change operations. For example:

```
DECLARE C1 CURSOR FOR SELECT salary FROM FINAL TABLE
  (INSERT INTO employee (name, salary, level)
   SELECT name, income, band FROM old_employee)
```

Errors that occur when fetching from a cursor whose definition contains an SQL data-change operation will not cause a rollback of the modified rows. Even if the errors result in the cursor's closing, the row modifications will remain intact because they were completed when the application opened the cursor.

Upon the opening of such a cursor, the database manager completely executes the SQL data-change operation and the result set is stored in a temporary table. If an error occurs while the cursor opens, the changes made by the SQL data-change operation are rolled back. Further updates to the target table or view will not appear in the result table rows for cursors that retrieve result sets from SQL data-change operations. For example, an application declares a cursor, opens the cursor, performs a fetch, updates the table, and fetches additional rows. The fetches after the UPDATE statement will return those values that were determined during open cursor processing prior to the UPDATE statement.

You can declare scrollable cursors for queries that retrieve result sets from SQL data-change operations. The data modifications have already been written to the target table or view, because the result table is generated when you OPEN the cursor. Cursors with queries that select rows from an SQL data change operation must be defined as INSENSITIVE or ASENSITIVE.

**Note:** Scrollable cursors are supported only in CLI, JDBC, and SQLJ applications.

If you declare a cursor with the WITH HOLD option and the application performs a COMMIT, all of the data changes are committed. Cursors that you do not declare

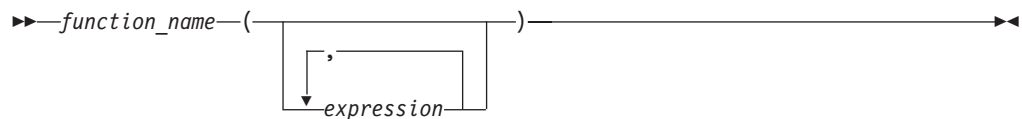
as WITH HOLD behave in the same manner. For all cursors, the SQL data-change operation included in the query is completely evaluated before any row is fetched.

When performing an explicit rollback for an OPEN CURSOR statement, or when rolling back to a save point prior to an OPEN CURSOR statement, all of the data changes for that cursor will be undone. For cursors with queries that retrieve result sets from SQL data-change operations, all data changes are undone after a rollback, but the cursor is retained and the previously inserted rows can still be fetched.

---

## References to functions

Each reference to a function, whether it is a UDF, or a built-in function, contains the following syntax:



In the preceding syntax diagram, `function_name` can be either an unqualified or a qualified function name. The arguments can number from 0 to 90 and are expressions. Examples of some components that can compose expressions are the following:

- a column name, qualified or unqualified
- a constant
- a host variable
- a special register
- a parameter marker

The position of the arguments is important and must conform to the function definition for the semantics to be correct. Both the position of the arguments and the function definition must conform to the function body itself. DB2 does not attempt to shuffle arguments to better match a function definition, and DB2 does not understand the semantics of the individual function parameters.

Use of column names in UDF argument expressions requires that the table references that contain the columns have proper scope. For table functions referenced in a join and using any argument involving columns from another table or table function, the referenced table or table function must precede the table function containing the reference in the FROM clause.

In order to use parameter markers in functions you cannot simply code the following:

```
BLOOP(?)
```

Because the function selection logic does not know what data type the argument might turn out to be, it cannot resolve the reference. You can use the CAST specification to provide a type for the parameter marker. For example, INTEGER, and then the function selection logic can proceed:

```
BLOOP(CAST(? AS INTEGER))
```

Some valid examples of function invocations are:

```

AVG(FLOAT_COLUMN)
BLOOP(COLUMN1)
BLOOP(FLOAT_COLUMN + CAST(? AS INTEGER))
BLOOP(:hostvar :indicvar)
BRIAN.PARSE(CHAR_COLUMN CONCAT USER, 1, 0, 0, 1)
CTR()
FLOOR(FLOAT_COLUMN)
PABLO.BLOOP(A+B)
PABLO.BLOOP(:hostvar)
"search_schema"(CURRENT FUNCTION PATH, 'GENE')
SUBSTR(COLUMN2,8,3)
SYSFUN.FLOOR(AVG(EMP.SALARY))
SYSFUN.AVG(SYSFUN.FLOOR(EMP.SALARY))
SYSIBM.SUBSTR(COLUMN2,11,LENGTH(COLUMN3))
SQRT((SELECT SUM(length*length)
      FROM triangles
      WHERE id= 'J522'
      AND legtype <> 'HYP'))

```

If any of the above functions are table functions, the syntax to reference them is slightly different than presented previously. For example, if PABLO.BLOOP is a table function, to properly reference it, use:

```
TABLE(PABLO.BLOOP(A+B)) AS Q
```

## Function selection

For both qualified and unqualified function references, the function selection algorithm looks at all the *applicable* functions, both built-in and user-defined, that have:

- The given name
- The same number of defined parameters as arguments in the function reference
- Each parameter identical to or promotable from the type of the corresponding argument.

Applicable functions are functions in the named schema for a qualified reference, or functions in the schemas of the SQL path for an unqualified reference. The algorithm looks for an exact match, or failing that, a best match among these functions. The SQL path is used, in the case of an unqualified reference only, as the deciding factor if two identically good matches are found in different schemas.

**Exception:** If there is an unqualified reference to a function named RID, and the function is invoked with a single argument that matches a table-reference in the FROM clause of the subselect, the schema is SYSIBM and the built-in RID function is invoked.

You can nest function references, even references to the same function. This is generally true for built-in functions as well as UDFs; however, there are some limitations when column functions are involved.

For example:

```
CREATE FUNCTION BLOOP (INTEGER) RETURNS INTEGER ...
CREATE FUNCTION BLOOP (DOUBLE) RETURNS INTEGER ...
```

Now consider the following DML statement:

```
SELECT BLOOP( BLOOP(COLUMN1)) FROM T
```

If column1 is a DECIMAL or DOUBLE column, the inner BLOOP reference resolves to the second BLOOP defined above. Because this BLOOP returns an INTEGER, the outer BLOOP resolves to the first BLOOP.

Alternatively, if column1 is a SMALLINT or INTEGER column, the inner bloop reference resolves to the first BLOOP defined above. Because this BLOOP returns an INTEGER, the outer BLOOP also resolves to the first BLOOP. In this case, you are seeing nested references to the same function.

By defining a function with the name of one of the SQL operators, you can actually invoke a UDF using *infix notation*. For example, suppose you can attach some meaning to the "+" operator for values which have distinct type BOAT. You can define the following UDF:

```
CREATE FUNCTION "+" (BOAT, BOAT) RETURNS ...
```

Then you can write the following valid SQL statement:

```
SELECT BOAT_COL1 + BOAT_COL2
FROM BIG_BOATS
WHERE BOAT_OWNER = 'Nelson Mattos'
```

But you can also write the equally valid statement:

```
SELECT "+"(BOAT_COL1, BOAT_COL2)
FROM BIG_BOATS
WHERE BOAT_OWNER = 'Nelson Mattos'
```

Note that you are not permitted to overload the built-in conditional operators such as >, =, LIKE, IN, and so on, in this way.

## Distinct types as UDF or method parameters

UDFs and methods can be defined with distinct types as parameters or as the result. The DB2 database system will pass the value to the UDF or method in the format of the source data type of the distinct type.

### Procedure

Distinct type values that originate in a host variable, and which are used as arguments to a UDF that has its corresponding parameter defined as a distinct type, **must be explicitly cast to the distinct type by the user**. There is no host language type for distinct types. The strong typing in DB2 database systems necessitates this, otherwise your results can be ambiguous. Consider the BOAT distinct type which is defined over a BLOB, and consider the BOAT\_COST UDF defined as follows:

```
CREATE FUNCTION BOAT_COST (BOAT)
  RETURNS INTEGER
  ...
```

In the following fragment of a C language application, the host variable :ship holds the BLOB value that is to be passed to the BOAT\_COST function:

```
EXEC SQL BEGIN DECLARE SECTION;
  SQL TYPE IS BLOB(150K) ship;
EXEC SQL END DECLARE SECTION;
```

Both of the following statements correctly resolve to the BOAT\_COST function, because both cast the :ship host variable to type BOAT:

```
... SELECT BOAT_COST (BOAT(:ship)) FROM ...
... SELECT BOAT_COST (CAST(:ship AS BOAT)) FROM ...
```

If there are multiple BOAT distinct types in the database, or BOAT UDFs in other schema, you must exercise care with your SQL path. Your results can otherwise be ambiguous.

## LOB values as UDF parameters

### Procedure

UDFs can be defined with parameters or results having any of the LOB types: BLOB, CLOB, or DBCLOB. DB2 will materialize the entire LOB value in storage before invoking such a function, even if the source of the value is a *LOB locator* host variable. For example, consider the following fragment of a C language application:

```
EXEC SQL BEGIN DECLARE SECTION;
    SQL TYPE IS CLOB(150K) clob150K ;           /* LOB host var */
    SQL TYPE IS CLOB_LOCATOR clob_locator1;    /* LOB locator host var */
    char          string[40];                 /* string host var */
EXEC SQL END DECLARE SECTION;
```

Either host variable `:clob150K` or `:clob_locator1` is valid as an argument for a function whose corresponding parameter is defined as `CLOB(500K)`. For example, suppose you have registered a UDF as follows:

```
CREATE FUNCTION FINDSTRING (CLOB(500K, VARCHAR(200)))
...
```

Both of the following invocations of `FINDSTRING` are valid in the program:

```
... SELECT FINDSTRING (:clob150K, :string) FROM ...
... SELECT FINDSTRING (:clob_locator1, :string) FROM ...
```

UDF parameters or results which have one of the LOB types can be created with the `AS LOCATOR` modifier. In this case, the entire LOB value is not materialized prior to invocation. Instead, a `LOB LOCATOR` is passed to the UDF, which can then use SQL to manipulate the actual bytes of the LOB value.

You can also use this capability on UDF parameters or results which have a distinct type that is based on a LOB. Note that the argument to such a function can be any LOB value of the defined type; it does not have to be a host variable defined as one of the `LOCATOR` types. The use of host variable locators as arguments is completely orthogonal to the use of `AS LOCATOR` in UDF parameters and result definitions.

## Invoking scalar functions or methods

The invocation of built-in scalar functions, user-defined scalar-functions and methods is very similar. Scalar functions and methods can only be invoked where expressions are supported within an SQL statement.

### Before you begin

- For built-in functions, `SYSIBM` must be in the `CURRENT PATH` special register. `SYSIBM` is in `CURRENT PATH` by default.
- For user-defined scalar functions, the function must have been created in the database using either the `CREATE FUNCTION` or `CREATE METHOD` statement.
- For external user-defined scalar functions, the library or class file associated with the function must be in the location specified by the `EXTERNAL` clause of the `CREATE FUNCTION` or `CREATE METHOD` statement.
- To invoke a user-defined function or method, a user must have `EXECUTE` privilege on the function or method. If the function or method is to be used by



all users, the EXECUTE privilege on the function or method can be granted to PUBLIC. For more privilege related information see the specific CREATE statement reference.

## Procedure

To invoke a scalar UDF or method:

Include a reference to it within an expression contained in an SQL statement where it is to process one or more input values. Functions and methods can be invoked anywhere that an expression is valid. Examples of where a scalar UDF or method can be referenced include the select-list of a query or in a VALUES clause.

## Example

For example, suppose that you have created a user-defined scalar function called TOTAL\_SAL that adds the base salary and bonus together for each employee row in the EMPLOYEE table.

```
CREATE FUNCTION TOTAL_SAL
(SALARY DECIMAL(9,2), BONUS DECIMAL(9,2))
RETURNS DECIMAL(9,2)
LANGUAGE SQL
CONTAINS SQL
NO EXTERNAL ACTION
DETERMINISTIC
RETURN SALARY+BONUS
```

The following is a SELECT statement that makes use of TOTAL\_SAL:

```
SELECT LASTNAME, TOTAL_SAL(SALARY, BONUS) AS TOTAL
FROM EMPLOYEE
```

## Invoking user-defined table functions

Once the user-defined table function is written and registered with the database, you can invoke it in the FROM clause of a SELECT statement.

### Before you begin

- The table function must have been created in the database by executing the CREATE FUNCTION.
- For external user-defined table functions, the library or class file associated with the function must be in the location specified by the EXTERNAL clause of the CREATE FUNCTION.
- To invoke a user-defined table function a user must have EXECUTE privilege on the function. For more privilege related information see the CREATE FUNCTION reference.

### About this task

#### Procedure

To invoke a user-defined table function, reference the function in the FROM clause of an SQL statement where it is to process a set of input values. The reference to the table function must be preceded by the TABLE clause and be contained in brackets.

For example, the following CREATE FUNCTION statement defines a table function that returns the employees in a specified department number.

```
CREATE FUNCTION DEPEMPL0YEEES (DEPTNO VARCHAR(3))
  RETURNS TABLE (EMPNO CHAR(6),
                 LASTNAME VARCHAR(15),
                 FIRSTNAME VARCHAR(12))
LANGUAGE SQL
READS SQL DATA
NO EXTERNAL ACTION
DETERMINISTIC
RETURN
  SELECT EMPNO, LASTNAME, FIRSTNME FROM EMPLOYEE
     WHERE EMPLOYEE.WORKDEPT = DEPEMPL0YEEES.DEPTNO
```

The following is a SELECT statement that makes use of DEPEMPL0YEEES:

```
SELECT EMPNO, LASTNAME, FIRSTNAME FROM TABLE(DEPEMPL0YEEES('A00')) AS D
```

---

## Appendix A. Overview of the DB2 technical information

DB2 technical information is available through the following tools and methods:

- DB2 Information Center
  - Topics (Task, concept and reference topics)
  - Help for DB2 tools
  - Sample programs
  - Tutorials
- DB2 books
  - PDF files (downloadable)
  - PDF files (from the DB2 PDF DVD)
  - printed books
- Command line help
  - Command help
  - Message help

**Note:** The DB2 Information Center topics are updated more frequently than either the PDF or the hardcopy books. To get the most current information, install the documentation updates as they become available, or refer to the DB2 Information Center at [ibm.com](http://ibm.com).

You can access additional DB2 technical information such as technotes, white papers, and IBM Redbooks® publications online at [ibm.com](http://ibm.com). Access the DB2 Information Management software library site at <http://www.ibm.com/software/data/sw-library/>.

### Documentation feedback

We value your feedback on the DB2 documentation. If you have suggestions for how to improve the DB2 documentation, send an email to [db2docs@ca.ibm.com](mailto:db2docs@ca.ibm.com). The DB2 documentation team reads all of your feedback, but cannot respond to you directly. Provide specific examples wherever possible so that we can better understand your concerns. If you are providing feedback on a specific topic or help file, include the topic title and URL.

Do not use this e-mail address to contact DB2 Customer Support. If you have a DB2 technical issue that the documentation does not resolve, contact your local IBM service center for assistance.

---

## DB2 technical library in hardcopy or PDF format

The following tables describe the DB2 library available from the IBM Publications Center at [www.ibm.com/e-business/linkweb/publications/servlet/pbi.wss](http://www.ibm.com/e-business/linkweb/publications/servlet/pbi.wss). English Version 9.7 manuals in PDF format can be downloaded from [www.ibm.com/support/docview.wss?uid=swg27015148](http://www.ibm.com/support/docview.wss?uid=swg27015148) and translated DB2 manuals in PDF format can be downloaded from [www.ibm.com/support/docview.wss?uid=swg27015149](http://www.ibm.com/support/docview.wss?uid=swg27015149).

Although the tables identify books available in print, the books might not be available in your country or region.

The form number increases each time a manual is updated. Ensure that you are reading the most recent version of the manuals, as listed below.

**Note:** The *DB2 Information Center* is updated more frequently than either the PDF or the hard-copy books.

*Table 50. DB2 technical information*

<b>Name</b>	<b>Form Number</b>	<b>Available in print</b>	<b>Last updated</b>
<i>Administrative API Reference</i>	SC27-2435-03	Yes	July, 2012
<i>Administrative Routines and Views</i>	SC27-2436-03	No	July, 2012
<i>Call Level Interface Guide and Reference, Volume 1</i>	SC27-2437-03	Yes	July, 2012
<i>Call Level Interface Guide and Reference, Volume 2</i>	SC27-2438-03	Yes	July, 2012
<i>Command Reference</i>	SC27-2439-03	Yes	July, 2012
<i>Data Movement Utilities Guide and Reference</i>	SC27-2440-01	Yes	July, 2012
<i>Data Recovery and High Availability Guide and Reference</i>	SC27-2441-03	Yes	July, 2012
<i>Database Administration Concepts and Configuration Reference</i>	SC27-2442-03	Yes	July, 2012
<i>Database Monitoring Guide and Reference</i>	SC27-2458-03	Yes	July, 2012
<i>Database Security Guide</i>	SC27-2443-02	Yes	July, 2012
<i>DB2 Text Search Guide</i>	SC27-2459-03	Yes	July, 2012
<i>Developing ADO.NET and OLE DB Applications</i>	SC27-2444-02	Yes	July, 2012
<i>Developing Embedded SQL Applications</i>	SC27-2445-02	Yes	July, 2012
<i>Developing Java Applications</i>	SC27-2446-03	Yes	July, 2012
<i>Developing Perl, PHP, Python, and Ruby on Rails Applications</i>	SC27-2447-02	No	July, 2012
<i>Developing User-defined Routines (SQL and External)</i>	SC27-2448-02	Yes	July, 2012
<i>Getting Started with Database Application Development</i>	GI11-9410-02	Yes	July, 2012

Table 50. DB2 technical information (continued)

<b>Name</b>	<b>Form Number</b>	<b>Available in print</b>	<b>Last updated</b>
<i>Getting Started with DB2 Installation and Administration on Linux and Windows</i>	GI11-9411-00	Yes	August, 2009
<i>Globalization Guide</i>	SC27-2449-00	Yes	August, 2009
<i>Installing DB2 Servers</i>	GC27-2455-03	Yes	July, 2012
<i>Installing IBM Data Server Clients</i>	GC27-2454-02	No	July, 2012
<i>Message Reference Volume 1</i>	SC27-2450-01	No	August, 2009
<i>Message Reference Volume 2</i>	SC27-2451-01	No	August, 2009
<i>Net Search Extender Administration and User's Guide</i>	SC27-2469-02	No	September, 2010
<i>Partitioning and Clustering Guide</i>	SC27-2453-02	Yes	July, 2012
<i>pureXML Guide</i>	SC27-2465-02	Yes	July, 2012
<i>Query Patroller Administration and User's Guide</i>	SC27-2467-00	No	August, 2009
<i>Spatial Extender and Geodetic Data Management Feature User's Guide and Reference</i>	SC27-2468-02	No	July, 2012
<i>SQL Procedural Languages: Application Enablement and Support</i>	SC27-2470-03	Yes	July, 2012
<i>SQL Reference, Volume 1</i>	SC27-2456-03	Yes	July, 2012
<i>SQL Reference, Volume 2</i>	SC27-2457-03	Yes	July, 2012
<i>Troubleshooting and Tuning Database Performance</i>	SC27-2461-03	Yes	July, 2012
<i>Upgrading to DB2 Version 9.7</i>	SC27-2452-03	Yes	July, 2012
<i>Visual Explain Tutorial</i>	SC27-2462-00	No	August, 2009
<i>What's New for DB2 Version 9.7</i>	SC27-2463-03	Yes	July, 2012
<i>Workload Manager Guide and Reference</i>	SC27-2464-03	Yes	July, 2012
<i>XQuery Reference</i>	SC27-2466-01	No	November, 2009

Table 51. DB2 Connect-specific technical information

Name	Form Number	Available in print	Last updated
<i>Installing and Configuring DB2 Connect Personal Edition</i>	SC27-2432-03	Yes	July, 2012
<i>Installing and Configuring DB2 Connect Servers</i>	SC27-2433-03	Yes	July, 2012
<i>DB2 Connect User's Guide</i>	SC27-2434-02	Yes	July, 2012

Table 52. Information Integration technical information

Name	Form Number	Available in print	Last updated
<i>Information Integration: Administration Guide for Federated Systems</i>	SC19-1020-02	Yes	August, 2009
<i>Information Integration: ASNCLP Program Reference for Replication and Event Publishing</i>	SC19-1018-04	Yes	August, 2009
<i>Information Integration: Configuration Guide for Federated Data Sources</i>	SC19-1034-02	No	August, 2009
<i>Information Integration: SQL Replication Guide and Reference</i>	SC19-1030-02	Yes	August, 2009
<i>Information Integration: Introduction to Replication and Event Publishing</i>	GC19-1028-02	Yes	August, 2009

## Ordering printed DB2 books

### About this task

If you require printed DB2 books, you can buy them online in many but not all countries or regions. You can always order printed DB2 books from your local IBM representative. Keep in mind that some softcopy books on the *DB2 PDF Documentation DVD* are unavailable in print. For example, neither volume of the *DB2 Message Reference* is available as a printed book.

Printed versions of many of the DB2 books available on the DB2 PDF Documentation DVD can be ordered for a fee from IBM. Depending on where you are placing your order from, you may be able to order books online, from the IBM Publications Center. If online ordering is not available in your country or region, you can always order printed DB2 books from your local IBM representative. Note that not all books on the DB2 PDF Documentation DVD are available in print.

**Note:** The most up-to-date and complete DB2 documentation is maintained in the DB2 Information Center at <http://publib.boulder.ibm.com/infocenter/db2luw/v9r7>.

To order printed DB2 books:

### Procedure

- To find out whether you can order printed DB2 books online in your country or region, check the IBM Publications Center at <http://www.ibm.com/shop/publications/order>. You must select a country, region, or language to access publication ordering information and then follow the ordering instructions for your location.
- To order printed DB2 books from your local IBM representative:
  1. Locate the contact information for your local representative from one of the following websites:
    - The IBM directory of world wide contacts at [www.ibm.com/planetwide](http://www.ibm.com/planetwide)
    - The IBM Publications website at <http://www.ibm.com/shop/publications/order>. You will need to select your country, region, or language to the access appropriate publications home page for your location. From this page, follow the "About this site" link.
  2. When you call, specify that you want to order a DB2 publication.
  3. Provide your representative with the titles and form numbers of the books that you want to order. For titles and form numbers, see “DB2 technical library in hardcopy or PDF format” on page 321.

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## Displaying SQL state help from the command line processor

DB2 products return an SQLSTATE value for conditions that can be the result of an SQL statement. SQLSTATE help explains the meanings of SQL states and SQL state class codes.

### Procedure

To start SQL state help, open the command line processor and enter:

```
? sqlstate or ? class code
```

where *sqlstate* represents a valid five-digit SQL state and *class code* represents the first two digits of the SQL state.

For example, ? 08003 displays help for the 08003 SQL state, and ? 08 displays help for the 08 class code.

---

## Accessing different versions of the DB2 Information Center

### About this task

For DB2 Version 9.8 topics, the *DB2 Information Center* URL is <http://publib.boulder.ibm.com/infocenter/db2luw/v9r8/>.

For DB2 Version 9.7 topics, the *DB2 Information Center* URL is <http://publib.boulder.ibm.com/infocenter/db2luw/v9r7/>.

For DB2 Version 9.5 topics, the *DB2 Information Center* URL is <http://publib.boulder.ibm.com/infocenter/db2luw/v9r5/>.

For DB2 Version 9.1 topics, the *DB2 Information Center* URL is <http://publib.boulder.ibm.com/infocenter/db2luw/v9/>.

For DB2 Version 8 topics, go to the *DB2 Information Center* URL at:  
<http://publib.boulder.ibm.com/infocenter/db2luw/v8/>.

---

## Displaying topics in your preferred language in the DB2 Information Center

### About this task

The DB2 Information Center attempts to display topics in the language specified in your browser preferences. If a topic has not been translated into your preferred language, the DB2 Information Center displays the topic in English.

### Procedure

- To display topics in your preferred language in the Internet Explorer browser:
  1. In Internet Explorer, click the **Tools** —> **Internet Options** —> **Languages...** button. The Language Preferences window opens.
  2. Ensure your preferred language is specified as the first entry in the list of languages.
    - To add a new language to the list, click the **Add...** button.

**Note:** Adding a language does not guarantee that the computer has the fonts required to display the topics in the preferred language.
    - To move a language to the top of the list, select the language and click the **Move Up** button until the language is first in the list of languages.
  3. Refresh the page to display the DB2 Information Center in your preferred language.
- To display topics in your preferred language in a Firefox or Mozilla browser:
  1. Select the button in the **Languages** section of the **Tools** —> **Options** —> **Advanced** dialog. The Languages panel is displayed in the Preferences window.
  2. Ensure your preferred language is specified as the first entry in the list of languages.
    - To add a new language to the list, click the **Add...** button to select a language from the Add Languages window.
    - To move a language to the top of the list, select the language and click the **Move Up** button until the language is first in the list of languages.
  3. Refresh the page to display the DB2 Information Center in your preferred language.

### Results

On some browser and operating system combinations, you must also change the regional settings of your operating system to the locale and language of your choice.

---

## Updating the DB2 Information Center installed on your computer or intranet server

A locally installed DB2 Information Center must be updated periodically.



## Before you begin

A DB2 Version 9.7 Information Center must already be installed. For details, see the “Installing the DB2 Information Center using the DB2 Setup wizard” topic in *Installing DB2 Servers*. All prerequisites and restrictions that applied to installing the Information Center also apply to updating the Information Center.

## About this task

An existing DB2 Information Center can be updated automatically or manually:

- Automatic updates - updates existing Information Center features and languages. An additional benefit of automatic updates is that the Information Center is unavailable for a minimal period of time during the update. In addition, automatic updates can be set to run as part of other batch jobs that run periodically.
- Manual updates - should be used when you want to add features or languages during the update process. For example, a local Information Center was originally installed with both English and French languages, and now you want to also install the German language; a manual update will install German, as well as, update the existing Information Center features and languages. However, a manual update requires you to manually stop, update, and restart the Information Center. The Information Center is unavailable during the entire update process.

This topic details the process for automatic updates. For manual update instructions, see the “Manually updating the DB2 Information Center installed on your computer or intranet server” topic.

## Procedure

To automatically update the DB2 Information Center installed on your computer or intranet server:

1. On Linux operating systems,
  - a. Navigate to the path where the Information Center is installed. By default, the DB2 Information Center is installed in the `/opt/ibm/db2ic/V9.7` directory.
  - b. Navigate from the installation directory to the `doc/bin` directory.
  - c. Run the `update-ic` script:  
`update-ic`
2. On Windows operating systems,
  - a. Open a command window.
  - b. Navigate to the path where the Information Center is installed. By default, the DB2 Information Center is installed in the `<Program Files>\IBM\DB2 Information Center\Version 9.7` directory, where `<Program Files>` represents the location of the Program Files directory.
  - c. Navigate from the installation directory to the `doc\bin` directory.
  - d. Run the `update-ic.bat` file:  
`update-ic.bat`

## Results

The DB2 Information Center restarts automatically. If updates were available, the Information Center displays the new and updated topics. If Information Center

updates were not available, a message is added to the log. The log file is located in `doc\eclipse\configuration` directory. The log file name is a randomly generated number. For example, `1239053440785.log`.

---

## Manually updating the DB2 Information Center installed on your computer or intranet server

If you have installed the DB2 Information Center locally, you can obtain and install documentation updates from IBM.

### About this task

Updating your locally-installed *DB2 Information Center* manually requires that you:

1. Stop the *DB2 Information Center* on your computer, and restart the Information Center in stand-alone mode. Running the Information Center in stand-alone mode prevents other users on your network from accessing the Information Center, and allows you to apply updates. The Workstation version of the DB2 Information Center always runs in stand-alone mode. .
2. Use the Update feature to see what updates are available. If there are updates that you must install, you can use the Update feature to obtain and install them

**Note:** If your environment requires installing the *DB2 Information Center* updates on a machine that is not connected to the internet, mirror the update site to a local file system using a machine that is connected to the internet and has the *DB2 Information Center* installed. If many users on your network will be installing the documentation updates, you can reduce the time required for individuals to perform the updates by also mirroring the update site locally and creating a proxy for the update site.

If update packages are available, use the Update feature to get the packages. However, the Update feature is only available in stand-alone mode.

3. Stop the stand-alone Information Center, and restart the *DB2 Information Center* on your computer.

**Note:** On Windows 2008, Windows Vista (and higher), the commands listed later in this section must be run as an administrator. To open a command prompt or graphical tool with full administrator privileges, right-click the shortcut and then select **Run as administrator**.

### Procedure

To update the *DB2 Information Center* installed on your computer or intranet server:

1. Stop the *DB2 Information Center*.
  - On Windows, click **Start > Control Panel > Administrative Tools > Services**. Then right-click **DB2 Information Center** service and select **Stop**.
  - On Linux, enter the following command:  

```
/etc/init.d/db2icdv97 stop
```
2. Start the Information Center in stand-alone mode.
  - On Windows:
    - a. Open a command window.
    - b. Navigate to the path where the Information Center is installed. By default, the *DB2 Information Center* is installed in the

*Program\_Files\IBM\DB2 Information Center\Version 9.7* directory, where *Program\_Files* represents the location of the Program Files directory.

c. Navigate from the installation directory to the `doc\bin` directory.

d. Run the `help_start.bat` file:

```
help_start.bat
```

• On Linux:

a. Navigate to the path where the Information Center is installed. By default, the *DB2 Information Center* is installed in the `/opt/ibm/db2ic/V9.7` directory.

b. Navigate from the installation directory to the `doc/bin` directory.

c. Run the `help_start` script:

```
help_start
```

The systems default Web browser opens to display the stand-alone Information Center.

3. Click the **Update** button (🔄). (JavaScript must be enabled in your browser.)

On the right panel of the Information Center, click **Find Updates**. A list of updates for existing documentation displays.

4. To initiate the installation process, check the selections you want to install, then click **Install Updates**.

5. After the installation process has completed, click **Finish**.

6. Stop the stand-alone Information Center:

• On Windows, navigate to the installation directory's `doc\bin` directory, and run the `help_end.bat` file:

```
help_end.bat
```

**Note:** The `help_end` batch file contains the commands required to safely stop the processes that were started with the `help_start` batch file. Do not use `Ctrl-C` or any other method to stop `help_start.bat`.

• On Linux, navigate to the installation directory's `doc/bin` directory, and run the `help_end` script:

```
help_end
```

**Note:** The `help_end` script contains the commands required to safely stop the processes that were started with the `help_start` script. Do not use any other method to stop the `help_start` script.

7. Restart the *DB2 Information Center*.

• On Windows, click **Start > Control Panel > Administrative Tools > Services**. Then right-click **DB2 Information Center** service and select **Start**.

• On Linux, enter the following command:

```
/etc/init.d/db2icdv97 start
```

## Results

The updated *DB2 Information Center* displays the new and updated topics.

---

## DB2 tutorials

The DB2 tutorials help you learn about various aspects of DB2 products. Lessons provide step-by-step instructions.

## Before you begin

You can view the XHTML version of the tutorial from the Information Center at <http://publib.boulder.ibm.com/infocenter/db2help/>.

Some lessons use sample data or code. See the tutorial for a description of any prerequisites for its specific tasks.

## DB2 tutorials

To view the tutorial, click the title.

### “pureXML®” in *pureXML Guide*

Set up a DB2 database to store XML data and to perform basic operations with the native XML data store.

### “Visual Explain” in *Visual Explain Tutorial*

Analyze, optimize, and tune SQL statements for better performance using Visual Explain.

---

## DB2 troubleshooting information

A wide variety of troubleshooting and problem determination information is available to assist you with using DB2 database products.

### DB2 documentation

Troubleshooting information can be found in the *Troubleshooting and Tuning Database Performance* or the Database fundamentals section of the *DB2 Information Center*. The troubleshooting information contains topics that can help you isolate and identify problems with DB2 diagnostic tools and utilities. There are also solutions to some of the most common problems and advice on how to solve problems you might encounter with your DB2 database products.

### IBM Support Portal

See the IBM Support Portal if you are experiencing problems and want help finding possible causes and solutions. The Technical Support site has links to the latest DB2 publications, TechNotes, Authorized Program Analysis Reports (APARs or bug fixes), fix packs, and other resources. You can search through this knowledge base to find possible solutions to your problems.

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